FUNCTIONAL TOOLS TO DETERMINE INJURY RISK IN UNIVERSITY NETBALL PLAYERS

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Thesis presented in partial fulfilment of the requirements for the degree Masters of Sport Science in the Department of Sport Science at Stellenbosch University

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March 2016

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (unless to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2016

ABSTRACT

Screening tools are widely used by coaches and other professionals to determine the risk for injury in athletes. This can be done either pre-season or post-injury prior to an athlete returns-to-play. The screening process aims to identify risk factors, including incorrect movement patterns, decreased flexibility and dynamic balance, amongst others. A history of previous injury remains a major risk factor, due to various neural implications involved. Specific movement patterns occur within predetermined activation patterns and sequences. Post-injury, this sequence may alter and unless corrected, compensatory patterns occur. The aim of screening tools should be to identify these compensatory patterns, so as to identify which athletes have altered movements within the kinetic chain. The kinetic chain reactions are pre-determined and when altered, could lead to injury. The Netball Movement Screening Tool consists of four different components, namely the Movement Competency Screen, the Jump component, the Active Straight Leg Raise Test and the modified Star Excursion Balance Test. The Bunkie test is an isometric modified plank position, performed bilaterally in five different positions.

The main aim of this study was to determine whether two specific screening tools, namely the Netball Movement Screening Tool (NMST) and the Bunkie test can be used as tools to predict injury in university netball players. Secondary aims include the following: to determine the inter- and intra-rater reliability of two components of the NMST and to determine the relationship between the modified Star Excursion Balance Test (SEBT) and the modified Bunkie test results. This was a descriptive study and all participants were members of the Stellenbosch University netball club.

Results revealed no significant findings for the logistic regression results, with an odds ratio of 0.47 (95% CI 0.13 – 1.65) and 1.00 (95% CI 0.98 – 1.02) for the Netball Movement Screening Tool (NMST) and Bunkie test, respectively. A weak to moderate correlation was found between the total modified Star Excursion Balance Test and total modified Bunkie test results ($r = 0.36 – 0.43$, $r^2 = 0.13 – 0.18$, $p \leq 0.05$). The inter- and intra-rater reliability (ICC agreement) for untrained raters were both 0.35 for the Movement Competency Screen and 0.34 and 0.64 for the Jump Category scores within the Netball Movement Screening Tool.

The inter- and intra-rater reliabilities for trained raters revealed ICC agreements of 0.98 and 0.93 for the Movement Competency Screen only, since the Jump components' agreement could not be calculated, due to a lack of variance.

The NMST and total Bunkie score results could not be used to predict injury in this group of university netball players. A relationship exists between the total modified SEBT and total modified Bunkie test score results.

Key words: Netball Movement Screening Tool, Bunkie test, Injury

OPSOMMING

Verskeie metodes kan gebuik word deur afrigters en ander profesionele persone wat met atlete werk, om beserings te voorkom. Die vorkoming van beserings word uitgevoer deur risiko faktore te identifiseer, deur gebruik te maak van verskeie hulpmiddels. Toetse wat risiko faktore identifiseer om beserings te voorkom, kan ondermeer insluit bewegingspatrone, soepelheidstoetse, dinamiese balanseringstoetse of ander faktore wat verhoogde risiko vir beserings veroorsaak. ‘n Vorige besering word beskou as een van die groot risiko faktore vir toekomstige beserings, as gevolg van die neurale veranderinge wat plaasvind wanneer ‘n atleet beseer is. Hierdie veranderinge kan ook bewegingspatrone verander, wat voor die besering in spesifieke aktiverings patrone moet plaasvind. Die doel van die hulpmiddels om risiko faktore te identifiseer, is ook om atlete met versteurde beweginspatrone te identifiseer, binne ‘n bepaalde kinetiese ketting. Hierdie ketting-reaksie tydens beweging is voorafgestel en wanneer dit verander word deur eksterne faktore, soos vorige beserings, lei dit potensieël na volgende beserings. Die “Netball Movement Screening Tool” bestaan uit vier verskillende komponente, naamlik ‘n Bewegingsbevoegdheidstoets, ‘n Spring Toets, ‘n Soepelheidstoets en ‘n aangepaste Dinamisiese Balans Toets. Die Bunkie toets bestaan uit vyf verskillende, isometriese posisies wat gehou word en waarvan elke een van hierdie posisies bilateraal uitgevoer word.

Die hoof doel van hierdie studie was om vas te stel of hierdie twee hulpmiddels, naamlik die “Netball Movement Screening Tool” en die totale Bunkie toets uitslae as funksionele toetse gebruik kan word om beserings te voorspel in universiteit netbal spelers. Sekondêre doelwitte sluit in die inter- en intra-puntebeheerder betroubaarheid van die “Netball Movement Screening Tool” vir onervare en ervare puntebeheerders, sowel as die bepaling van ‘n verwantskap tussen die aangepaste dinamiese balans toets (“Star Excursion Balance Test”) en totale aangepste Bunkie toets uitslae. Hierdie beskrywende studie is uitgevoer met deelnemers van die Universiteit van Stellenbosch se netbalklub lede.

Statistiese toetse het getoon dat geen noemenswaardige bevindinge vir die logistieke regressie gevind is nie, met waardes van 0.47 (95% CI 0.131 – 1.654) en 1.00 (95% CI 0.983 – 1.021) vir die "Netball Movement Screening Tool" en die totale Bunkie toets uitslae. Swak tot gemiddelde korrelasies is bevind tussen die aangepaste Dinamiese Balans Toets en die Bunkie toets ($r = 0.36 – 0.43$, $r^2 = 0.13 – 0.18$, $p \leq 0.05$). Die inter- en intra-puntebeheerder se betroubaarheid (geraporteer as "ICC" ooreenstemmings) vir onervare puntebeheerders was albei 0.35 vir die Bewegingsbevoegdheidstoets en 0.34 en 0.64 vir die Spring komponente se uitslae, binne-in die "Netball Movement Screening Tool". Dieselfde uitslae vir ervare puntebeheerders wys "ICC" ooreenstemmings van 0.98 en 0.93 vir die Bewegingsbevoegdheidstoets alleenlik, maar as gevolg van 'n tekort aan verskille kan die ooreenstimming vir die Spring komponent deur geoefende puntebeheerders nie bepaal word nie.

Hoewel die "Netball Movement Screening Tool" en totale "Bunkie" toets uitslae nie beserings kon voorspel nie, was daar 'n positiewe korrelasie tussen die totale Dinamiese Balans Toets en totale Bunkie toets uitslae.

Sleutel woorde: "Netball Movement Screening Tool", Bunkie toets, Beserings

ACKNOWLEDGEMENTS

I would like to thank the following individuals for their contribution to this study.

Thank you to our Heavenly Father, whose blessings I am grateful for every day.

My dear husband, who sat with me during the late nights and who continuously supports me and encourages me to follow my dreams. Thank you for your love and support.

To my family, especially my parents who taught me to never give up and to always work hard. Without those life-lessons, I would not have completed this thesis. You have always supported me and I love you both dearly.

Dr Ranel Venter (Supervisor) who believed in me, motivated and supported me through difficult times. Thank you for your patience and encouragement. Even when I thought it was all over, you pushed me harder and made me stronger. You are an amazing person who always acknowledges others and I admire that.

Dr Karen Welman (Co-supervisor), thank you for your kindness and for all the motivation over this period. I am grateful for the lessons learnt and the time you have invested.

Prof Martin Kidd, statistician at Stellenbosch University. Thank you for all the time you spent on my stats. Though you were not at full health, you still completed everything I asked for and for this, I thank you dearly.

Dr Babette van der Zwaard, thank you for every skype session, phone call, message and weekend you have contributed to this study. You are an inspiration to me and I am honoured to have worked with you.

My dear colleagues, who have worked so hard and supported me through this study. Thank you for all the days that you have kept the practice going, even in my absence. This hard work and dedication is not overlooked and I appreciate each and every one of you.

Lastly, to my friends: thank you for always supporting me.

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LIST OF ABBREVIATIONS

NMST	Netball Movement Screening Tool
FMS™	Functional Movement Screen
MCS	Movement Competency Screen
ASLR	Active Straight Leg Raise test
SEBT	Star Excursion Balance Test
CNS	Central Nervous System
APL	Anterior Power Line Bunkie test
PPL	Posterior Power Line Bunkie test
LSL	Lateral Stabilising Line Bunkie test
MSL	Medial Stabilising Line Bunkie test
PSL	Posterior Stabilising Line Bunkie test
Ant	Anterior reach direction in SEBT
PM	Posteromedial reach direction in SEBT
PL	Posterolateral reach direction in SEBT
OR	Odds Ratio
CI	Confidence Interval
ICC	Intraclass Correlation Coefficient
L	Left
R	Right
US	University of Stellenbosch

APPENDICES

CHAPTER ONE

INTRODUCTION AND PROBLEM STATEMENT

1.1 Structure of the Thesis

Chapter One: **INTRODUCTION AND PROBLEM STATEMENT**

This chapter provides an introduction to this thesis and includes the problem statement, primary aim of the study, objectives for each article represented in this study and the motivation of the study.

Chapter Two: **THEORETICAL CONTEXT**

This is an explanatory section that describes the findings of previous studies with relation to the topic of this study. Each section is described in detail and provides information from other relevant sources.

Chapter Three: **RESEARCH ARTICLE ONE**

In this chapter the Netball Movement Screening Tool (NMST) and Bunkie test results will be used together with injury statistics of the tested players, to determine whether these two screening tools can predict injury in university netball players. In this article, the inter- and intra-rater reliability of the Netball Movement Screening Tool will also be described specifically for the Movement Competency Screen (MCS) and the Jump components of the screening tool. The reliability is determined for trained and untrained raters. Referencing style may vary, as the journal guidelines for *Physical Therapy in Sport* (Appendix G) was followed.

Chapter Four: **RESEARCH ARTICLE TWO**

This article describes and discusses the findings between the relationship of the modified Star Excursion Balance Test (SEBT) results and the modified Bunkie test results. Referencing style of this article may vary from the rest of this thesis, as it is in accordance with the guidelines for the *International Journal of Sport Science and Coaching* (Appendix H).

Chapter Five: **SUMMARY, CONCLUSION, LIMITATIONS AND FUTURE RESEARCH**

The chapter will capture the thesis in a summary and include the conclusions drawn from the results. It will also state the limitations of the study and make suggestions for future research possibilities.

1.2 Introduction

Netball is a team sport, played predominantly by female participants in various countries all over the world, including Australia, New Zealand, England, Malaysia, South Africa and Namibia. As with all other sports, the risk for injury is a reality and various researchers have tried to identify possible risk factors associated with injury as well as those players who are inherently at increased risk of injury. Risk factors can be either intrinsic or extrinsic. Frisch et al. (2011) mentioned that hypermobility, muscular fatigue, lower cardiorespiratory endurance, poor coordination and poor muscle strength have been identified as possible intrinsic risk factors. To identify these intrinsic risk factors, screening tools are frequently used during pre-season testing. Once a specific risk factor has been identified, various steps may be implemented to reduce the risk of injury, with relation to the specific risk factor identified. The challenge remains to accurately determine possible risk factors in each sporting code as well as how to implement standard protocols so as to reduce and possibly prevent injury.

Screening tools primarily consist of functional movement patterns, flexibility tests and / or strength tests (Dallinga, Benjaminse & Lemmink, 2012; Cook, Burton & Hoogenboom, 2006a; McKeown, Taylor McKeown, Woods & Ball, 2014). Functional movement patterns are based on the fundamental aspects of daily human movement patterns, as these are present in most sporting activities (Cook, et al., 2006a). It is suggested that improvement in sports performance is dependent on the ability of an athlete to execute these fundamental movements optimally under pressure (McKeown et al., 2014).

The fundamental movements consist of squatting, jumping, lunging, pushing, pulling and bracing (Cook et al. 2006a; McKeown et al., 2014). When a screening tool is used to assess these movement patterns, the aim is usually to evaluate dysfunction in the pattern during execution. For the extremities of the body to function efficiently during movement patterns, core stability has to be present. Core stability is described as the ability to prevent collapsing and to be able to return to stability after discomposure, with the use of the lumbopelvic hip complex musculature (Peate, Bates, Lunda, Francis & Bellamy, 2007). Kibler, Press and Sciascia (2006) suggests that a single definition for core stability is not available and that it can be defined as follows: “The ability to control the position and motion of the trunk over the pelvis and leg to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities”. According to Kibler et al. (2006), core stability should be included during the assessment of all extremity injuries. This is suggested, because core activity is present during sporting activities such as running and throwing. Hodges and Richardson (1997) suggested that prior to any movement of a limb, the trunk muscles are activated and produce a form of stability to protect and brace the spine.

For sporting activities, activation and sufficient strength of the core muscles are necessary to provide stability in various planes, as functional movement does not occur in a single plane of motion (Leetun, Ireland, Wilson, Ballantyne & Davis, 2004). Core muscles include musculature such as the transversus abdominus, the internal and external obliques, the erector spinae, the rectus abdominus and the multifidus. Leetun et al. (2004) also suggested that female athletes with hip and trunk musculature weakness may not be able to stabilise these specific segments sufficiently and will be susceptible to injury when external forces are applied, specifically in the frontal and transverse planes.

Various screening tools have been developed in an attempt to determine injury risk in athletes. Some of the instruments include the Functional Movement Screen™ (FMS), the Movement Competency Screen (MCS) and the Netball Movement Screening Tool (NMST) (Cook et al., 2006a; Cook et al., 2006b; Kritz, 2012; Vanweerd, 2013).The NMST was specifically designed to identify netball players at higher risk for injury. The unique NMST comprises of four different screening components to identify intrinsic risk factors for netball specific injuries. These components are the Movement Competency Screen (MCS), the Jump Category, the Active Straight Leg Raise Test (ASLR) and the modified Star Excursion Balance Test (SEBT). These components do not address hypermobility, muscular fatigue, poor coordination or muscle strength directly, which have all been described as intrinsic risk factors for injury by Frisch et al. (2011). Injury prevention would reduce the costs involved in treatment and rehabilitation therapies. In addition it could reduce the time lost from participation, due to recovery.

The Bunkie test has been introduced as a core stability test to determine functionality of the ‘fascial lines’ as described by de Witt & Venter (2009). Though the direct testing of ‘fascia’ by means of the Bunkie test needs scientific support (Ronai, 2015), it is useful as a tool to test all core muscle directions bilaterally. It has been suggested that the Bunkie test can be used to predict injury, by determining poor muscle activation within a specific kinetic chain and revealing weakness and imbalance.

One single screening tool cannot be used to identify players at risk, as most injury risk factors are multifactorial. Thus it is important to find the relationship between different screening tools and to identify the most accurate combination of tests for a specific sporting code, according to the sporting demands and requirements.

1.3 Problem statement and motivation

Although there are many assessment tools available to determine possible injury risk in athletes, not many have been designed for netball players specifically.

The NMST includes the screening of functional movement patterns, jump and land patterns as well as flexibility and dynamic balance. As stated previously, all functional movements require core stability to be executed efficiently, though this screening tool does not isolate the testing of core stability. The Star Excursion Balance Test (SEBT) has previously been used in female basketball players to predict injury of the lower extremities (Plisky, Rauh, Kaminski & Underwood, 2006).

Although it can be argued that functional movement patterns will show poor results in those with poor core stability, other factors, such as biomechanical abnormalities, may also influence function, as produced by the kinetic chain (Kibler et al., 2006) and increase the risk of injury (Neely, 1998). Since core stability is required in all sporting activities, it should be included and isolated in screening tools. The Bunkie test, as a relatively new and simple assessment tool for muscle function, relating to core stability, could prove valuable for implementation in a netball setting.

1.4 Aim and objectives of the study

1. The primary aim of this study was to determine whether the Netball Movement Screening Tool (NMST) and the Bunkie test results can be used to predict injury in university netball players.
2. To determine the inter-rater and intra-rater reliability of trained and untrained raters.
3. To determine the relationship between the modified Star Excursion Balance Test (SEBT) results and the modified Bunkie test results.

CHAPTER TWO

THEORETICAL CONTEXT

2.1 Introduction

This chapter aims to create the context for the study. Firstly, a brief description of netball, netball injuries and possible risk factors for injuries are presented. Secondly, some movement and core stability screening tools for use in team sports are described, as well as aspects relating to rating or scoring during testing, Finally, the statistical analyses used is explained.

2.2 Netball

Netball is a popular sport in various countries over the world and is played by both men and women. Flood and Harrison (2009) reported that netball is played by more than 20 million people worldwide. Participation is mostly amongst female participants and is played at various levels of competition ranging from school to elite international competitions. According to McManus, Stevenson and Finch (2006), an estimate of one in seven females in Australia participate in netball on a regular basis. Netball is a fast-paced sport that involves running, pivoting, sudden changes in direction, jumping, catching and passing (Vanweerd, 2013). Therefore the skill requirements include, amongst others, good dynamic balance, endurance, power and flexibility (Reid, Vanweerd, Larmer & Kingstone, 2015).

2.3 Netball injuries

The identification of netball injury sites is not the only important aspect when it comes to identifying athletes that are at risk. Injury types and mechanisms are equally important to understand and of which to take note. In netball specifically, the two most injured body regions include the ankle and knee joints (Ferreira and Spamer, 2010; Gamble, 2011a; Hopper, Elliott & Lalor, 1995). A study conducted by

Hootman, Dick and Agel (2007) revealed that out of 15 collegiate sports over a prolonged period, women's basketball players had the second highest rate of ankle ligament sprains and the shared highest rate of ACL ligament injuries, together with female gymnasts. This again provides evidence of the similarity in injury profiles of netball and basketball players (similar to that of Flood & Harrison, 2009). Injury type is predominantly ligamentous of nature (Gamble, 2011a), especially with regards to the ankle joint. Injury mechanism is important to understand, as this is modifiable and can thus indirectly assist in the reduction of injuries. According to Ferreira and Spamer (2010), Gamble (2011a) and Hopper et al. (1995), the most common injury mechanism is incorrect landing techniques. This is followed by a slip, fall or sudden stop and then player contact.

Injury onset can be classified as acute or sudden onset associated with trauma, and overuse or gradual onset without any known trauma (Ferreira & Spamer, 2010; Steffen, Myklebust, Andersen, Holme & Bahr, 2008). A majority of these injuries are identified as acute injuries. This does not suggest that netball players do not suffer from chronic injuries it merely states that the most amount of reported injuries in netball are acute.

2.3.1 Acute injuries

Acute injuries are classified as an injury where a specific incident occurs and a player experiences pain. These injuries can include contact or non-contact incidents.

The most common sites for acute netball injuries have been reported as the ankle and knee joints (Cassell, Kerr & Clapperton, 2012; Ferreira & Spamer, 2010; Gamble, 2011a; Hopperet al., 1995). A South African study by Ellapen, Schoeman, Zaca, van Heerden & Ramiah (2015) has found that acute injuries amongst adolescent female netball players in the Kwa-Zulu Natal region in South Africa were primarily injuries of the knee and ankle joints. Injury severity can often be associated with the site of injury. Ankle injuries were considered less serious, but knee injuries are more likely to be serious injuries. Cassellet al. (2012) reported that over a three year period, 66% of hospitalised injuries were lower extremity injuries, of which 90% were knee injuries and only 9% were ankle and foot injuries. Though ankle injuries are usually considered less serious in comparison to knee injuries, residual effects can lead to increased risk for re-injury (Hertel, Braham, Hale & Olmsted Kramer, 2006; Hiller, Refshauge, Bundy, Herbert & Kilbreath 2006; McManuset al., 2006;).

Lateral ankle sprains are the most commonly reported ankle injuries (Gamble, 2011a; Hopperet al., 1995; Leeet al., 2014). After an initial ankle sprain, residual symptoms may persist and an increased risk of re-injury occurs. The residual symptoms include giving way of the ankle, swelling, pain and instability. Instability can be categorised as mechanical instability or functional instability. Should an individual have recurrent sprains, as well as mechanical and/or functional instability, they can be classified as having chronic ankle instability (Gamble, 2011a; Gribble et al., 2013; Lee et al., 2014; Wikstrom et al., 2012).

Knee injuries can include meniscal injuries and ligamentous injuries, of which the most traumatic injury is an anterior cruciate ligament (ACL) rupture. The mechanism most often linked to knee injuries can include incorrect landing techniques, pivoting of the body with the foot planted and contact injuries with the foot planted (Gamble, 2011a; Hopper et al., 1995).

The rules of netball are set out by the International Federation of Netball Associations (All Australia Netball Association, 2012) and specifically with reference to the foot rule, it states that when a player catches the ball with one foot grounded or when landing on one foot from a jump, she is only allowed to: a) step with the other foot and then lift, b) step with the other foot and use it to pivot, c) step with the other foot and jump or d) jump from the landing foot. Should the player gain possession of the ball and land on both feet or have both feet grounded, she is allowed to: a) step with either foot and lift the other, b) step with either foot and pivot on the other foot, c) jump from both feet and land on either foot or d) step with either foot and then jump. Otago (2004) suggested a change in the footwork rule in an attempt to decrease the ACL injuries in netball players.

Injuries resulting in hospitalisation in Australia between 2000 and 2004 as reported by Flood and Harrison (2009) for female netball and basketball players can be seen in Table 2.1.

Table 2.1. Knee, leg, ankle and foot injuries for netball and basketball players, resulting in hospitalisation in Australia between 2000 and 2004 (Flood and Harrison, 2009).

	Netball Players	Basketball Players
TOTAL KNEE / LEG INJURIES	37.4%	28.6%
Dislocation, sprain or strain of joints or ligaments in the knee	31.8% of which 17.2% ACL rupture	21.9% of which 11.0% ACL rupture
TOTAL ANKLE / FOOT INURIES	19.3%	9.3%
Dislocation, sprain or strain of joints or ligaments in the ankle / foot	2.9%	2.2%

This is not necessarily a full description of injuries, since these are only hospital admissions, but it does highlight that in both sports knee injuries and in netball, ankle injuries form a large contribution to medical costs.

2.3.2 Overuse injuries

Overuse injuries (classically known as chronic injuries according to Paterno, Taylor-Haas, Myer & Hewett, 2013) are defined as injuries that occur following repetitive loading and an inability of the body to dissipate such forces, leading to micro-trauma in the absence of an incident or trauma. Overuse injuries can include some of the following conditions, but are not limited to these: Patellofemoral pain syndrome, medial Tibial stress syndrome, tendinopathies, bursitis, stress fractures and lumbar region discomfort (Ferreira & Spamer, 2010; Yang et al., 2012).

Symmetry of the muscular system can refer to contralateral muscle balance as well as agonist / antagonist muscular balance. Page and Frank (2002) described a functional approach to musculoskeletal medicine, taking into consideration all the systems within the body. This approach is mostly related to overuse injuries or pain. The functional approach suggests that optimal movement patterns require balance between opposing muscle groups and movement dysfunction can occur as a result of muscle imbalance.

The Janda approach described in the article by the Thera-Band Academy (Page and Frank, 2002), states that an interdependence of the central nervous system (CNS) and the musculoskeletal system is present and these systems cannot be separated functionally. This specifically refers back to the definition of the functional system of human movement, known as the “sensorimotor” system (Page, 2006). Vladimir Janda previously stated that the site of pain and its source is often two different things (Janda, 1978; Liebenson, 2012). A similar phenomenon is again described by Sueki, Cleland and Wainner (2013), but is referred to as ‘regional interdependence’, as suggested by Wainner, Whitman, Cleland and Flynn (2007). This concept is important in understanding the mechanism, prevention and treatment of overuse injuries, as the site of pain is not always the site of concern (Cook, Burton, Hoogenboom & Voight, 2014a). This may potentially influence the diagnosis, the rehabilitation plan and can be a confounding variable. It also emphasizes the importance of maintaining muscular balance to prevent movement dysfunction.

2.4 Netball player profiles

The anthropometric composition of netball players may vary, depending on the playing positions. Centre players are typically shorter than the average attacking or defensive players. Soh, Ruby and Soh (2006) reported an average body mass index (BMI) of 18.93 kg/m^2 (SD 4.41) for the national female netball team of Malaysia and the average age for this group was 23.91 years (SD 3.36). Ferreira and Spamer (2010) reported that in their study group the age varied between 18 and 23 years for elite female university netball players in the North-West region of South Africa and the average BMI for the study group was 22.37 kg/m^2 (SD 0.61). Though the pre-season BMI values are acceptable, the body fat percentage average was slightly increased (26.61%, SD 0.43). The body fat percentages and BMI values of the university players increased significantly from pre-season to post-season measurements in this specific population. Another South African study found the average body fat percentage of a group of regional netball players in the Boland region, to be 25% (SD 4.3) (Venter, Fourie, Ferreira & Terblanche, 2005).

Increased body fat percentages and BMI scores can indirectly increase the risk of injury in netball players (Ferreira & Spamer, 2010), by loading their bodies and allowing fatigue to set in earlier. This early onset of fatigue may be explained by a potential increase in energy required to move a heavier body around and oxygen consumption requirements can be influenced, influencing the metabolic rate of individuals. The use of BMI as a measure is not the best measure to consider in athletic populations, since it cannot distinguish between muscle mass or fat mass gain / loss. Soh et al. (2006) mentioned that increased body fat is a risk factor for injury.

The average age of players in most of the studies was similar, but Soh, Ruby and Soh's study group was slightly older. Ferreira and Spamer (2010) had participants between the ages of 18 and 23 years, Venter et al. (2005) had participants with an average age of 20.4 years (SD 3.3) and Sohet al. (2006) had an average age of 23.91 years (SD 3.36) as their sample group.

2.5 Injury risk factors

Gamble (2011a) mentioned that the primary objective for physical preparation in netball players, as with any other sporting code, should be to prevent injury by identifying intrinsic and extrinsic risk factors and addressing them during training. He also suggested that screening of musculoskeletal and dynamic profiles of players to identify these risk factors should occur prior to designing a training program (Gamble, 2011b). Bahr and Krosshaug (2005) suggested an injury causation model, which proposed that various internal risk factors such as age and BMI (Dallingaet al., 2012) can lead to a predisposed athlete. When the predisposed athlete is exposed to external risk factors, the athlete is more susceptible to injury.

Yanget al. (2012) determined that over a period of four years, female collegiate athletes had a higher rate of overuse injuries than their male counterparts. This could imply that intrinsic risk factors are gender -based to a certain extent. One of the reasons for the increased risk and rate of injuries in female athletes could be the difference in muscle activation patterns with the quadriceps demonstrating dominance over gluteal activation (Gamble, 2011a; Liebenson, 2012) and the tendency to exhibit ligament dominance (Gamble. 2011a), meaning that they primarily rely on passive joint stability. Hughes and Watkins (2006) also determined that female athletes have a tendency to present with greater knee valgus and decreased knee flexion during a landing mechanism. All of these factors can lead to the conclusion that gender as such could be a risk factor for injuries with females experiencing greater risk for injury than their male counterparts.

Intrinsic risk factors include age, gender, body composition, physical fitness, previous injuries, kinematic patterns and psychological factors (Bahr & Krosshaug, 2005; Hughes & Watkins, 2006; James, Kelly & Beckman, 2014; Paterno et al., 2013). Most of these risk factors are considered modifiable risk factors, which can be improved with the application of an injury prevention program. Letafatkar, Hadadnezhad, Shojaedin and Mohamadi (2014) included agonist / antagonist muscle ratios for strength and endurance, neuromuscular control, structural musculoskeletal abnormalities, core weakness and contralateral muscular imbalances as intrinsic risk factors. McCall et al. (2014) suggested that non-contact injury risk factors included a previous injury, fatigue and muscle imbalances.

Fatigue has also been identified as a risk factor, but more specifically to ACL injuries (Hughes & Watkins, 2006). Fatigue is a key factor when injury risk factors are identified and considered (Frisch et al., 2011). According to findings by Wassinger et al. (2014) even upper body fatigue can influence dynamic balance testing results. Since netball is a sport requiring not only the lower body to exert strength, but also the upper body it could increase risk for injury. As noted by Letafatkar et al. (2014) and McCall et al. (2014), muscle imbalances should also be considered as an intrinsic risk factor and can be included in athlete screening protocols to identify and limit such imbalances. It could be proposed that previous injury and muscle imbalances as risk factors are symbiotic. Support for this statement would be the response of muscle tone to nociception as influenced by the sensorimotor system (Page & Frank, 2002). This statement is with specific reference to joint pathology and its effect on muscle tone. Some examples of this include the atrophy of the multifidus musculature in response to chronic low back pain and the inhibition of the Vastus medialis muscle in response to knee effusion. These responses are not limited to these examples and include muscle firing pattern alterations in other joint injuries such as the knee and ankle.

Extrinsic risk factors can increase the risk of injury of the athlete. These include training programs, the environment (e.g. maintenance of court and court type), rules of the sport, equipment (e.g. shoes) and lack of recovery time or rest (Paterno et al., 2013), though one study concluded that the shoe design did not increase the risk of ankle sprains in collegiate basketball players (Curtis, Laudner, McLoda & McCaw, 2008). It is only one study and it should not lead to the exclusion of shoe design as a possible risk factor for injuries in basketball or netball players. McManus et al. (2006) have suggested that not warming up should also be included as a risk factor for injury.

In netball specifically, the rules of the game can be considered as an extrinsic risk factor which may contribute significantly to injuries. The rules lead to a high probability that a player has one foot planted, while pivoting on the same foot and also the presence of sudden deceleration or stopping throughout the game, which is considered a high risk mechanism for knee injuries (Gamble, 2011a; Hughes & Watkins, 2006; Ter Stege, Dallinga, Benjaminse & Lemmink, 2014).

2.6 Screening tools

Lockie et al. (2013) stated: “Effective screening can reveal issues related to movement ability and awareness. Some of the major goals of athletic screening are to provide brief, cost-effective, and easy-to-implement methods for identifying characteristics that could limit musculoskeletal performance”.

Frisch et al*.* (2011) suggest that pre-season screening cannot predict injury risk during the entire season and screening should be continued throughout the season. As fatigue may increase towards the end of the season and towards the end of each game, the risk for injury increases significantly (Frisch et al*.*, 2011). This suggests that athletes should concentrate more on their recovery and have sufficient cardiovascular fitness, endurance and strength throughout the season to prevent excessive fatigue.

This suggestion has also been made by Ferreira and Spamer (2010), who tested university netball players pre-season and again post-season and found that quadriceps flexibility decreased significantly for the whole group, pelvic asymmetries increased during the season and active straight leg raise scores deteriorated. Significant increases in body weight, BMI (body mass index) and fat percentages were also recorded, as well as decreased explosive power throughout the season. On the other hand, external rotation mobility improved and improvements in agility and balancing abilities are also recorded. They concluded that biomechanical deviations were present in female netball players that have sustained more injuries previously. The aim of screening should be identified by the health professional and / or coach, prior to commencement. Pre-season screening to determine performance might be sufficient, but screening to determine injury risk of players, should be repeated throughout the season. Various screening tools exist and can be used by trained professionals to help identify athletes that are at a higher risk for injury. It is suggested that movement screening is most effective at determining the risk of overuse injuries (Whatman, 2013). Though this may be the case, it is widely known that movement screening is not only used for risk profiling of athletes, but also to determine their performance capabilities and their return-to-play profile, following injury. Should an athlete not perform well on a specific task within the screening tool, it may be that an increased risk for injury or re-injury in this movement pattern or joint is present.

2.6.1 Functional Movement Screen (FMS)

The functional movement screening tool (FMS™) was developed by Gray Cook and is primarily used to fill the gap between pre-participation tests and performance tests, by evaluating individuals in not only a functional capacity, but also in a dynamic manner (Cook et al., 2014b). The seven fundamental movements used in the FMS include the following: Deep squat; Hurdle step; In-line lunge; Shoulder mobility; Active straight-leg raise; Trunk stability push-up and Rotary stability. Scoring consists of a score from zero to three, where three is the score allocated for a flawless execution.

A maximum total score of 21 is possible. Tests are completed and scored on the left and right sides separately, but only the lowest score contributes to the total score. Figure 2.1 shows the seven fundamental movements from the FMS™.

Figure 2.1 The Functional Movement Screen (FMS™) movements in order representing the Deep squat; Hurdle step; In-line lunge; Shoulder mobility; Active straight leg raise; Trunk stability push-up and Rotary stability. *(Downloaded from [http://www.builtlean.com/2014/06/03/functional-movement-screen-review/)](http://www.builtlean.com/2014/06/03/functional-movement-screen-review/)*

Individuals, who can perform at high levels of sport, but struggle to complete the movements as set out in the FMS™, could be compensating for shortcomings. This can indicate inefficient movement patterns and could lead to poor biomechanics, which in return can lead to an increased risk for micro- or macro-traumatic injuries. Poor movement patterns are not only developed through poor biomechanics as a result of compensatory patterns for direct insufficient mobility and stability, but also as a result of indirect compensatory patterns due to the presence of a previous injury (Cook et al., 2006a; Cook et al., 2014a).

The highest possible score one can obtain on FMS™ is 21. Letafatkar et al. (2014) found that there was a relationship between injury and pre-season FMS™ scores in University athletes. They also concluded that when an athlete has a score of less than 17 on the FMS™, their likelihood of sustaining an injury to the lower extremity is increased by 4.7 times.

The FMS™ in a study that was carried out on football players was shown to be highly specific (0.91) and if a participant has an FMS™ score of 14 or less the participant is seen as having an eleven-fold increased chance of injury (Kiesel, Plisky & Voight, 2007). In a study done by Kiesel, Plisky and Butler (2011) it was found that right and left asymmetry in the FMS™ scores are related to injury. They hypothesised that if asymmetries were present it may contribute to overall restrictions in movements.

According to Schneiders, Davidsson, Hörman and Sullivan (2011), the primary goal of the FMS™ is to evaluate the body's own kinetic chain system. It can be noted that the kinetic chain is only as strong as its weakest link, since one altered reaction in the chain can contribute to an incorrect pattern further in the chain. Reliability of the FMS™ has been reported and ranges from 0.76 to 0.98 (Parenteau-G et al., 2014), while validity of the FMS™ is lacking (Kritz, 2012), Kazman, Galecki, Lisman, Deuster and O'Connor (2014) suggested that construct validity should be further researched.

2.6.2 Netball Movement Screening Tool (NMST)

The NMST was first introduced by Vanweerd (2013) as a screening tool that specifically relates to netball. The tool consists of a double and single leg squat, lunge, twist, bend, pull and push-up to determine fundamental movement patterns, jump components to determine player characteristics when jumping and landing, the Active Straight Leg Raise (ASLR) test as a component of the FMS, to measure flexibility and the modified SEBT to help determine the dynamic balance of athletes, as required specifically for the sport. According to Vanweerd (2013) the screen covers most aspects of possible injury risk factors through either isolated movements or functional movement patterns. The four tests are illustrated in Figure 2.2.

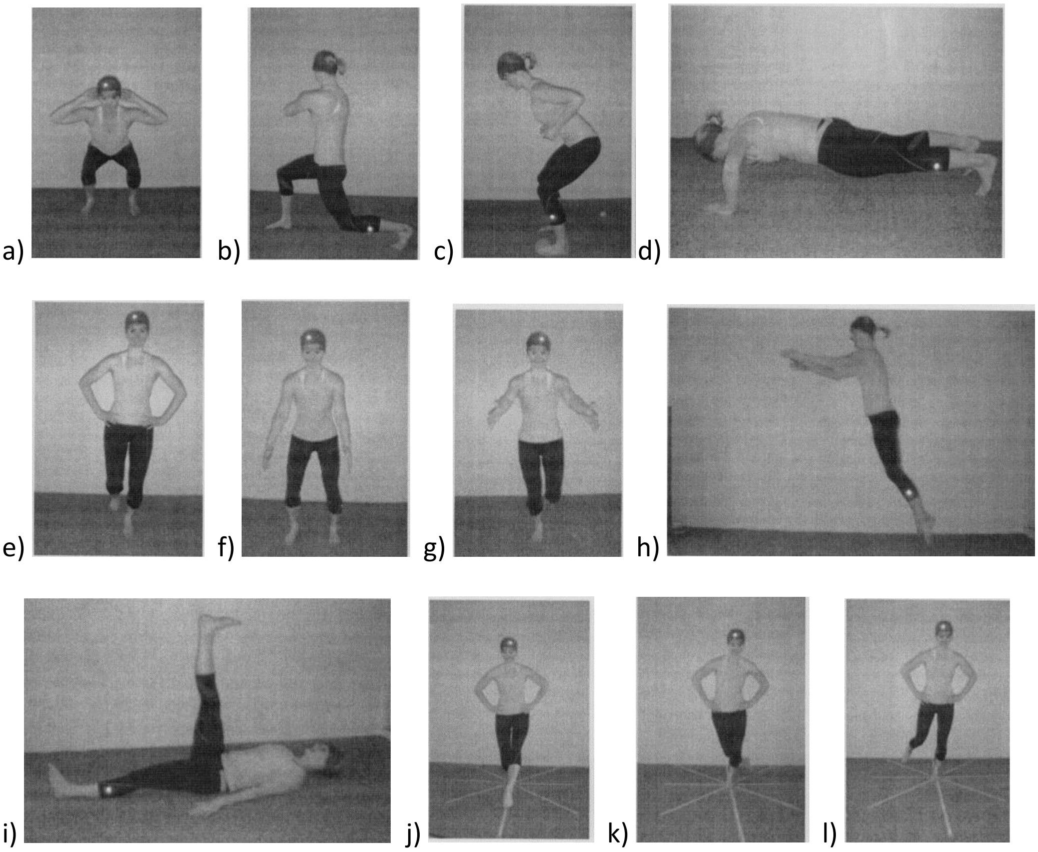

Figure 2.2 Netball Movement Screening Tool: a) MCS squat, b) MCS lunge and twist, c) MCS bend and pull, d) MCS push-up, e) MCS single leg squat, f) Jump test double leg, g) Jump test single leg, h) Jump test long, i) ASLR, j) Modified SEBT ANT, k) Modified SEBT PL, l) Modified SEBT PM (Vanweerd, 2013).

Each individual test and/or movement pattern in the NMST (excluding the modified SEBT) is scored out of 3. This means that the NMST score total is 33, of which a maximum score of 21 is scored from the Movement Competency Screen (MCS), a maximum of nine is scored from the Jump component's three jump tests and a maximum score of 3 can be obtained from the Active Straight Leg Raise score (ASLR). The NMST has been determined to have excellent inter-rater (ICC 0.84) and intra-rater (ICC 0.96) reliability for the overall NMST score (Vanweerd, 2013). To score the NMST reliably, raters of different clinical experience can be used, but they have to have the same training for the scoring system (Vanweerd, 2013) to obtain reliable results.

Movement Competency Screen (MCS)

The Movement Competency Screen (MCS) was developed by Kritz (2012) and takes into consideration the development of an athlete's long-term performance and injury prevention. Very similar to the FMS™, it uses fundamental movements to screen athletes at increased risk. Movements executed during this test include the squat, lunge and twist, bend and pull, push-up and single leg squats. Incorrect movement patterns can be detected and compensatory patterns should be noted.

The scoring system is also similar to the FMS™ in the sense that each movement is scored separately and then a total combined score comprises to determine whether or not the athlete will perform well or is potentially prone to injury. Execution of movements are not the same as the FMS™ in that it requires athletes to combine movements, though scoring is done separately for each aspect of the total movement pattern. For example the lunge and twist: though the athlete executes the movement as a lunge, then twist in the lunge end position, the scoring for the lunge and the twist components are done separately. Vanweerd (2013) reported that the validity of the MCS has not been reported. Kritz (2012) reported inter-rater reliability of the MCS for the average of all patterns as 0.79.

Jump component

Another aspect of the total NMST scoring system is the Jump component. This comprises three different jump tests, directly applicable to netball. The scoring is done according to a pre-determined sheet and a rating is given for each jump, with the lowest score contributing to the total NMST score.

The three jump tests include: a) double leg vertical jump with a double leg landing; b) double leg vertical jump with a single leg landing and c) double leg broad jump with a single leg landing. Jump tests and box drop tests are often used to screen athletes for incorrect landing biomechanics, predisposing an athlete to injury.

As reported previously in the injury profile section, incorrect landing mechanisms are one of the leading causes of netball injuries.

Active Straight Leg Raise (ASLR)

The inclusion of the active straight leg raise (ASLR) in the FMS™ is not solely to test relative hip mobility, but also includes the ability of the athlete to disassociate the trunk and the lower extremity, while maintaining the stability in the torso (Cook et al. 2014b). A score below three can indicate asymmetric hip mobility and functional hamstring flexibility can a cause or true hamstring flexibility can be masked by tightness of the Iliopsoas muscle of the opposite hip. Should a score below three be obtained, further investigation into the cause of this result can reveal the true identity of the risk factor leading to pelvic and hip asymmetry.

Junior netball players may have an increased risk of injury, when general hypermobility is present (Smith, Damodaran, Swaminathan, Campbell & Barnsley, 2005). Joint hypermobility, due to ligament laxity post injury, may also be considered when considering hypermobility as a risk factor. This can indicate why mobility and flexibility should be included in a screening tool for injury risk classification and injury prevention. The increased mobility alone is not the sole concern with increased injury risk, but also the decrease in proprioceptive ability in hypermobile joints (Smith et al., 2005). Contradictory to Neely (1998), who previously stated that muscle tightness cannot be seen as a predisposition for muscle strains, Dallinga et al. (2012) indicated that a lack of mobility can be associated with increased risk injury

Modified Star Excursion Balance Test (SEBT)

The SEBT is a valid test to determine the dynamic balance and to predict lower extremity injury of an individual (Plisky et al., 2006). The test is done bilaterally and normalised test results can be used to identify individuals at risk for lower extremity injuries (Plisky et al., 2006). Normalised results are achieved with a specific formula where the structural leg length is included (Plisky et al., 2006; Vanweerd, 2013,). While Plisky et al. (2006) and Vanweerd (2013) measured the leg length from the anterior superior iliac spine to the lateral malleolus and previously, other studies suggested that the measurement should be taken to the medial malleolus. This should however not influence the test results, as long as determining structural leg length is done with consistency. For the purpose of this study, leg length measurements were done in accordance with Plisky et al. (2006) and Vanweerd (2013) and a modified SEBT test was used.

In the NMST specifically, only three of the eight possible directions of the SEBT are tested, thus a modified SEBT. This includes the anterior (ANT), posteromedial (PM) and posterolateral (PL) directions. Individual results that identify imbalances between left and right legs can also be noted and can indicate increased risk of injury, should a significant difference for a single direction be present. The anterior direction can be used as an indication or risk factor classification for ankle sprains, as decreased ankle dorsiflexion is a positive risk factor. Dallinga et al. (2012) found that a difference between the left and right side of more than four centimetres in the anterior reach direction, could predict leg injuries in girls.

Throughout the execution of the test, the heel of the stance foot may not lift and no weight bearing is allowed on the foot that has to tap at the farthest possible point along allocated lines on the floor. Muscle activation at these specific directions has been established and it is concluded that the Vastus medialis obliquus (VMO) and Vastus lateralis (VL) activity is higher at the anterior position, Tibialis anterior (AT) is higher at the posteromedial direction and at the posterolateral reach direction, the Tibialis anterior (AT) and Biceps femoris (BF) muscles are activated more (Earl & Hertel, 2001).

The intra-rater reliability for each direction is provided as follows: anterior (ICC = 0.84), posterior medial (ICC = 0.82) and posterior lateral (ICC = 0.87). The inter-rater reliability for the anterior, posterior medial and posterior lateral reach directions is 0.89, 0.93 and 0.91, respectively (Plisky et al., 2006).

2.6.3 Video versus real-time scoring

Screening in real-time is more time-effective than to record all movement patterns and then score each athlete from a video. Real-time scoring of the NMST inter-rater (ICC = 0.84) and intra-rater (ICC = 0.96) reliability was good (Reid et al., 2015). Other studies that involved the FMS had kappa scores that ranged between 0.40 – 0.10 (Minick et al., 2010) and 0.33 – 1.00 (Onate et al., 2012) where Minick et al. (2010), scored from a video recording and Onate et al. (2012), did real-time scoring.

McKeown et al. (2014) reported that during the Athletic Ability Assessment (AAA) tool, an excellent correlation between the video and real-time scores was present (r = 0.94). A suggestion has been made that tests which involve quick movements such as jumping and landing should be scored from video recordings, to increase reliability (Vanweerd, 2013).

2.7 Core stability

The definition of core stability has to be carefully defined. Poor core stability has been linked to lower limb and back injuries (Cowley & Swensen, 2008; Huxel Bliven & Anderson, 2013; Kibler et al., 2006).

Core stability is applicable to each sporting type and movement pattern, as the CNS activates the muscles of the trunk prior to gross motor movement, to provide a stable base for expected forces to be produced by the limbs, meaning that core stabilization precedes movement (Cowley & Swensen, 2008; Hodges & Richardson, 1997; Okada, Huxel & Nesser, 2011). According to Kibler et al. (2006) the structures that form the core include the muscles of the pelvis and trunk that are responsible for stability of the spine and pelvis. All extremity activities (e.g. kicking, running and throwing) involve core activity. To select the most appropriate core stability test to identify players who are at risk is difficult and many of the tests simply identify stability of the trunk muscles in a single plane of motion. According to Kibler et al. (2006), optimal core stability may require control in all three movement planes of the trunk, namely the sagittal, frontal and transverse planes. All planes of movement should be included to identify weaknesses in the core musculature and to identify imbalances which could lead to compensatory movement patterns or simply movement dysfunction. Panjabi (1992) described a model that recommends core stability consists of three subsystems, namely the passive, active and neural control subsystems. Each subsystem consists of different structures and the active subsystem consists of the core musculature.

Kibler et al. (2006) and Gamble (2011b) suggests that core stability is an important component of athletic function, where function is considered to be produced by the kinetic chain. The kinetic chain is defined as the coordinated sequence of events that activate body segments and places each distal segment in an ideal position for the specific task (Kibler et al., 2006).

Evaluation of the kinetic chain reveals the necessity of certain joints to be mobile and other joints have to be stable to work optimally (Liebenson, 2012). Should a stable joint become unstable, it can lead to a mobile joint becoming “stiff” or less mobile. This can occur in the kinetic chain reaction (Liebenson, 2012),for example, if the ankle becomes stiff, the foot and / or knee joints will become unstable to compensate for the lack of mobility provided by the ankle. This stiffness is produced by incorrect firing patterns of the muscles. This concept is inter-linked with the observations of Vladimir Janda, whom proposed that muscle imbalances can be predicted throughout the body, leading to incorrect movement patterns (Janda, 1978). He suggested that training should occur within movement patterns and should not consist of isolated muscle contractions. By isolating muscles during training, it can enforce incorrect movement patterns and then create compensatory muscle imbalances (Liebenson, 2012). This suggests that core stability testing procedures should not isolate any specific muscle / muscle groups, but should rather be executed in the kinetic chain and movement patterns.

2.7.1 Bunkie test

The word Bunkie is derived from the Afrikaans word “bankie”, referring to a small bench (Brumitt, 2015; de Witt & Venter, 2009). It is a functional assessment of core stability and imbalances. The test is conducted with a bench (approximate height between 25 and 30 centimetres) and a non-slip mat. The athlete will place their feet on the bench and their elbows on the mat and lift the entire body off the floor in a plank / bridge position. Once a stable position is reached, the athlete will be instructed to lift one foot off the bench and maintain the position for as long as possible, maintaining correct postural positioning and form. An imbalance between the left and right sides can be detected with this test, as well as specific weakness and short-comings in the fascial lines as described by de Witt and Venter (2009). These lines, according to de Witt and Venter (2009) consist of two power lines, anterior and posterior, and three stabilizing lines, posterior, lateral and medial. Weakness during this test can be ascribed to fascia being ‘locked-long’ and thus inhibiting specific muscle activation potential, which can lead to injury, according to de Witt and Venter (2009), though others have assigned the contribution to kinetic chain weakness (Kibler et al., 2006; Leetun et al., 2004; Oliver, Dwelly, Sarantis, Helmer & Bonacci, 2010). To execute core stability tests on one leg has been shown to increase muscle activation (Gottshall, Mills & Hastings, 2013), making the execution of the test more challenging.

Ideally, if there is no weakness in the specific position being tested, all muscles within this position (kinetic chain) will be activated by the test position and work together. Each test direction or plane measures core stability as endurance, but the legs and shoulder girdle contribute significantly (Ronai, 2015). This can imply that the Bunkie test includes all the major joints involved in the entire kinetic chain as recorded by Liebenson (2012). Therefore, a weakness revealed by a specific Bunkie test direction can be considered a true weakness or muscle imbalance, should the correct posture not be maintained throughout testing procedure. The test positions for the Bunkie test is shown in Figure 2.3.

Figure 2.3 The Bunkie test positions in order of presentation: Anterior Power Line (APL), Posterior Power Line (PPL), Lateral Stabilising Line (LSL), Medial Stabilising Line (MSL) and Posterior Stabilising Line (PSL) (www.lynosport.co.za©)

Major muscles involved in each of the positions of the Bunkie test (Ronai, 2015) directions are as follows:

APL: Rectus abdominus, Rectus femoris, Iliopsoas, Tibialis anterior.

PPL: Erector spinae, Thoracodorsal fascia, lateral Soleus and Gastrocnemius, Gluteus maximus, Biceps femoris.

LSL: Sternocleidomastoid, Upper Trapezius fibres, Latissimus dorsi, Obliques of the trunk, Serratus anterior, Gluteus medius, Tensor Fascia Lata, Iliotibial band, Vastus lateralis, lateral Gastrocnemius and Soleus and the Peronei musculature.

MSL: Adductor longus, Pectineus, medial Gastrocnemius and Soleus, Sartorius and Gracilis.

PSL: Trapezius, Semitendinosus and Semimembranosus, medial Gastrocnemius and Soleus, Sartorius and Gracilis.

The test was designed to test the ability of an athlete to maintain a specific position for an amount of time, depending on the sporting type and requirements. The position is usually held between 20 – 40 seconds, where endurance athletes should be able to hold each of the five positions for 40 seconds on each side without experiencing any sensation of pain, burning, cramping or strain (de Witt & Venter, 2009).

Ronai (2015) highlights in his article that reliability and validity results are not readily available, but Brumitt (2015) had provided face validity for the Bunkie test and van Pletzen and Venter (2012) conducted a test-retest experiment to assess the reliability and found no significant differences between the results of the four separate Bunkie test occasions.

Intraclass correlation coefficients for the Bunkie test for the anterior power line, posterior power line, lateral stabilising line, posterior stabilising line and medial stabilising line was 0.82, 0.95, 0.95, 0.92 & 0.95, respectively (Brumitt, 2015).

2.8 Core stability and functional movement

Functional movement can be defined as the capability to sustain the equilibrium between mobility and stability along the kinetic chain while executing fundamental patterns efficiently (Okada et al., 2011). Although no correlation was found between the FMS™ and core stability (Okada et al., 2011), in contrast, Mitchell, Johnson and Adamson (2015) tested children between the ages of eight and eleven years and found a significant, but small positive correlation between the FMS™ and core stability tests (prone plank and side plank positions). As mentioned by Murphy, Connolly and Beynnon (2003), muscle imbalance can be considered a risk factor for ankle and knee injuries.

Core stability definition influences the testing protocol and can explain why there are contradicting findings with regards to the relationship of functional movement screening protocols and core stability. Some studies have proposed only the trunk muscles be included where others have suggested the inclusion of shoulder and hip musculature, as energy is transferred from the trunk and pelvis to the extremities through the shoulders and hips (Hibbs, Thompson, French, Wrigley & Spears, 2008). For the purpose of this study, core stability will include the trunk, pelvis, shoulder girdle and hip musculature, since the Bunkie test includes all of these aspects. During sporting activities, especially those related to netball, all of the muscles and joints involved in this definition are being used simultaneously. This amplifies the importance of all the muscles and joints within each kinetic chain reaction to work in harmony and with optimal performance. Huxel Bliven and Anderson (2013) have emphasised the importance of core stability in fundamental movement patterns and that it maintains a neutral spine and allows for load transfer along the kinetic chain.

2.9 Statistical analysis

Descriptive statistics of participants such as age, height, weight, body mass index (BMI) and leg lengths are reported as means, together with standard deviation (SD). Frequency tables are used so as to determine the age at which players started playing netball, as well as the number of years spent playing netball and the number of injuries reported in the past 12 months. Old injuries were reported by the players themselves and the analysis of variance (ANOVA) was completed. The resulting data is presented as a percentage of the total number of participants (Appendix I). All available players from the Stellenbosch University netball club participated in the study. Two of the 39 players did not complete all tests, since one player withdrew voluntarily and one player experienced discomfort during a specific testing protocol.

Inter-rater and intra-rater reliability was calculated and is presented as the intraclass correlation coefficient (ICC) agreement. Cowley and Swensen (2008) mention in their study that ICC cannot be reported solely as a statistical measure of reliability, as it is affected by sample heterogeneity (de Vet, Terwee, Knol & Bouter, 2006) and a recommendation is made that SEM, CV and limits of agreement should be determined in conjunction with the ICC (Cowley & Swensen, 2008).

The relationship between the NMST, its components and the Bunkie test was calculated as Spearman correlation (reported as Rho values) and the alpha level set at 0.05 (Appendix I). Results for the relationship between the Bunkie test and SEBT was calculated using the Pearson correlation with alpha set at 0.05, using SPSS for Windows, Version 22.0 (Chicago, SPSS Inc.)

A logistic regression was completed, and reported as an odds ratio, to determine whether players had a higher chance of becoming injured.

2.10 Summary

When an athlete experiences an injury such as ankle instability, various muscle activation patterns are affected, joint position sense is poor and balance is reduced (Gamble, 2011a; Terada, Pietrosimone & Gribble, 2014). It is important that athletes are tested prior to returning to the sport, to prevent future injuries, as a result of previous injury. Biomechanical deviations are often implicated as a causative factor for chronic injuries (Ferreira & Spamer, 2010) and should be identified as soon as possible in athletes that are at risk. An ACL rupture will most probably result in surgery and a player having to miss out on the rest of the season to recover and rehabilitate. Thus it is important for coaches and players to prevent such injuries at all cost.

Risk factors are rarely tested throughout the season to determine whether the risk of the athletes increases throughout the season as the player's fatigue and various other physiological and anthropometrical changes occur. It is important to determine risk profiles of each player throughout the season, not only pre-season.

Given the link between core stability and injuries, specifically lower limb and back injuries, it is important to add a component of core stability testing to screening tools. The injuries most often experienced by netball players include lower limb injuries, especially the ankle and knee joints which highlights the necessity for core stability testing.

The researcher hypothesizes that both these screening tools should be able to identify injury risk.

CHAPTER THREE

RESEARCH ARTICLE ONE

THE USE OF THE NETBALL MOVEMENT SCREENING TOOL AND THE BUNKIE TEST TO PREDICT INJURY IN UNIVERSITY NETBALL PLAYERS

The referencing style used in this Chapter is in accordance with the guidelines of the Physical Therapy in Sport journal (Appendix G) and can thus vary from the referencing style used in the rest of this thesis.

The use of the Netball Movement Screening Tool and the Bunkie test to predict injury in university netball players

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Running title: Functional tools to determine injury risk in university netball players.

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The use of the Netball Movement Screening Tool and the Bunkie test to predict injury in university netball players

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ABSTRACT

Screening tools are required to identify athletes at risk for injuries or as a precautionary measure when athletes return to play. The Netball Movement Screening Tool (NMST) is a screening tool that uses various components to identify specific risk factors aimed at netball players. Core stability improvement through exercises has previously been proposed as an injury prevention strategy. The Bunkie test is used to test core stability. Scoring for the NMST was done from video recordings and results were used to determine the inter- and intra-rater reliability. The Bunkie test was scored in real-time. Data from 37 university netball players were used. Logistic regression results revealed no significant findings for the SEBT (OR = 0.47, 95% CI = 0.13 – 1.65) or the Bunkie test (OR = 1.00, 95% CI = 0.98 – 1.02). Inter-rater reliability between untrained and trained raters was poor (ICC = 0.34). Intra-rater reliability was good (ICC = 0.93 – 0.99) in untrained and trained raters. The NMST and Bunkie test did not predict injury in this group of university netball players and raters have to obtain training prior to using the NMST.

KEY NOTES

Netball Movement Screening Tool, Bunkie test, Reliability, Trained, Untrained

INTRODUCTION

Screening tools are designed with the intention of predicting and preventing injuries by identifying athletes that are predisposed to specific injuries (1 – 3). These screening tools primarily identify isolated risk factors, though it has been proposed that testing protocols should assess multiple domains simultaneously, with the intention of improving the accuracy of identifying athletes at risk (1, 4). The focus has been placed on improving movement patterns and the quality thereof, to identify compensatory movement patterns caused by muscle weakness, muscle tightness and poor neuromuscular patterns, with the intention of reducing injuries (5, 6). Filipa, Byrnes, Paterno, Myer & Hewett (7) have focused on core stability as part of an intervention for neuromuscular training programs to improve dynamic balance and reduce the risk of injury. Huxel-Belvin & Anderson (8) acknowledge core stability as a risk factor for lower extremity injuries.

The Netball Movement Screening Tool (NMST) consist of various testing protocols, as used by Reid et al. (1) includes the Movement Competency Screen (MCS), the Jump components, the Active Straight Leg Raise Test (ASLR) and the modified Star Excursion Balance Test (SEBT). The various components aim to test functional movement patterns, flexibility and dynamic balance. These skills are all required by netball players, to perform optimally and to prevent injury (1). Netball injuries, similar to basketball injuries in female players, often occur to the lower extremities and acute injuries primarily occur at the ankle and knee joints (1, 9, 10, 11). According to Flood & Harrison (9), hospital submissions for specific injuries and injury sites from July 2000 – June 2004 included injuries to the foot and ankle, as well as the knee or leg of female basketball and netball players (see Table 3.1).

Table 3.1 Netball and Basketball injuries hospitalised in Australia between July 2000 and June 2004 (Flood & Harrison, 2009).

	Netball	**Basketball**
Knee or leg injuries	37.4%	28.6%
Ankle or foot injuries	19.3%	9.3%

The Bunkie test is a core stability test that is performed by holding five different isometric plank-type positions for as long as the athlete can keep form or does not experience discomfort. It was first described by de Witt and Venter in 2009 (12) and has been designed to test the function of the fascial lines.

Screening tools have to prove validity and reliability. Since screening tools are designed to identify risk factors for injury, they should provide information about predicting injury.

The reliability of the SEBT and ASLR has previously been determined by Vanweerd (13). The inter-rater agreement for the ASLR, SEBT left and SEBT right were 1.00, 0.99 and 0.99, respectively. The intra-rater agreements were 0.90 (ASLR), 0.81 (SEBT left) and 0.79 (SEBT right). Others have reported intra-rater agreements for the SEBT between 0.82 – 0.87 (4) and agreements of >0.90 and 0.94 for the ASLR (3, 5). Only one study has previously been conducted to determine the inter-rater and intra-rater reliability of the NMST and it was conducted by two physiotherapists, who both received training prior to scoring. This is to date, according to the knowledge of the researcher. Research is required to determine whether the NMST can be administered reliably by other professionals and by raters with varying levels of clinical experience. Brumitt (14) has obtained initial validation for the Bunkie test in the rehabilitation of an endurance runner. He also confirmed that the results for the Bunkie test obtained in this case study by Brumitt (14) correlated with manual muscle testing results he completed, suggesting that the Bunkie test is a valid test for the function of the core. Van Pletzen and Venter (15) conducted a small test-retest experiment with the Bunkie test over a period of five days and the results revealed no significant differences.

The primary aim of this study was to determine whether the NMST and the Bunkie test can predict injury in university netball players. A secondary objective was to determine the inter-rater and intra-rater reliability of trained and untrained raters for the MCS and Jump components of the NMST.

METHODS

Participants

All 39 participants who volunteered were players at the Stellenbosch University's netball club. During the first visit, players were informed of the testing procedures and received an information sheet with all procedures on. During the second visit, each player was asked to sign an informed consent form and received verbal instructions prior to the execution of each test. The jump totals were only completed by 38 players, as one player experienced pain and was excluded from the jump category and another player did not complete all testing protocols, as she voluntarily terminated the testing procedure (n = 37).

NMST

Clear verbal instructions were provided to players to complete the NMST protocol. Each player was recorded for the execution of these movement patterns and each movement had to be completed six times. If the movement is executed bilaterally, it was executed 12 times. Movements were executed and recorded on video from an anterior and lateral view. The completed movements included a squat, lunge and twist, bend and pull, push-up, single leg squat, double leg jump, single leg jump, broad jump and the ASLR. Although the SEBT is included as a component of the NMST, the score does not contribute to the total NMST score, due to the variation in scoring. All scores for the NMST are recorded as a score out of three and the SEBT score is not. This brings it to a total maximum NMST score of 33.

Bunkie test

The word Bunkie is derived from the Afrikaans word “bankie”, meaning a small bench (12). Testing is performed with the feet placed on a small bench and the elbows placed on a non-slip mat. The height of the bench should be between 25cm and 30cm (12, 14, 15). Five different positions are tested bilaterally, providing a total of ten different scores. The position assumed has to be held by the athlete to a maximum of 30 seconds, for the purpose of this study. A maximum time of 40 seconds has been recommended for endurance athletes (12), but a norm has been proposed for healthy individuals to obtain scores of >40 seconds before postural deviations occur or the athlete selects to terminate the test (16).

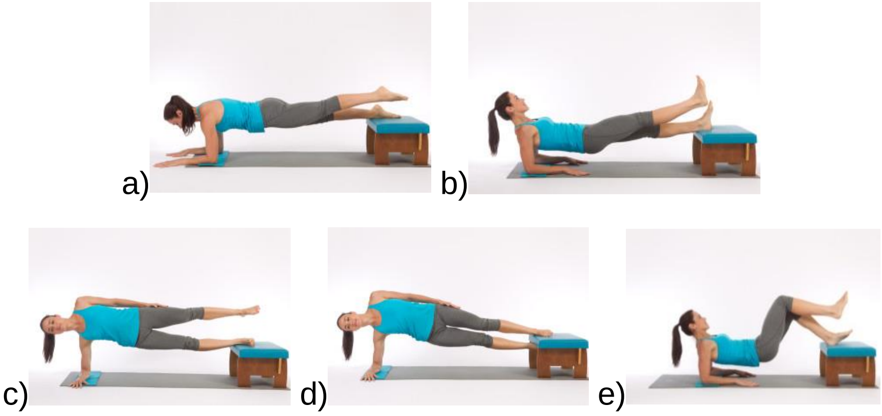

Figure 3.1 The Bunkie test presenting the following positions: a) Anterior Power Line (APL), b) Posterior Power Line (PPL), c) Lateral Stabilising Line (LSL), d) Medial Stabilising Line (www.lynosport.co.za©)

Raters

For the purpose of this study, four raters were used. Two raters were postgraduate honours students in sport science and had no clinical experience (untrained) and two raters were both registered Biokineticists (Allied Health Professionals) with clinical experience between three and seven years (trained).

Data collection

NMST movement patterns were analysed and scored according to the methods used by Reid, Vanweerd, Larmer and Kingstone (1) and described by Kritz (17). The only difference being for the purpose of this study, it was scored from video footage and not real-time scoring as with Reid, Vanweerd, Larmer and Kingstone (1). Each movement pattern as described for the MCS was scored separately, meaning double movements such as the lunge and twist was scored for the execution of the lunge movement, the twist movement and for each side separately. Scoring criteria were also followed, as described by Kritz (17) and a scoring sheet was used for this. The scoring sheet contains primary and secondary areas of concern and each rater received an instructional page that describes the criteria for the primary and secondary areas of concern, per MCS and Jump component (13, 17). Depending on the amount of primary or secondary areas that were ticked, per movement pattern, a maximum score of three and minimum score of one was allocated. The lowest score for bilateral movement patterns was used to contribute to the total score. Total MCS scores were out of 21, total Jump component scores were out of nine and the ASLR score maximum was three.

The Bunkie test is performed with the participant placing her feet on a bench and the elbows are placed on a non-slip mat on the floor. Once the participant is in position, the hips are lifted off the ground and the participant will carry the weight on the elbow(s) and one foot, placed on top of the bench. The position is held for as long as the participant can maintain a good correct posture or does not experience any symptoms of discomfort or cramping. When the athlete does experience any discomfort or cramping, or simply cannot hold the position any longer, she was allowed to stop. Should a participant lack the maintenance of correct posture or reach 30 seconds on the clock, the researcher stopped the test. A score is noted as the amount of seconds held in each position for each leg / side.

The untrained raters were provided with the video recordings, scoring sheets and the information sheet that contained all the recommended criteria for scoring. They only received a short explanation of the scoring process and were informed that they may pause, replay and stop the video as often as required. The second untrained rater was asked to repeat all scores again at a later stage, to determine intra-rater reliability. The same video footage was used. Trained raters had to record practice footage from another source to play and score daily for seven days, as part of familiarisation with the protocol and criteria. Scoring was conducted after the training had been completed and both raters were comfortable with using the scoring system. One week post scoring, rater one of the trained raters repeated all scoring to determine the intra-rater reliability of a trained rater.

The majority of netball injuries recorded in literature is for lower extremity injuries (ankle and knee injuries) and these were noted. . Hence, injuries to the lumbar spine and below were only recorded by the team physiotherapist and then sorted according to injury location. Lacerations and contusions were excluded. An injury was noted as a score of 1 and no injury was noted as a score of 0. Specific cut-off scores were used for the NMST total score and when an athlete scored above the cut-off, a score of 1 was allocated or below the cut-off, a score of 0 was allocated. These cut-off scores are derived from the percentage as determined for the

Functional Movement Screen (FMS™). A general cut-off score of 14/21 is typically used to determine an increased risk for injury by eleven-fold (18). A cut-off score has not been determined for the NMST and this percentage [(14/21)*100) = 66.67%] was used to determine a cut-off score for the purpose of this study. This lead to a cut-off score of [(33*0.6667) = 22]. No cut-off scores for the SEBT and Bunkie test total score results were used.

Statistical analysis

Data with regards to participants are calculated and reported as the average (SD) and age is reported as a range.

A logistic regression was done with SPSS for Windows Version 22.0 (Chicago, SPSS Inc.) to determine whether or not the outcome of the tests can predict injury in this sample. The outcome of this test is reported as an odds ratio (OR).

The total scores for each component (MCS and Jump) and the total NMST scores were reported and used for calculations of the Intraclass Correlation Coefficient (ICC) agreement. SPSS for Windows Version 22.0 (Chicago, SPSS Inc.) was used for the calculations of all variance and reliability scores. Since the reliability between raters was being measured by untrained and trained raters, the ICC agreement parameter was used. The inter-rater reliability between the two untrained raters was calculated and the inter-rater reliability between the two trained raters was calculated. The inter-rater reliability (ICC agreement) for the total NMST scores was also calculated between the untrained and trained raters. One rater in each category, namely untrained and trained, had to repeat the scoring of participants to determine an intra-rater reliability score.

RESULTS

Participants

Participants (n = 37) had a mean age of 19.49 years (SD 1.59), a mean height of 1.75 m (SD 0.69) and a mean weight of 68.60 kg (SD 7.98). The age ranged from 18-25 years and all participants were female.

Logistic regression

The logistic regression results are reported as an odds ratio and can be seen in Table 3.2. Injury data was collected by the physiotherapist treating the participants and provided to the researcher with permission. Testing occurred at the start of the competition phase and all players had good fitness levels.

Table 3.2 Logistic regression results for the NMST, SEBT and Bunkie Test results (OR, 95%CI)

	OR	**95% CI**
NMST	0.47	0.13 – 1.65
SEBT	1.00	0.92 – 1.08
BUNKIE TEST (TOTAL SCORE)	1.00	0.98 – 1.02

Inter-rater and intra-rater reliability

The inter- and intra-rater reliability is presented in Table 3.3 below and is reported as the ICC agreement. Only the total ICC agreement scores are noted here. The inter-rater reliability ICC agreement for untrained raters ranged between 0.35 – 0.34 for the MCS and Jump components separately and 0.98 for the MCS of trained raters. The Jump component for trained raters could not be calculated, since the variance was 0.

The intra-rater reliability for each component for untrained raters were 0.35 – 0.64 and for trained raters 0.93. The clinical significance for ICC agreement was defined as follows (3): below 0.50 is poor, 0.50 – 0.75 is moderate and anything above 0.75 is good.

Table 3.3 The ICC agreements for inter- and intra-rater reliability for untrained and trained raters

	ICC AGREEMENT	Clinical signficance
INTER-RATER RELIABILITY		
NMST TOTAL UNTRAINED RATER	0.43	Poor
NMST TOTAL TRAINED RATER	0.99	Good
NMST TOTAL UNTRAINED:TRAINED RATER	0.14	Poor
INTRA-RATER RELIABILITY		
NMST TOTAL UNTRAINED RATER	0.93	Good
NMST TOTAL TRAINED RATER	0.99	Good

DISCUSSION

The logistic regression was calculated to determine whether the test outcomes can predict injury. It is reported as an Odds Ratio (95% CI) and revealed that none of the tests can predict lower body injury. The OR for the SEBT and Bunkie tests were 1.00 with 95% CI moving across 1, which means that whether an athlete scored a high or a low score in these two tests, their chance of injury was similar. The OR for the NMST was below 1.00, but the 95% CI still moved across 1 (0.13 – 1.65) and can thus not predict injury. One reason for this could be that each player is not solely limited to seeing the team physiotherapist for treatment of injuries and some injuries may be excluded or not reported to the physiotherapist. Another reason could be that the players consider an injury insignificant (grade I ankle sprain or chronic injuries) and may try self-medication to treat the injury and not report it to the physiotherapist. An injury reporting system should be in place to be sure to record all injuries correctly and accurately.

When the NMST is used as a screening tool and more than one rater is used, both raters should have similar training experience in the assessment tool's scoring system rather than the same clinical experience (1). The results confirm this with poor inter-rater reliability results for untrained raters and good inter-rater reliability results for trained raters. Although the trained raters have a clinical experience, a difference of approximately four years, the ICC agreement remains good. They had the same training, specifically for the scoring of the NMST. This is consistent with other screening tools and the inter-rater reliability between raters of different clinical experience, but similar training (2, 3, 5), though one study found that experienced raters tend to be more critical and thus influence the inter-rater reliability (6) especially on individual test scores, but the total score reliability was good. Another study (20) found that rater experience does influence the reliability of results as scored for movement screening tools, with poor reliability found for less experienced raters. Only the total scores for each component were considered for this study and results may vary for individual test scores.

Intra-rater reliability of the MCS was poor amongst untrained raters and the jump was moderate. Irrespective of these findings, the total intra-rater NMST score's reliability was good. These results indicate that untrained raters should rather consider NMST total scores and not individual scores for components of the NMST. The trained raters also had good ICC agreements for the NMST total score, but the MCS ICC agreement was much better in trained raters as opposed to untrained raters. This holds true for the jump scores as well.

One possible reason for the good agreement of the Jump components (0 variability, ICC agreement approaching 1) could be the fact that video footage was used for the scoring of the NMST movement patterns. The video was also allowed to be paused at any point in time, however, real-time analysis for the jump category, scoring would be more difficult as this is a fast movement and clinical experience can influence the scoring of the jump.

Therefore, in order to have a reliable NMST score, raters should be trained, irrespective of the clinical experience. One reason for high intra-rater reliability could be the video scoring system. Each movement was executed exactly the same and no variance amongst players were possible.

Further research is required to re-examine the NMST components and the Bunkie test to predict injury. A full season's injury statistics are required, all injuries should be reported or considered and screening should be performed throughout the season to determine the extent of change in results and injury prediction.

Limitations

Real-time and video assessment agreement is low (ICC 0.23) (21). The agreement should be good, because variability is limited and all scoring was completed from the same video footage, whether testing for inter-rater or intra-rater reliability. This does not guarantee the same results for real-time scoring for untrained and trained raters.

Minimal detectable change could not be calculated from this study, as the scoring was performed from the same video recording of the movement patterns and not in real-time.

ICC agreement was calculated, as this study only determined the reliability parameter of the NMST and not the parameter of agreement. Future research is needed to determine minimal detectable change (MDC) and agreement parameters for clinical relevance.

Players are allowed to use their own choice of physiotherapists for treatment too and it could be that not all injuries were reported to the team physiotherapist.

CONCLUSION

The NMST cut-off points and Bunkie test total score results could not be used to predict injury in this study. The inter-rater reliability of trained raters are good and the intra-rater reliability of untrained and trained raters are good, with the use of video recordings to score participants. Inter-rater reliability between untrained and trained raters is poor.

All raters should undergo formal training before using the NMST, irrespective of clinical experience.

ACKNOWLEDGEMENTS

Thank you to all the Stellenbosch University netball players and staff for your support and participation.

REFERENCES

1. Reid, D.A., Vanweerd, R.J., Larmer, P.J. & Kingstone, R., The inter and intra rater reliability of the Netball Movement Screening Tool, Journal of Science and Medicine in Sport, 2015, 18(3), 353-357.

2. Onate, J., Cortes, N., Welch, C. & Van Lunen, B., Expert versus novice interrater reliability and criterion validity of the landing error scoring system, Journal of Sport Rehabilitation, 2010, 19, 41-56.

3. Smith, C.A., Chimera, N.J., Wright, N.J. & Warren, M., Interrater and intrarater reliability of the functional movement screen, The Journal of Strength and Conditioning Research, 2013, 27(4), 982-987.

4. Plisky, P.J., Rauh, M.J., Kaminski, T.W. & Underwood, F.B., Star excursion balance test as a predictor of lower extremity injury in high school basketball players, Journal of Orthopaedic & Sports Physical Therapy, 2006, 36(12), 911-919.

5. Minick, K.I., Kiesel, K.B., Burton, L., Taylor, A., Plisky, P. & Butler, R.J., Interrater reliability of the functional movement screen, The Journal of Strength and Conditioning Research, 2010, 24(2), 479-486.

6. Gulgin, H. & Hoogenboom, B., The functional movement screening (FMS™): an inter-rater reliability study between raters of varied experience, The International Journal of Sports Physical Therapy, 2014, 9(1), 14-20.

7. Filipa, A., Byrnes, R., Paterno, M.V., Myer, G.D. & Hewett, T.E., Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes, Journal of Orthopaedic & Sports Physical Therapy, 2010, 40(9), 551-558.

8. Flood, L. & Harrison, J.E., Epidemiology of basketball and netball injuries that resulted in hospital admission in Australia, 2000-2004, Medical Journal of Australia, 2009, 190(2), 87-90.

9. Huxel Bliven, K.C. & Anderson, B.E., Core stability training for injury prevention, Athletic Training, 2013, 5(6), 514-522.

10. Hootman, J.M., Dick, R. & Agel, J., Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives, Journal of Athletic Training, 2007, 42(2), 311-319.

11. Ellapen, T.J., Schoeman, K.T., Zaca, L.T.N., van Heerden, H.J. & Ramiah, P.D., Prevalence of musculoskeletal injuries among adolescent recreational netballers in Kwa-Zulu Natal, South Africa, British Journal of Medicine & Medical Research, 2015, 9(3), 1-5.

12. De Witt, B. & Venter, R., The 'Bunkie' test: Assessing functional strength to restore function through fascia manipulation, Journal of Bodywork and Movement Therapies, 2009, 13, 81-88.

13. Vanweerd, R., The inter and intra-rater reliability of the Netball Movement Screening Tool, MPhil, Auckland University of Technology, 2013.

14. Brumitt, J., Successful rehabilitation of a recreational endurance runner: Initial validation for the Bunkie test, Journal of Bodywork & Movement Therapies, 2011, 15, 384-390.

15. Van Pletzen, D. & Venter, R.E., The relationship between the Bunkie-test and physical performance in rugby union players, International Journal of Sports Science & Coaching, 2012, 7(2), 545-555.

16. Brumitt, J., The Bunkie test: Descriptive data for a novel test of core muscular endurance, Rehabilitation Research and Practice, 2015, 2015, 1-9.

17. Kritz, M., Development, reliability and effectiveness of the Movement Competency Screen (MCS), PhD Thesis, Auckland University of Technology, 2012.

18. Kiesel, K., Plisky, P.J. & Voight, M.L., Can serious injury in professional football be predicted by a preseason functional movement screen?, North American Journal of Sport Physical Therapy, 2007, 2(3), 147-158.

19. De Vet, H.C.W., Terwee, C.B., Knol, D.L & Bouter, L.M., When to use agreement versus reliability measures, Journal of Clinical Epidemiology, 2006, 59, 1033-1039.

20. Glaws, K.R., Juneau, C.M., Becker, L.C., Di Stasi, S.L. & Hewett, T.E., Intra- and inter-rater reliability of the selective functional movement assessment (SFMA), The International Journal of Sports Physical Therapy, 2014, 9(2), 195-207.

21. Mischiati, C.R., Comerford, M., Gosford, E., Swart, J., Ewings, S., Botha, N., Stokes, M. & Mottram, S.L., Intra and inter-rater reliability of screening for movement impairment movement control tests from the foundation matrix, Journal of Sports Science and Medicine, 2015, 14, 427-440.

CHAPTER FOUR

RESEARCH ARTICLE TWO

THE RELATIONSHIP BETWEEN THE BUNKIE TEST AND THE STAR EXCURSION BALANCE TEST IN UNIVERSITY NETBALL PLAYERS

The referencing style used in this Chapter is in accordance with the guidelines of the International Journal of Sport Science and Coaching (Appendix H) and can thus vary from the referencing style used in the rest of this thesis.

The relationship between the Bunkie test and the Star Excursion Balance Test in university netball players

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Field of study: Sport Science (Injury prevention)

Running title: Functional tools to determine injury risk in university netball players.

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THE RELATIONSHIP BETWEEN THE BUNKIE TEST AND THE STAR EXCURSION BALANCE TEST IN UNIVERSITY NETBALL PLAYERS

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ABSTRACT

Various screening tools have been developed to predict and prevent injury in sport, but these instruments often require trained professionals or expensive equipment for assessments. Two relatively simple tests to use in a team sport environment are the Star Excursion Balance Test (SEBT) and the Bunkie test. The SEBT is known for its use to predict injury in lower extremities. The Bunkie test is a tool that measures the function of core muscles. The purpose of this study was to determine whether there is a relationship between the modified SEBT and the modified Bunkie test. University netball players participated in the study (n = 37) and had to complete three SEBT reach directions and four Bunkie test positions. Results revealed weak to moderate positive correlations ($r = 0.36 – 0.43$, $p \leq 0.05$, $r^2 = 0.13 – 0.18$) between ipsilateral and contralateral total modified Bunkie test results and the modified SEBT results.

KEY WORDS

Bunkie test, Star Excursion Balance Test (SEBT), Balance, Netball

INTRODUCTION

Prediction and prevention of injuries in sport has long been a challenge to coaches and trainers. Over the years, many tools have been developed to address this need for injury prediction and possible prevention. Correct lower extremity biomechanics is directly influenced by the trunk and hip musculature and correct function has to be maintained to prevent lower back pain and lower extremity injuries (1, 2). To quantify lower extremity biomechanics, the Star Excursion Balance Test (SEBT) can be used. Though it is known to assess dynamic balance (3, 4), it is sensitive to functional deficits which are related to musculoskeletal injuries (5). Besides the fact that it is a dynamic test, the SEBT is also a closed-kinetic chain exercise similar to the single-leg squat exercise. Good strength, proprioception, range of motion, coordination and neuromuscular control is required at the hip, knee and ankle joints of the stance leg (3, 4, 6). A combination of requirements is needed to perform well during the SEBT and this mimics the team sport environment where multiple skills are required simultaneously. It has been shown to predict injury risk for lower extremities in athletes (3, 5, 7) and various studies have specifically looked at the link between the SEBT and chronic ankle instability or anterior cruciate ligament (ACL) injuries (3, 7, 8, 9, 10).

The Bunkie test is an isometric test which proposes to determine the function of the core muscles involved in specific fascial lines (1, 11). These fascial lines refer to the functional unity of connective tissue systems, working in lines, described as "anatomy trains" by Myers (12). Both these tests can identify imbalances between the contralateral side of the body and the Bunkie test can further identify imbalances on the ipsilateral side.

Core strengthening has been introduced in sports training, to condition athletes with the purpose of preventing injury to the spine and/or extremities (13). Borghuis, Hof and Lemmink (14) implied that core stability is controlled by the trunk and is related to the body's ability to react to various external or internal stimuli. It has previously been suggested that poor core stability can increase the prevalence of injury in athletes, particularly females (15).

Netball is a fast-paced sport, mostly played by female participants, that involves running, pivoting, sudden changes in direction, jumping, catching and passing (16). The two most injured body regions in netball players are the ankle and knee joints (17, 18, 19)

The main aim of this study was to determine whether there is a relationship between the results of the modified Bunkie test and the modified SEBT. It is known that the SEBT can identify athletes that have an increased risk for injuries, specifically lower extremity injuries. This also includes identifying imbalances between limbs, since it is considered a risk factor for injuries to the lower extremities and, more specifically, injuries to the ACL (15). Though some studies have found no improvements on the SEBT reach directions after participants followed a six week core strength training program (20). Should there be a relationship between the two tests, the Bunkie test, being a novel and relatively simple test, could be used by coaches or athletes to screen players pre- and in-season.

METHODS

Participants

For the purpose of this descriptive study, university level netball players (n = 37) voluntarily participated. Initially, there were 39 players, but one player voluntarily terminated participation and another player experienced discomfort during testing and further participation was terminated. The remaining players were all tested at the start of the competitive phase, after the initial preparatory phase of the new season. They were relatively fit and well-conditioned and were all coached and trained by the same coaches.

All players attended an initial information session where the objectives of the study were explained and an information sheet was handed out to players. The second visit entailed signing of the informed consent form and testing. Players were provided with a questionnaire that included a self-reporting injury history. Each player had the right to terminate participation at any point during the testing, without penalty. Ethics clearance for the study was granted by the institutional research ethics committee in accordance with the Declaration of Helsinki.

Anthropometrics

Testing started with anthropometric measurements of weight (kg), height (m) and leg length (cm). The weight and height measurements were taken while players were barefoot and wearing shorts and a racerback tight fitting top. To measure the leg length, participants were asked to lie on their backs and a standard tape measure was used to measure from the anterior superior iliac spine (ASIS) to the lateral malleolus (3, 16).

Modified SEBT

This dynamic balance test is performed on one leg with the opposite foot reaching in a specific direction as far out as possible and then tapping on the floor along an allocated line. These lines are depicted by a large asterisk sign, when laid out on the floor, with each direction separated by a 45 degree angle (6). The stance leg is the side being measured.

The SEBT is usually performed in all eight directions, but a modified SEBT was performed for this study only three directions, namely the anterior (ANT), posteromedial (PM) and posterolateral (PL) directions (Figure 4.1). Although only four practice trials in the three reach directions have been suggested (5), players were asked to perform six trials in each of the three directions as a warm-up, to limit the learning effect as previously described (3, 6, 16). Three test trials were executed in each direction and the maximum distance in each direction was measured with a standard measuring tape.

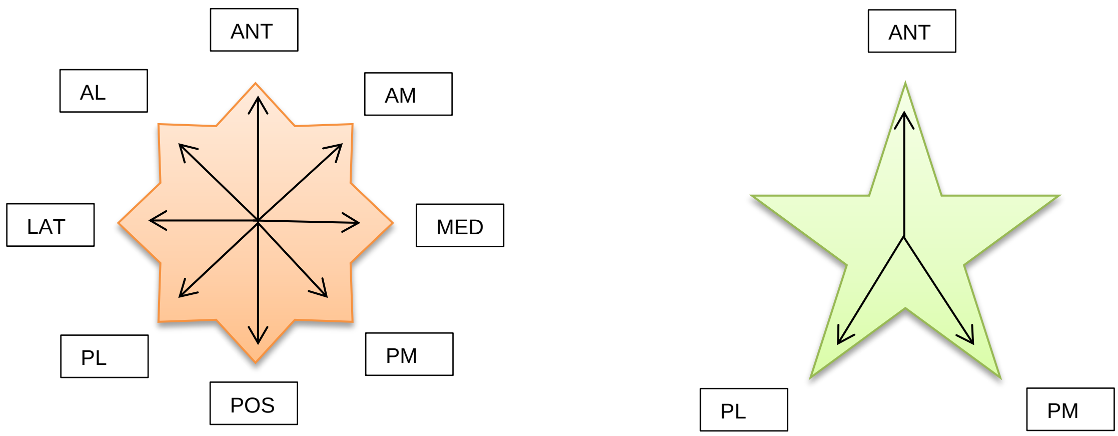

Figure 4.1 Typical SEBT and modified SEBT reach directions for a left foot measurement (ANT: Anterior, AM: Anteromedial, MED: Medial, PM: Posteromedial, POS: Posterior, PL: Posterolateral, LAT: Lateral, AL: Anterolateral)

During the test, players wore their usual netball training shoes and were instructed to place their hands on their hips. The non-weight bearing foot had to reach in one of the allocated directions while the stance foot remained completely flat on the floor and no weight was allowed to be placed onto the reaching foot. The intra-rater reliability for each direction is provided as follows: ANT (ICC = 0.84), PM (ICC 0.82) and PL (ICC 0.87). The inter-rater reliability for the ANT, PM and PL reach directions is 0.89, 0.93 and 0.91, respectively (3).

Modified Bunkie test

To execute this test, a small bench (Bunkie) is used, with a standard height of 30cm, as recommended by de Witt and Venter (11). There are five different Bunkie positions and each one of these is performed bilaterally, consisting of the anterior power line (APL), posterior power line (PPL), posterior stabilising line (PSL), lateral stabilising line (LSL) and medial stabilising line (MSL). For the purpose of this study, the test was modified to use only four of the five positions, as illustrated in Figure 3.2. These are the APL, PPL, MSL and LSL. The reason for this is to reveal the imbalances of ipsilateral scores, since co-contractions contribute to core stability (14) and there is no counter-movement for the PSL.

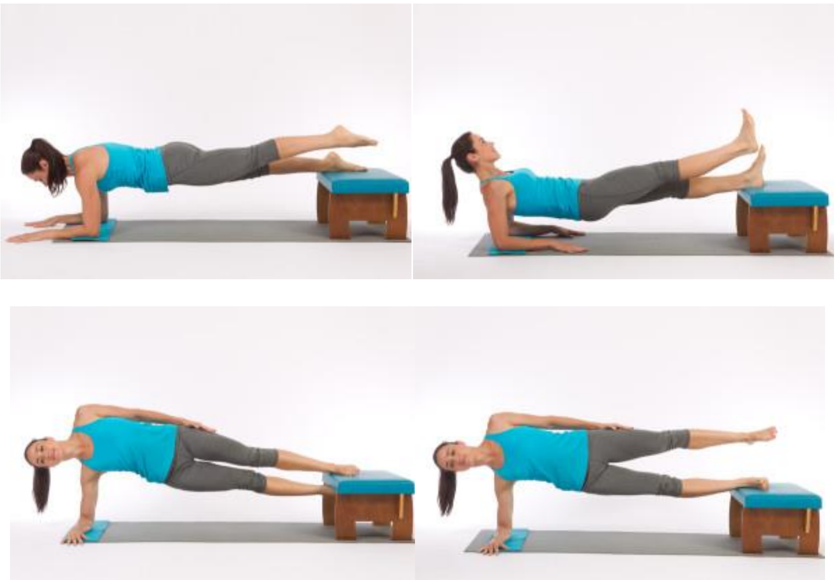

Figure 4.2 Bunkie test as presented by the Lyno Sport website (www.lynosport.co.za©) and presenting the anterior power line, the posterior power line, the lateral stabilising line and the medial stabilising line.

The significance of measuring imbalances and obtaining limb symmetry is to identify not only side-to-side imbalances as risk factors (15), but also imbalances between co-contractions on an ipsilateral side. Sporting activities can stimulate specific, repetitive movement patterns which lead to specific sports-related imbalances. When an imbalance is significant, it may lead to an increased risk for injury.

To execute the modified Bunkie test, players were instructed to place their feet on the bench and their elbows on a non-slip mat on the floor. They had to wear their usual netball training shoes for the test, to prevent slipping on the bench. De Witt and Venter (11) suggest a maximum test time of 40 seconds for endurance athletes and since netball players require not only endurance, but also strength and power, a time limit of 30 seconds was proposed. Although other core endurance tests have tested times of over 90 seconds (21). Testing was terminated when there was loss of form, a time of 30 seconds was reached or if the player could not continue in the specific position due to cramping or discomfort (11, 22). No rest was provided for between tests, though the side and position of testing was randomised.

Intraclass correlation coefficients for the Bunkie test has been reported as follows: APL (0.82), PPL (0.95), MSL (0.95), LSL (0.95) (23).

Data Analysis

Descriptive data is reported as percentages of the number of observations (%), mean and standard deviation (SD).

All modified SEBT scores were normalised for the total of the three reach directions and the leg length recorded (16). Each side was calculated with the following formula: the ANT reach direction, PM reach direction and the PL reach directions were added together and then divided by the sum of three times the leg length measured. This result is then multiplied by 100, to obtain a percentage (16). Each leg was calculated separately.

In order to assess imbalance using the Bunkie test, the difference between the counter-movements were calculated for each leg (i.e. the difference between APL and PPL and again between the MSL and LSL Bunkie results). Pearson correlation (two-tailed) between the modified SEBT and modified Bunkie test results were deemed significant if $p \leq 0.05$. The total Bunkie test result is the total score added together for the APL, PPL, MSL and LSL. All analyses were performed using the SPSS for Windows, Version 22.0 (Chicago, SPSS Inc.).

RESULTS

Participants

The average age of the netball players was 19.49 years (SD 1.59), average weight was 68.60kg (SD 7.98), average height was 1.75m (SD 0.69) and the average leg length was 93.20 cm (SD 4.94) and 93.22 (SD 5.03) for left and right, respectively.

It was noted that 51.4% of the players started playing netball at the age of seven and 29.7% of all players have been playing netball for 11 years. Self-reported number of injuries revealed 17 (45.9%) of the players had no injury in the past 12 months, 16 (43.2%) had one injury, two (8.1%) had two injuries and one player had four injuries.

Correlation table

Table 4.1 shows the results of the relationship between the modified SEBT and modified Bunkie test results, as calculated by the difference between the anterior and posterior Bunkie test results (BUNKIE ANT_POST), as well as the medial and lateral Bunkie test result differences (BUNKIE MED_LAT) left and right. The total Bunkie test scores for all four Bunkie positions revealed significant correlations to the modified SEBT results.

Table 4.1 Modified SEBT and modified Bunkie test correlations.

	SEBT TOTAL RIGHT	SEBT TOTAL LEFT
BUNKIE ANT_POST RIGHT	- 0.12	0.20
BUNKIE ANT_POST LEFT	0.27	- 0.16
BUNKIE MED_LAT RIGHT	0.09	0.07
BUNKIE MED_LAT LEFT	0.18	0.26
BUNKIE TOTAL RIGHT	0.43 **	0.36 *
BUNKIE TOTAL LEFT	0.37 *	0.38 *

* = p ≤ 0.05 ** = p ≤ 0.01

DISCUSSION

One of the reasons for isolating the difference between the anterior and posterior or medial and lateral Bunkie test in relation to the SEBT was that it can reveal an imbalance between these fascial lines and it is known that the SEBT can reveal imbalances (15). The fascia is a type of connective tissue, which help provide shape and structure to the body (22). Muscles are enveloped by fascial tissue and it could thus be this static tissue structures that provide the stability, but also this tissue that restricts muscular function within the fascial lines.

A large difference in either co-contraction patterns, while still maintaining a stance position can possibly reveal a compensatory pattern, which could lead to improper functioning of the muscles within the kinetic chain. These compensatory patterns may lead to muscle imbalances, which may potentially lead to injury (22). This can indicate that large differences between co-contracting Bunkie positions, can indicate poor contraction of the agonist/antagonist muscles. Though there was no significant correlation found between the differences of the Bunkie positions chosen and the modified SEBT.

The relation between the total modified Bunkie scores and the total modified SEBT scores are significant and range between $r = 0.36$ ($p < 0.05$) and $r = 0.43$ ($p < 0.01$), revealing a weak to moderately strong correlation. The highest r^2 value is between the total modified Bunkie scores right and the total modified SEBT results right. 18% of the variance in the netball player's modified total Bunkie results right can be explained by the variation in the player's total modified SEBT results right and vice-versa. R^2 is 0.14, revealing a 14% of variance for the same test results on the left.

The SEBT is a dynamic test that determines the level of balance ability by making use of strength, proprioception, neuromuscular control and range of motion and the Bunkie test is an isometric test that is presumed to test restrictions in fascial lines, these findings could confirm that core stabilisers that function correctly, are correlated to good dynamic balance. This is supported by the findings of Filipa et al. (15), which stated that the implementation of neuromuscular training programs that focus on core stability exercises specifically, has significantly improved the composite reach directions of the SEBT in the experimental group.

It has been mentioned by Borghuis, Hof and Lemmink (14) that increases in the flexor-extensor muscle co-activation can improve spinal stability. They also refer to trunk muscle activation, prior to lower extremity activation patterns, implying that the central nervous system (CNS) creates stability through co-contraction, prior to lower extremity movement. Borghuis, Hof and Lemmink (14) suggested that the co-contraction between the upper and lower extremities via the abdominal fascial system unites the stability of the extremities. If this is the case, trunk muscle strength is needed to control the movement of the extremities and if the Bunkie test can provide a way of improving the trunk muscle strength and / or endurance, it may potentially influence extremity movement.

Although static tissues contribute to the stability, muscle tissue mainly contributes to the dynamic function (2). Identification of muscular imbalances and dysfunction is important, as maintaining muscle balance is necessary to prevent injury and identification of imbalances can help predict injury or pain occurrence (11, 13). This supports the importance and necessity of the Bunkie test as a screening tool, though more studies are required to determine to what extent the Bunkie test can predict and prevent injury in athletes.

Limitations

This study has a few limitations, which include the fact that a sample of convenience was used to collect data. The sample size was small (n = 37) and this could influence the results of the study.

The modified Bunkie test protocol was used as described originally by de Witt and Venter (11), though only four of the five positions were used for the purpose of this study and this could influence the results. Participants were allowed to terminate each testing position when a burning or cramping sensation is felt or a loss of correct posture was noted. This protocol was very subjective and Brumitt (23) has applied and suggested a different protocol to determine descriptive data for healthy participants. In his study, test terminationoccurred when a participant stopped the test as a result of fatigue or if they were unable to maintain the correct posture / position (23). As a result of this subjective definition of burning or cramping, players may have stopped the testing protocol earlier than necessary.

CONCLUSION

The SEBT has previously been used for prediction of injuries. This study aimed to determine whether there is a relationship between the modified SEBT and the total modified Bunkie test results to determine whether the novel and relatively simple Bunkie test can also be used in a similar manner as the SEBT to predict injury.

A significant relationship was noted between the total modified SEBT and total modified Bunkie scores for each side. This is true for ipsilateral and contralateral results, meaning that improved Bunkie test results may improve with an improvement in overall dynamic balance.

Future studies should determine if the Bunkie test is useful to predicting injuries in athletes.

ACKNOWLEDGEMENTS

To the Stellenbosch University netball club: thank you for your support and for allowing us to test your players.

REFERENCES

1. Brumitt, J., Successful rehabilitation of a recreational endurance runner: Initial validation for the Bunkie test, Journal of Bodywork & Movement Therapies, 2011, 15, 384-390.

2. Peate, W.F., Bates, G., Lunda, K., Francis, S. & Bellamy, K., Core strength: A new model for injury prediction and prevention, Journal of Occupational Medicine and Toxicology, 2007, 2(1), 3-11.

3. Plisky, P.J., Rauh, M.J., Kaminski, T.W. & Underwood, F.B., Star excursion balance test as a predictor of lower extremity injury in high school basketball players, Journal of Orthopaedic & Sports Physical Therapy, 2006, 36(12), 911-919.

4. Munro, A.G. & Herrington, L.C., Between-session reliability of the star excursion balance test, Physical Therapy in Sport, 2010, 11, 128-132.

5. Robinson, R.H., Phillip, M.A. & Gribble, A., Support for a reduction in the number of trials needed for the star excursion balance test, Archives of Physical Medicine and Rehabilitation, 2008, 89(2), 364-370.

6. Earl, J.E. & Hertel, J., Lower-extremity muscle activation during the star excursion balance tests, Journal of Sport Rehabilitation, 2001, 10, 93-104.

7. Gribble, P.A., Hertel, J. & Plisky, P., Using the star excursion balance test to assess dynamic postural-control deficits and outcome in lower extremity injury: A literature and systematic review, Journal of Athletic Training, 2012, 47(3), 339-357.

8. Gribble, P.A., Hertel, J., Denegar, C.R. & Buckley, W.E., The effects of fatigue and chronic ankle instability on dynamic postural control, Journal of Athletic Training, 2004, 39(4), 321-329.

9. Hertel, J., Braham, R.A., Hale, S.A. & Olmsted-Kramer, L.C., Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability, Journal of Orthopaedic & Sports Physical Therapy, 2006, 36, 131-137.

10. McGuine, T.A., Greene, J.J., Best, T. & Leverson, G., Balance as a predictor of ankle injuries in high school basketball players, Clinical Journal of Sport Medicine, 2000, 10, 239-244.

11. De Witt, B. & Venter, R., The ‘Bunkie’ test: Assessing functional strength to restore function through fascia manipulation, Journal of Bodywork and Movement Therapies, 2009, 13, 81-88.

12. Myers, T., An Introduction to Anatomy Trains: Myofascial Meridians, in Dalton, E., ed., Dynamic Body® Exploring Form, Expanding Function , Freedom from Pain Institute, Oklahoma City, 2012, 164-189.

13. Nadler, S.F., Malanga, G.A., Bartoli, L.A., Feinberg, J.H., Prybichien, M. & Deprince, M., Hip muscle imbalance and low back pain in athletes: influence of core strengthening, Medicine & Science in Sports & Exercise, 2002, 34(1), 9-16.

14. Borghuis, J., Hof, A.L. & Lemmink, K.A.P.M. The importance of sensory-motor control in providing core stability: Implications for measurement and training. Sports Medicine, 2008, 38(11), 893-916.

15. Filipa, A., Byrnes, R., Paterno, M.V., Myer, G.D. & Hewett, T.E., Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes, Journal of Orthopaedic & Sports Physical Therapy, 2010, 40(9), 551-558.

16. Vanweerd, R., The inter- and intra-rater reliability of the Netball Movement Screening Tool, MPhil, Auckland University of Technology, 2013.

17. Ferreira, M.A. & Spamer, E.J., Biomechanical, anthropometrical and physical profile of elite University netball players and the relationship to musculoskeletal injuries, South African Journal for Research in Sport, Physical Education and Recreation, 2010, 32(1), 57-67.

18. Gamble, P., Physical preparation for netball – Part 1: Needs analysis and injury epidemiology, UK Strength and Conditioning Association, 2011, 22, 10-15.

19. Hopper, D., Elliott, B. & Lalor, J., A descriptive epidemiology of netball injuries during competition: a five year study, British Journal of Sports Medicine, 1995, 29(4), 223-228.

20. Sato, K. & Mokha, M., Does core strength training influence running kinetics, lower-extremity stability, and 5000-m performance in runners? Journal of Strength & Conditioning Research, 2009, 23(1), 133-140.

21. Waldhelm, A. & Li, L., Endurance tests are the most reliable core stability related measurements. Journal of Sport and Health Science, 2012, 1, 121-128.

22. Van Pletzen, D. & Venter, R.E., The relationship between the Bunkie-test and physical performance in rugby union players, International Journal of Sports Science & Coaching, 2012, 7(2), 545-555.

23. Brumitt, J., The Bunkie test: Descriptive data for a novel test of core muscular endurance, Rehabilitation Research and Practice, 2015, 1-9.

CHAPTER FIVE

SUMMARY, CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

5.1 Summary

The results reveal that the NMST and Bunkie test total score results for this study could not predict injury in university netball players. The OR value of 1.00 means that whether the results obtained from the screening tool was high or low (good or poor), the chance of a player getting injured is similar. For all components, namely the total NMST, modified SEBT and Bunkie test total score results, the 95% CI crossed over 1.00.

Page and Frank (2002) suggested that a functional approach to medicine or injury prevention refers to chronic injuries. Functional movement patterns cannot isolate muscle imbalances, as compensatory patterns can mask the muscular imbalances. Though muscle imbalance can lead to movement dysfunction. This suggests that screening tools that make use of functional movement patterns as the testing criteria are more likely screening for chronic injuries (Whatman, 2013). Reid and Kearney (2013) commented that a screening tool should be merely used to identify an underlying risk factor, and that it does not determine the reason for the finding. This can only be done with further investigation and testing. Previous injuries can lead to muscle weakness and imbalances, which could contribute as a risk factor for future injuries (Murphy et al., 2003). It is important to obtain and maintain muscular balance, specifically to prevent ankle, knee and overuse leg injuries. This might suggest that functional screening tools only identify risk factors, but cannot predict injury as a result of the identified risk factors, because the reason for the risk factor is the cause of the injury. This could identify why pre-season screening tools cannot solely be used to identify risk factors and prevent injury, as the risk factors for acute injuries are not being identified with the use of the functional screening tools. Previous injury is a known indicator for increased injury risk in the future and a possible explanation can be as a result of muscle deactivation patterns occurring, caused by the CNS post-injury (Page & Frank, 2002). These deactivation patterns lead to dysfunction, which influences the muscle contraction potential within a specific kinetic chain.

Kibler et al. (2006) have proposed that core stability is an important component of efficient athletic function, which is produced by the kinetic chain. The Bunkie test can identify dysfunctions within the kinetic chains and can support health professionals to identify specific regions in need of rehabilitation, with specific reference to muscle endurance, spinal and pelvic stability (Ronai, 2015). The Bunkie test can reveal imbalances between agonist and antagonist musculature or contralateral muscular function. Increased knee valgus forces have been determined to increase the risk of ACL injuries in athletes. It has also been suggested that increased knee valgus forces are present during landing and squatting manoeuvres in athletes with altered hip musculature activity. More specifically it refers to hip abduction weakness and hip flexor tightness. Tightness or shortening of the hip flexors can alter hip extension strength. The influence of these agonist / antagonist muscle imbalances did not reveal a relationship between the Bunkie test and the SEBT results. One reason could be that the body compensates for the difference in these muscle activation patterns and the ability to maintain dynamic balance. There is however a significant relationship between the total modified Bunkie test results (APL, PPL, MSL, LSL) and the total modified SEBT results. These findings are significant for the ipsilateral and contralateral sides.

Van Pletzen and Venter (2012) theorised that the medial Bunkie test is vital in predicting and preventing knee injuries in female players. The co-contraction between medial and lateral musculature within the fascial lines may potentially contribute to this theory. A study has found that endurance times for the side bridge endurance test were significantly lower for female athletes than for male athletes (Evans, Refshauge & Adams, 2007) and it is well-known that female athletes have a higher tendency to ACL injuries, specifically.

Brumitt (2015) mentioned in his study to determine normative data for the Bunkie test, that in asymptomatic individuals the lateral stabilising line on the left had significant differences in the holding times for females specifically, with and without a history of musculoskeletal injury. Though the injuries may have occurred elsewhere, the left lateral line specifically, was affected. This could perhaps partly be explained by the regional interdependence model (Cook et al., 2014; Minick et al., 2010; Sueki, Cleland & Wainner, 2013; Wainner et al., 2007) which states that seemingly unrelated impairments in various isolated regions of the body may in fact contribute to the patients' main report of symptoms. Nadleret al. (2002) found that female athletes with weaker left hip abductor strength were significantly more prone to develop lower back pain. The left lateral Bunkie test result (LSL) had a significant relationship to the total NMST ($p \leq 0.05$) and total modified SEBT left and right ($p \leq 0.01$). The left LSL and MSL also had a significant ($p \leq 0.05$) relationship to the individual modified SEBT results in the PM and PL directions for both sides (Appendix I). Further investigation is required to confirm the use of isolated Bunkie tests to determine injury risk, since the logistic regression did not reveal a significant finding to predict injury with the total NMST, total modified SEBT or total Bunkie test results.

To obtain good inter-rater and intra-rater reliability of the NMST, training is required. It is important that all raters obtain the same level of training, irrespective of clinical experience. This could be due to the specified marking criteria of each screening tool and the specificity of the scoring in relation to the marking criteria.

5.2 Conclusion

The results reveal that the NMST and Bunkie test results for this study could not predict injury in university netball players. Though injury could not be predicted with the pre-season testing results, it may be required by coaches or other professionals to screen players throughout the season.

A suggestion could be made to use functional movement screens, such as the NMST to identify risk factors in netball players, but also include tests or data that specify fatigue, fitness levels and injury history. Further investigation will be required to support this.

Suggestions to use the Bunkie test as a core muscle endurance test can possibly be made,when the test positions are isolated and used to identify netball players (and other athletes) at risk for acute injuries. Prior to any extremity movement, the muscles of the trunk and pelvis are activated and if this activation holds good endurance capabilities, it should be able to counter the movements involved in acute injuries by correcting the posture and biomechanics within the kinetic chain, even when fatigue sets in. With this the hips and shoulders should be included in core stability testing and where possible, it should be done by means of dynamic testing. Further research will be required to support this statement, since the left lateral and medial stabilising lines of the Bunkie test had a significant relationship to two of the three modified SEBT positions on the ipsilateral and contralateral sides.

5.3 Limitations

A sample of convenience was used for this study and thus, results cannot necessarily be transferred over to other university netball players.

The sample size is also a limitation (n = 37).

The Bunkie protocol of de Witt and Venter (2009) was followed and results are thus subjective (with reference to the participant, not the rater). The protocol required players to terminate testing when cramping or discomfort was noted or when a maximum time of 30 seconds was reached. Brumitt (2015) described a different Bunkie testing protocol, where subjects were only allowed to stop when they lose proper posture or could no longer hold the position. This has been proposed as a more reliable protocol and in future, this protocol's reliability can be tested.

During the testing protocol, no rest was provided for between the Bunkie tests. Brumitt (2015) provided one minute rest periods between the Bunkie test positions, to prevent fatigue from influencing the test results.

Core muscle endurance tests, as a core stability test in an isometric position, only tests the muscles in one position and consideration should be given to include core muscle power and strength tests that include movement while activating the core stabilizers (Cowley & Swensen, 2008).

Researchers did not consider the menstrual cycle of players as a factor to influence neuromuscular or biomechanical results. Abt et al. (2007) found no significant differences between the phases of the menstrual cycle on testing results for neuromuscular and biomechanical variables, but this is only one study and future research is required to determine the degree to which this can influence results.

Minimal detectable change (MDC) could not be calculated, as a result of the video footage being used to score the participants and not real-time scoring. This decreases the variability in scores and results.

ICC agreement values were reported separately and not in combination with standard error of mean (SEM), coefficient of variance (CV) and limits of agreement.

Injury recordings may not be accurate, since athletes are not obligated to use the team physiotherapist and can make use of other health care professionals without reporting an injury or simply leave an injury untreated and not report it to the coach or physiotherapist.

The lack of measurement and inclusion of Q-angle data can be a limitation.

5.4 Future research

In the future, researches can determine to what degree fascial restrictions can influence muscle function and whether the Bunkie is a true test of fascial lines or purely muscle activation within the kinetic chain.

Another study would also be required to consider the relationship between the NMST and core muscle power tests, as described by Cowley and Swensen (2008), instead of core muscle endurance testing, as is the case of this thesis.

Future studies may be conducted to determine to what extent the variation between the ipsilateral medial and lateral Bunkie test results may predict the risk of ACL injuries in female athletes.

5.5 Recommendations

Netball clubs or teams that use the NMST should be sure to have trained raters that execute the scoring of the screening tool. Their clinical experience can be different, but each rater should have similar training for the use of the NMST. Real-time scoring is recommended for the MCS as it is considered reliable and is time efficient, but the Jump components can be scored more accurately by making use of video footage.

The Bunkie test protocol can be changed so athletes hold the position for as long as they can or until they lose the correct postural position. It should be used with the intention to prevent muscle imbalances or weakness, with reference to core muscle endurance.

The components of these screening tools can also be implemented into the training programs, either as an isolated training session or as a warm-up, prior to netball specific training tasks. Peate et al. (2007) used the FMS™ and core stability exercises as an intervention in their study and recommends this for injury prevention.

Pre-season screening to determine injury risk profiles of netball players should be continuously tested throughout the season.

REFERENCES

All Australia Netball Association (Ltd) (2012). *Official rules of netball* [Online]. Retrieved April 24, 2015: http://netball.com.au/wp-content/uploads/2014/07/Official-Rules-of-Netball_Revised-2012.pdf .

Abt, J.P., Sell, T.C., Laudner, K.G., McCrory, J.L., Loucks, T.L., Berga, S.L. & Lephart, S.M. (2007). Neuromuscular and biomechanical characteristics do not vary across the menstrual cycle. *Knee Surgery, Sports Traumatology, Arthroscopy,* 15(7), 901-907.

Bahr, R. & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. *British Journal of Sports Medicine,* 39, 324-329.

Borghuis, J., Hof, A.L. & Lemmink, K.A.P.M. (2008). The importance of sensory-motor control in providing core stability: Implications for measurement and training. *Sports Medicine*, 38(11), 893-916.

Brumitt, J. (2011). Successful rehabilitation of a recreational endurance runner: Initial validation for the Bunkie test. *Journal of Bodywork & Movement Therapies*, 15, 384-390.

Brumitt, J., (2015). The Bunkie test: Descriptive data for a novel test of core muscular endurance. *Rehabilitation Research and Practice,* 2015, 1-9.

Cassell, E., Kerr, E. & Clapperton, A. (2012). Adult sports injury hospitalisations in 16 sports: the football codes, other team ball sports, team bat and stick sports and racquet sports. *Hazard: Victorian Injury Surveillance Unit,* 74, 1-36.

Cook, G., Burton, L. & Hoogenboom, B. (2006a). Pre-participation screening: The use of fundamental movements as an assessment of function – Part 1. *North American Journal of Sports Physical Therapy,* 2006, 1(2), 62-72.

Cook, G., Burton, L. & Hoogenboom, B. (2006b). Pre-participation screening: The use of fundamental movements as an assessment of function – Part 2. *North American Journal of Sports Physical Therapy,* 2006, 1(3), 132-139.

Cook, G., Burton, L., Hoogenboom, B.J. & Voight, M. (2014a). Functional movement screening: The use of fundamental movements as an assessment of function – Part 1. *The International Journal of Sports Physical Therapy,* 9(3), 396-409.

Cook, G., Burton, L., Hoogenboom, B.J. & Voight, M. (2014b). Functional movement screening: The use of fundamental movements as an assessment of function – Part 2. *The International Journal of Sports Physical Therapy,* 9(4), 549-563.

Cowley, P.M. & Swensen, T.C. (2008). Development and reliability of two core stability field tests. *Journal of Strength and Conditioning Research*, 22(2), 619-624.

Curtis, C.K., Laudner, K.G., McLoda, T.A. & McCaw, S.T. (2008). The role of shoe design in ankle sprain rates among collegiate basketball players. *Journal of Athletic Training*, 43(3), 230-233.

Dallinga, J.M., Benjaminse, A. & Lemmink, K.A.P.M. (2012). Which screening tools can predict injury to the lower extremities in team sports? A systematic review. *Sports Medicine,* 42(9), 791-815.

De Vet, H.C.W., Terwee, C.B., Knol, D.L. & Bouter, L.M. (2006). When to use agreement versus reliability measures. *Journal of Clinical Epidemiology,* 59, 1033-1039.

De Witt, B. (1996). *The Bunkie test* [Online]. Retrieved December 18, 2013: http://www.lynosport.co.za/the-bunkie-test/.

De Witt, B. & Venter, R. (2009). The 'Bunkie' test: Assessing functional strength to restore function through fascia manipulation. *Journal of Bodywork and Movement Therapies,* 13, 81-88.

Earl, J.E. & Hertel, J. (2001). Lower-extremity muscle activation during the star excursion balance tests. *Journal of Sport Rehabilitation,* 10, 93-104.

Ellapen, T.J., Schoeman, K.T., Zaca, L.T.N., van Heerden, H.J. & Ramiah, P.D. (2015). Prevalence of musculoskeletal injuries among adolescent recreational netballers in Kwa-Zulu Natal, South Africa. *British Journal of Medicine & Medical Research*, 9(3), 1-5.

Evans, K., Refshauge, K.M. & Adams, R. (2007). Trunk muscle endurance tests: Reliability, and gender differences in athletes, *Journal of Science and Medicine in Sport,* 10, 447-455.

Ferreira, M.A. & Spamer, E.J. (2010). Biomechanical, anthropometrical and physical profile of elite University netball players and the relationship to musculoskeletal injuries. *South African Journal for Research in Sport, Physical Education and Recreation,* 32(1), 57-67.

Filipa, A., Byrnes, R., Paterno, M.V., Myer, G.D. & Hewett, T.E. (2010). Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes. *Journal of Orthopaedic & Sports Physical Therapy*, 40(9), 551-558.Flood, L. & Harrison, J.E. (2009). Epidemiology of basketball and netball injuries that resulted in hospital admission in Australia, 2000-2004. *Medical Journal of Australia*, 190(2), 87-90.

Frisch, A., Urhausen, A., Seil, R., Croisier, J.L., Windal, T. & Theisen, D. (2011). Association between preseason functional tests and injuries in youth football: A prospective follow-up. *Scandinavian Journal of Medicine & Science in Sports,* 21, e468-e476.

Gamble, P. (2011a). Physical preparation for netball – Part 1: Needs analysis and injury epidemiology. *UK Strength and Conditioning Association,* 22, 10-15.

Gamble, P. (2011b). Physical preparation for netball – Part 2: Approaching programme design. *UK Strength and Conditioning Association,* 23, 13-21.

Gamble, P. (2013). Movement screening protocols: Rationale versus evidence. *New Zealand Journal of Sports Medicine* [Commentary], December, 83-86.

Glaws, K.R., Juneau, C.M., Becker, L.C., Di Stasi, S.L. & Hewett, T.E. (2014). Intra- and inter-rater reliability of the selective functional movement assessment (SFMA). *The International Journal of Sports Physical Therapy*, 9(2), 195-207.

Gribble, P.A., Delahunt, E., Bleakley, C., Caulfield, B., Docherty, C., Fourchet, F., Fong, D., Hertel, J., Hiller, C., Kaminski, T., McKeon, P., Refshauge, K., Van der Wees, P., Vicenzino, B. & Wikstrom, E. (2013). Selection Criteria for Patients With Chronic Ankle Instability in Controlled Research: A Position Statement of the International Ankle Consortium. *Journal of Orthopaedic & Sports Physical Therapy,* 43(8), 585-591.

Gribble, P.A., Hertel, J., Denegar, C.R. & Buckley, W.E. (2004). The effects of fatigue and chronic ankle instability on dynamic postural control. *Journal of Athletic Training*, 39(4), 321-329.

Gribble, P.A., Hertel, J. & Plisky, P. (2012). Using the star excursion balance test to assess dynamic postural-control deficits and outcome in lower extremity injury: A literature and systematic review. *Journal of Athletic Training*, 47(3), 339-357.

Gottschall, J.S., Mills, J. & Hastings, B. (2013). Integration core exercises elicit greater muscle activation than isolation exercises. *The Journal of Strength and Conditioning Research*, 27(3), 590-596.

Gulgin, H. & Hoogenboom, B. (2014). The functional movement screening (FMS™): an inter-rater reliability study between raters of varied experience. *The International Journal of Sports Physical Therapy*, 9(1), 14-20.

Hertel, J., Braham, R.A., Hale, S.A. & Olmsted-Kramer, L.C. (2006). Simplifying the Star Excursion Balance Test: Analyses of Subjects With and Without Chronic Ankle Instability. *Journal of Orthopaedic & Sports Physical Therapy,* 36(3), 131-137.

Hibbs, A.E., Thompson, K.G., French, D., Wrigley, A. & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine*, 38(12), 995-1008.

Hiller, C.E., Refshauge, K.M., Bundy, A.C., Herbert, R.D. & Kilbreath, S.L. (2006). The Cumberland Ankle Instability Tool: A report of validity and reliability testing. *Archives of Physical Medicine and Rehabilitation,* 87, 1235-1241.

Hodges, P.W. & Richardson, C.A. (1997). Contraction of the abdominal muscles associated with the movement of the lower limb. *Physical Therapy,* 77, 132-142.

Hootman, J.M., Dick, R. & Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *Journal of Athletic Training*, 42(2), 311-319.

Hopper, D., Elliott, B. & Lalor, J. (1995). A descriptive epidemiology of netball injuries during competition: a five year study. *British Journal of Sports Medicine,* 29(4), 223-228.

Hughes, G. & Watkins, J. (2006). A risk-factor model for anterior cruciate ligament injury. *Sports Medicine,* 36(5), 411-428.

Huxel Bliven, K.C. & Anderson, B.E. (2013). Core stability training for injury prevention. *Athletic Training*, 5(6), 514-522.

James, L.P., Kelly, V.G. & Beckman, E.M. (2014). Injury risk management plan for volleyball athletes. *Sports Medicine*, 44, 1185-1195.

Janda, V. (1978). Muscles, central nervous motor regulation and back problems. *The Neurobiologic Mechanisms in Manipulative Therapy*, 27-41.

Kazman, J.B., Galecki, J.M., Lisman, P., Deuster, P.A. & O'Connor, F.G. (2014). Factor structure of the Functional Movement Screen in Marine Officer Candidates. *The Journal of Strength and Conditioning Research*, 28(3), 672-678.

Kibler, W.B., Press, J. & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine*, 36(3), 189-198.

Kiesel, K., Plisky, P. & Butler, R. (2011). Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scandinavian Journal of Medicine and Science in Sport*, 21, 287-292.

Kiesel, K., Plisky, P.J. & Voight, M.L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sport Physical Therapy*, 2(3):147-158.Kritz, M. (2012). *Development, reliability and effectiveness of the Movement Competency Screen (MCS)*. Unpublished Doctoral thesis, Auckland University of Technology.

Lee, K.T., Park, Y.U., Jegal, H., Park, J.W., Choi, J.P. & Kim, J.S. (2014). New method of diagnosis for chronic ankle instability: comparison of manual anterior drawer test, stress radiography and stress ultrasound. *Knee Surgery, Sports Traumatology, Arthroscopy,* 22, 1701-1707.

Leetun, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T. & Davis, I.M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sports & Exercise,* 36(6), 926-934.

Letafatkar, A., Hadadnezhad, M., Shojaedin, S. & Mohamadi, E. (2014). Relationship between functional movement screening score and history of injury. *The International Journal of Sports Physical Therapy,* 9(1), 21-27.

Liebenson, C. (2012). A rehabilitation roadmap. In E. Dalton (Ed.), *Dynamic Body® Exploring Form, Expanding Function* (pp. 74-95). Oklahoma City: Freedom from Pain Institute.

Lockie, R.G., Schultz, A.B., Luczo, T.M., Berry, S.P., Jeffriess, M.D., Callaghan, S.J. & Jordan, C.A. (2013). The use of between-leg asymmetries in jump performance as a screening tool in female team sport athletes. *Journal of Athletic Enhancement,* 5(2), 1-9.

McCall, A., Carling, C., Nedelec, M., Davison, M., Le Gall, F., Berthoin, S. & Dupont, G. (2014). Risk factors, testing and preventative strategies for non-contact injuries in professional football: current perceptions and practices of 44 teams from various premier leagues. *British Journal of Sports Medicine,* 48, 1352-1357.

McGuine, T.A., Greene, J.J., Best, T. & Leverson, G. (2000). Balance as a predictor of ankle injuries in high school basketball players. *Clinical Journal of Sport Medicine*, 10, 239-244.McKeown, I., Taylor-McKeown, K., Woods, C. & Ball, N. (2014). Athletic ability assessment: A movement assessment protocol for athletes. *The International Journal of Sports Physical Therapy*, 9(7), 862-873.

McManus, A., Stevenson, M.R. & Finch, C.F. (2006). Incidence and risk factors for injury in non-elite netball. *Journal of Science and Medicine in Sport,* 9, 119-124.

Minick, K.I., Kiesel, K.B., Burton, L., Taylor, A., Plisky, P. & Butler, R.J. (2010). Interrater reliability of the functional movement screen. *The Journal of Strength and Conditioning Research,* 24(2), 479-486.

Mischiati, C.R., Comerford, M., Gosford, E., Swart, J., Ewings, S., Botha, N., Stokes, M. & Mottram, S.L. (2015). Intra and inter-rater reliability of screening for movement impairment movement control tests from the foundation matrix, *Journal of Sports Science and Medicine*, 14, 427-440.

Mitchell, U.H., Johnson, A.W. & Adamson, B. (2015). Relationship between functional movement screen scores, core strength, posture, and body mass index in school children in Moldova. *The Journal of Strength and Conditioning Research*, 29(5), 1172-1179.

Munro, A.G. & Herrington, L.C. (2010). Between-session reliability of the star excursion balance test, *Physical Therapy in Sport*, 11, 128-132.Murphy, D.F., Connolly, D.A.J. & Beynnon, B.D. (2003). Risk factors for lower extremity injury: a reiview of the literature. *British Journal of Sports Medicine*, 37, 13-29.

Myers, T. (2012). An Introduction to Anatomy Trains: Myofascial Meridians, in Dalton, E., ed. 164-189. Dynamic Body® Exploring Form, Expanding Function. Freedom from Pain Institute, Oklahoma City.

Nadler, S.F., Malanga, G.A., Bartoli, L.A., Feinberg, J.H, Prybicien, M. & Deprince, M. (2002). Hip muscle imbalance and low back pain in athletes: influence of core strengthening. *Medicine & Science in Sports & Exercise*, 34(1), 9-16.

Neely, F.G. (1998). Biomechanical risk factors for exercise-related lower limb injuries. *Sports Medicine*, 26(6), 395-413.

Okada, T., Huxel, K.C. & Nesser, T.W. (2011). Relationship between core stability, functional movement, and performance. *The Journal of Strength and Conditioning Research,* 25(1), 252-261*.*

Oliver, G.D., Dwelly, P.M., Sarantis, N.D., Helmer, R.A. & Bonacci, J.A. (2010). Muscle activation of different core exercises. *The Journal of Strength and Conditioning Research*, 24(11), 3069-3074.

Onate, J., Cortes, N., Welch, C. & Van Lunen, B. (2010). Expert versus novice interrater reliability and criterion validity of the landing error scoring system. *Journal of Sport Rehabilitation*, 19, 41-56.

Onate, J.A., Dewey, T., Kollock, R.O., Thomas, K.S., Van Lunen, B.L., DeMaio, M & Ringleb, S.I. (2012). Reat-time intersession and interrater reliability of the functional movement screen. *The Journal of Strength and Conditioning Research*, 26(2), 408-415.

Otago, L. (2004). Kinetic analysis of landings in netball: is a footwork rule change required to decrease ACL injuries? *Journal of Science and Medicine in Sport*, 7(1), 85-95.

Page, P. (2006). Sensorimotor training: A “global” approach for balance training. *Journal of Bodywork and Movement Therapies*, 10, 77-84.

Page, P. & Frank, C. (2002). The Janda approach to chronic musculoskeletal pain. *Thera-Band Academy: © The Hygenic Corporation*, 1-9.

Panjabi, M.M. (1992). The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders*, 5(4), 383-389.

Parenteau-G, E., Gaudreault, N., Chambers, S., Boisvert, C., Grenier, A., Gagne, G. & Balg, F. (2014). Functional movement screen test: A reliable screening test for young elite ice hockey players. *Physical Therapy in Sport*, 15(3), 169-175.

Paterno, M.V., Taylor-Haas, J.A., Myer, G.D. & Hewett, D.E. (2013). Prevention of overuse sports injuries in the young athlete. *Orthopedic Clinics of North America,* 44(4), 553-564.

Peate, W.F., Bates, G., Lunda, K., Francis, S. & Bellamy, K. (2007). Core strength: A new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology*, 2(1), 3-11.

Perry, M. (2014). *Functional Movement Screen review: Top 5 benefits* [Online]. Retrieved August 5, 2015: http://www.builtlean.com/2014/06/03/functional-movement-screen-review/.

Plisky, P.J., Rauh, M.J., Kaminski, T.W. & Underwood, F.B. (2006). Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *Journal of Orthopaedic & Sports Physical Therapy,* 36(12), 911-919.

Reid, D.A. & Kearney, S. (2013). *New Zealand Journal of Sports Medicine* [Comment], December, 86-87.

Reid, D.A., Vanweerd, R.J., Larmer, P.J. & Kingstone, R. (2015). The inter and intra rater reliability of the Netball Movement Screening Tool. *Journal of Science and Medicine in Sport*, 18(3), 353-357.

Robinson, R.H., Phillip, M.A. & Gribble, A. (2008). Support for a reduction in the number of trials needed for the star excursion balance test. *Archives of Physical Medicine and Rehabilitation*, 89(2), 364-370.

Ronai, P. (2015). The Bunkie test. *Strength and Conditioning Journal,* 37(3), 89-92.

Sato, K. & Mokha, M. (2009). Does core strength training influence running kinetics, lower-extremity stability, and 5000-m performance in runners? *Journal of Strength & Conditioning Research,* 23(1), 133-140.

Schneiders, Dr. A.G., Davidsson, Å, Hörman, E. & Sullivan, Prof.S.J. (2011). Functional Movement Screen™ Normative Values in a Young, Active Population. *The International Journal of Sports Physical Therapy,* 6(2), 75-82.

Smith, C.A., Chimera, N.J., Wright, N.J. & Warren, M. (2013). Interrater and intrarater reliability of the functional movement screen. *The Journal of Strength and Conditioning Research*, 27(4), 982-987.

Smith, R., Damodaran, A.K., Swaminathan, S., Campbell, R. & Barnsley, L. (2005). Hypermobility and sports injuries in junior netball players. *British Journal of Sports Medicine,* 39, 628-631.

Soh, K.G., Ruby, H. & Soh, K.L. (2006). Body fat comparison between basketball and netball players in Malaysia. *The Journal of Health and Translational Medicine,* 9(1), 20-22*.*

Steffen, K., Myklebust, G., Andersen, T.E., Home, I. & Bahr, R. (2008). Self-reported injury history and lower limb function as risk factors for injuries in female youth soccer. *The American Journal of Sports Medicine,* 36(4), 700-708.

Sueki, D.G., Cleland, J.A. & Wainner, R.S. (2013). A regional interdependence model of musculoskeletal dysfunction: research, mechanisms, and clinical implications. *Journal of Manual and Manipulative Therapy*, 21(2), 90-102.

Ter Stege, M.H.P., Dallinga, J.M., Benjaminse, A. & Lemmink, K.A.P.M. (2014). Effect of interventions on potential, modifiable risk factors for knee injury in team ball sports: A systematic review. *Sports Medicine,* 44, 1403-1426*.*

Terada, M., Pietrosimone, B.G. & Gribble, P.A. (2014). Alterations in neuromuscular control at the knee in individuals with chronic ankle instability. *Journal of Athletic Training,* 49(5), 599-607.

Van Pletzen, D. & Venter, R.E. (2012). The relationship between the Bunkie-test and physical performance in rugby union players. *International Journal of Sports Science & Coaching*, 7(2), 545-555.

Vanweerd, R. (2013). *The inter and intra-rater reliability of the Netball Movement Screening Tool*. Unpublished Master's thesis, Auckland University of Technology.

Venter, R.E., Fourie, L., Ferreira, S. & Terblanche, E. (2005). Physical and physiological profiles of Boland netball players. *South African Journal of Sports Medicine,* 17(2), 3-7*.*

Wainner, R.S., Whitman, J.M., Cleland, J.A. & Flynn, T.W. (2007). Regional Interdependence: A musculoskeletal examination model whose time has come [Guest Editorial]. *Journal of Orthopaedic & Sports Physical Therapy*, 37(11), 658-660.

Waldhelm, A. & Li, L. (2012). Endurance tests are the most reliable core stability related measurements. *Journal of Sport and Health Science,* 1, 121-128.

Wassinger, C.A., McKinney, H., Roane, S., Davenport, M.J., Owens, B., Breese, U., Sokell, G.A. (2014). The influence of upper body fatigue on dynamic standing balance. *The International Journal of Sports Physical Therapy*, 9(1), 40-46.

Whatman, C. (2013). Is the screen clear enough to see the road ahead? *Journal of Sports Medicine New Zealand* [Editorial], 40(1), 4-5.

Wikstrom, E.A., Tillman, M.D., Chmielewski, T.H., Cauraugh, J.H., Naugle, K.E. & Borsa, P.A. (2012). Discriminating between copers and those with chronic ankle instability. *Journal of Athletic Training,* 47(2), 136-142.

Yang, J., Tibbetts, A.S., Covassin, T., Cheng, G., Nayar, S. & Heiden, E. (2012). Epidemiology of overuse and acute injuries among competitive collegiate athletes. *Journal of Athletic Training,* 47(2), 198-204.

APPENDIX A

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
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Approval Notice
New Application

20-Jun-2015
Le Roux, Dominic DC

Proposal #: DESC/LeRoux/April2015/7
Title: The relationship between the netball movement screening tool and balance and stability in university netball players

Dear Mrs Dominic Le Roux,

Your **New Application** received on **09-Apr-2015**, was reviewed
Please note the following information about your approved research proposal:

Proposal Approval Period: **24-Apr-2015 -23-Apr-2016**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**DESC/LeRoux/April2015/7**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Included Documents:
DESC Checklist form
Research Proposal
REC Application form

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

APPENDIX B (English)

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STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

The relationship between the Netball Movement Screening Tool (NMST) and the Bunkie test in university netball players.

You are asked to participate in a research study conducted by Dominic Christine le Roux, BSc Sport Science and BSc Sport Science Honours (Biokinetics), from the Department of Sport Science at Stellenbosch University. The results obtained during this research project will be used in the thesis that will be handed in. You were selected as a possible participant in this study because you are a netball player at Stellenbosch University between the age of 18 and 25.

1. **PURPOSE OF THE STUDY**

To determine the relationship between the Netball Movement Screening Tool (NMST) and the Bunkie test in university netball players. It will also further determine the relationship between the Bunkie results and the different components of the NMST and an injury history.

2. **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

Participant recruitment and questionnaires

Participants that comply with all the inclusion and exclusion criteria will be asked to meet at the Sport Science Department of the University. Here you will be informed about the aims of the study and all procedures for testing protocols and requirements will be explained to you. Once you have voluntarily agreed to participate in the study, you will have to sign this informed consent form and you will be asked to complete a pre-participation form. This pre-participation form is required to obtain information from you with regards to your injury history, netball participation history and various personal details. You will also be required to choose a testing day and time, as per slots available.

Testing

All testing will commence on the same day. You may not participate in any sporting activities before the testing is complete. It is expected that you wear a comfortable exercise short, a tight fitting racer back (or similar) top and bring along your netball shoes.

Place of testing

Testing will take place at the Sport Science Department of Stellenbosch University. Players will be expected to arrive at your specific time slot for testing and all testing will be conducted in a specific order. All anthropometric measurements will be done first.

3. POTENTIAL RISKS AND DISCOMFORTS

You may experience some difficulty to execute all tests, but no pain should be experienced.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

Should a positive relationship be noted between specific components of the Netball Movement Screening Tool and the Bunkie test, then they can together be used as a pre-season or pre-participation screening tool to help decrease the risk for injury. It can also be used as a measure to screen players, before returning to play after an injury.

5. PAYMENT FOR PARTICIPATION

Participants in the study will not be paid to participate in the study. Participation will have to be done at own cost. If the results of the study are significant, you may contribute towards the findings of the study and the significance it might have in the netball community.

6. CONFIDENTIALITY

All information obtained throughout this study will be handled with confidentiality and any information that can be identified with you, will be kept confidential. Any personal information will only be disclosed with your permission or as may be required by law. Each participant will be allocated with a number and only your number will be used in the study (no names will be mentioned or published). Testing data will also be recorded according to the allocated number.

Any forms that have been completed by you and all data collection forms will be kept in a locked room at the Sport Science Department of Stellenbosch University. Only the researcher and both study supervisors will have access to the data. Data collected and kept on an external hard drive or computer, will be password protected and access will be limited to the researcher and the study supervisors.

7. PARTICIPATION AND WITHDRAWAL

Participation in this study is completely voluntary and you may withdraw from the study at any time, without any consequences. Should there be any questions that you do not want to answer, you may refuse to answer the questions and still remain in the study.

Should specific circumstances arise, which carries enough weight, the researcher may withdraw you from the study. If you obstruct the researcher from completing a test accurately, the researcher may ask you to leave the testing area.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Dominic le Roux (Tel: +264812793045 or +27825500067, E-mail: 14412721@sun.ac.za), Dr. R.E. Venter (Tel: +27 (0)21 808 4721, Sport Science Department, US) or Dr. K. Welman (Tel: +27 21 808 4733, Sport Science Department, US).

8. RIGHTS OF RESEARCH PARTICIPANTS

Participation discontinuation or withdrawal of your consent may be done at any time. No penalty will be involved, should any of the mentioned occur. No legal claims, rights or remedies are being waved because of your participation in the study. Any questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH PARTICIPANT OR LEGAL REPRESENTATIVE

The information above was described to [*the participant]* by [*name of relevant person]* in [*Afrikaans/English/Xhosa/other]* and [*I/the participant]* in command of this language or it was satisfactorily translated to [*her*]. [*I/the participant]* was given the opportunity to ask questions and these questions were answered to *[myself/her]* satisfaction.

[I hereby consent voluntarily to participate in this study/I hereby consent that the participant may participate in this study.] I have been given a copy of this form.

____

Name of Participant

____

Name of Legal Representative (if applicable)

____________________________________ ______________

Signature of Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to __________________ [*name of the subject/participant]* and/or [his/her] representative ____________________ [*name of the representative]. [He*/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into* ___________ by _______________________].

____ ______________

Signature of Investigator **Date**

APPENDIX B (Afrikaans)

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INWILLIGING OM DEEL TE NEEM AAN NAVORSING

Die verwantskap tussen die Netbal Beweeglikheids Toetsing Toerusting (NMST) en die Bankie toets in universiteits netbalspelers.

U word gevra om deel te neem aan 'n navorsingstudie uitgevoer te word deur Dominic le Roux, BSc Sportwetenskap en BSc Sportwetenskap Honneurs (Biokinetika), van die Sportwetenskap Departement aan die Universiteit Stellenbosch. Die resultate van die studie sal gebruik word in 'n tesis, wat ingedien sal word. U is as moontlike deelnemer aan die studie gekies omdat u 'n netbalspeler is wat tussen die ouderdom van 18 en 25 is.

1. DOEL VAN DIE STUDIE

Die primêre doel is van die studie is om die verwantskap tussen die Netbal Beweeglikheids Toetsing Toerusting (NMST) en die Bankie toetsresltat in universiteits netbalspelers te bepaal. Verder is dit ook 'n doel om die verskeie komponente van die NMST toetsaparaat en die Bankie toetse se verwantskap te toets, sowel as die Bankie toets en beseringsgeskiedenis verwantskap.

2. PROSEDURES

Indien u inwillig om aan die studie deel te neem, vra ons dat u die volgende moet doen:

Deelnemers aanstel en vraelyste

Deelnemers wat voldoen met al die insluitingsvereistes en uitsluitingsvereistes sal gevra word om by die Sportwetenskap Departement van Stellenbosch Universitiet te ontmoed waar al die prosedures en verwagtinge van die studie aan jou verduidelik sal word. Hier sal jy ook 'n inwilliging van deelname aan die studie onderteken, indien jy alle inligting gekry het en tevrede is daarmee om vrywilliglik deel te neem aan die studie. Daar sal ook van jou verwag word om ’n persoonlike inligtingsvorm in te vul, wat inligting sal invorder rakende jou beseringsgeskiedenis, jou netbaldeelname en verskeie ander persoonlike inligting. Indien al hierdie vorms voltooi is en jy is seker dat jy vrywilliglik wil deelneem aan die studie, sal jy ’n tydstip en dag vir toetsings moet kies.

Toetsing

Die toetse sal almal plaasvind op dieselfde dag. ’n Gemaklike kortbroek (oefenbroek), jou netbal skoene en ’n stywe hemp sal verkieslik aangetrek moet word.

Plek van studie en oefen sessies

Toetsing sal plaasvind by die Departement van Sportwetenskap aan die Universiteis van Stellenbosch. Deelnemers sal verwag word om betyds te arriveer vir hul toetsings, soos per tydstip wat gekies is. Toetse sal in ’n spesifieke volgorde plaasvind en alle antropometriese toetse sal eerste gedoen word.

3. MOONTLIKE RISIKO’S EN ONGEMAKLIKHEID

Moontlike ongemak mag ervaar word tydens die uitvoering van al die beplande toetse, maar geen pyn mag ervaar word nie.

4. MOONTLIKE VOORDELE VIR PROEFPERSONE EN/OF VIR DIE SAMELEWING

Indien daar wel ’n positiewe verwantskap tussen die NMST en die Bankie toetse gevind word, kan hulle moontlik saam gebruik word tydens die voor-seisoen en voor-deelname toetsings om te bepaal of die speler ’n hoër risiko vir beserings dra of nie. Hierdie spesifieke kombinasie kan dan moontlik gebruik word om beserings tydens die seisoen te verminder of verhoed. Hierdie toetsings kan ook as ’n toets dien om te bepaal of spelers reg is om weer te speel na ’n operasie of besering.

5. VERGOEDING VIR DEELNAME

Deelnemers ontvang geen vergoeding vir hulle deelname aan die studie nie en u sal aan die studie deelneem op eie onkoste. Indien die resultate statisties beduidend is, sal u help om by te dra tot die bevindinge vir onthalwe van die netbalgemeenskap en ook die studie self.

6. VERTROULIKHEID

Enige inligting wat ingevorder word tydens die verloop van die studie sal met vertroulikheid behandel word. Enige inligting wat spesifiek na jou verwys sal vertroulik behou word. Persoonlike inligting sal net openbaar word met jou toestimming of in lyn met wetgewing. Elke deelnemer sal ’n nommer ontvang en geen name sal gebruik word in die studie nie. Toetsdata sal ook net op die deelnemer nommer ingevorder word en geen name sal ingevul word nie.

Alle vorms wat ingevul word en die data invorderingsvorms sal in ’n geslote kamer by die Sportwetenskap Departement bly en toegang sal ook alleenlik moontlik wees deur die navorser en die studieleiers. Dataversameling wat op ’n eksterne-hardeskyf of skootrekenaar gestoor word, sal met ’n wagwoord beskerm word en die navorser en studieleiers alleenlik sal toegang tot hierdie inligting hê.

Indien die studie se bevindindinge gepubliseer word, sal die name van die deelnemers vertroulik behoue bly en net die nommers wat geallokeer is sal gebruik word.

7. DEELNAME EN ONTTREKKING

Deelname aan hierdie studie is vrywilliglik en jy kan enige tyd jouself van die studie onttrek, sonder enige nadelige gevolge. U mag weier om ’n bepaalde vraag te antwoord, maar steeds aan die studie deelneem. Die navorser kan u aan die studie onttrek, indien omstandighede dit regverdig. Sou u enige gedrag toon wat die navorser verhoed om ’n toets akkuraat uit te voer, mag die navorser u vra om die studie te verlaat.

8. IDENTIFISERING VAN ONDERSOEKERS

Indien u enige vrae of besorgdheid omtrent die navorsing het, staan dit u vry om in verbinding te tree met Dominic le Roux (Tel: +264812793045 of +27825500067, E-pos: 14412721@sun.ac.za), Dr. K. Welman (Tel: +27 21 808 4733, Sportwetenskap Departement, US) of Dr. R. Venter (Tel: +27 21 808 4721, Sportwetenskap Departement, US).

9. REGTE VAN DEELNEMERS

U kan te eniger tyd u inwilliging terugtrek en u deelname beëindig, sonder enige nadelige gevolge vir u. Deur deel te neem aan die navorsing doen u geensins afstand van enige wetlike regte, eise of regsmiddel nie. Indien u vrae het oor u regte as proefpersoon by navorsing, skakel met Me Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] van die Afdeling Navorsingsontwikkeling.

VERKLARING DEUR PROEFPERSOON OF SY/HAAR REGSVERTEENWOORDIGER

Die bostaande inligting is aan my, [*naam van proefpersoon/deelnemer*], gegee en verduidelik deur [*naam van die betrokke persoon*] in [*Afrikaans/English/Xhosa/other]* en [*ek is/die proefpersoon is/die deelnemer is*] dié taal magtig of dit is bevredigend vir [*my/hom/haar*] vertaal. [*Ek/die deelnemer/die proefpersoon*] is die geleentheid gebied om vrae te stel en my/sy/haar vrae is tot my/sy/haar bevrediging beantwoord.

[*Ek willig hiermee vrywillig in om deel te neem aan die studie/Ek gee hiermee my toestemming dat die proefpersoon/deelnemer aan die studie mag deelneem.*] 'n Afskrif van hierdie vorm is aan my gegee.

____

Naam van deelnemer

____

Naam van regsverteenwoordiger (indien van toepassing)

____ _______________

Handtekening van deelnemer of regsverteenwoordiger **Datum**

VERKLARING DEUR ONDERSOEKER

Ek verklaar dat ek die inligting in hierdie dokument vervat verduidelik het aan [*naam van die proefpersoon/deelnemer*] en/of sy/haar regsverteenwoordiger [*naam van die regsverteenwoordiger*]*.* Hy/sy is aangemoedig en oorgenoeg tyd gegee om vrae aan my te stel. Dié gesprek is in [*Afrikaans/*Engels/*Xhosa/*Ander*] gevoer en [*geen vertaler is gebruik nie/die gesprek is in _______________ vertaal deur* _______________________________].

____________________________________ _______________

Handtekening van ondersoeker **Datum**

Goedgekeur Subkomitee A 25 Oktober 2004

APPENDIX C

INFORMATION SHEET TO PARTICIPANTS

Research Title

The relationship between the Netball Movement Screening Tool and the Bunkie test in university netball players

Invitation to participate

If you are between the ages of 18 and 25 years and you play netball at Stellenbosch University, you are invited to take part in this research project. The research that will be conducted is done to determine whether there is a positive relationship between the netball movement screening tool and the Bunkie test results. This can help to identify possible risk increases for injury prevention. Each participant will be tested on one occasion and all tests will be conducted then. Your data will be treated with confidentiality and no individual data will be revealed in the study, only group averages.

Informed consent and Information sheet

Once you have decided to voluntarily participate in the study and you are satisfied with all your questions at the information session, then you will be asked to complete an informed consent form and a pre-participation form with various personal details.

Termination of participation

You are allowed to terminate participation at any point during the study, without any consequences.

What is expected of you during the study?

After you have decided to voluntarily participate in the study and you have signed the informed consent form, you will be asked to meet at the Sport Science Department, where testing will commence. You should wear comfortable exercise shorts and a tight fitting racer back top and bring along or wear your netball shoes. The tests that will be performed include body weight, body height, structural leg length measurements, various functional movements, dynamic balance, flexibility and

Bunkie test (similar to the isometric plank or bridge). Should any pain be experienced during the tests, the results will be discarded. The only discomfort or difficulty that might be experienced is during the Bunkie test. This will only be due to a level of difficulty (not necessarily), but will not produce pain. A moderate risk is taken when doing the dynamic balance test, as there is a small risk of falling, but all precautions will be taken to prevent this.

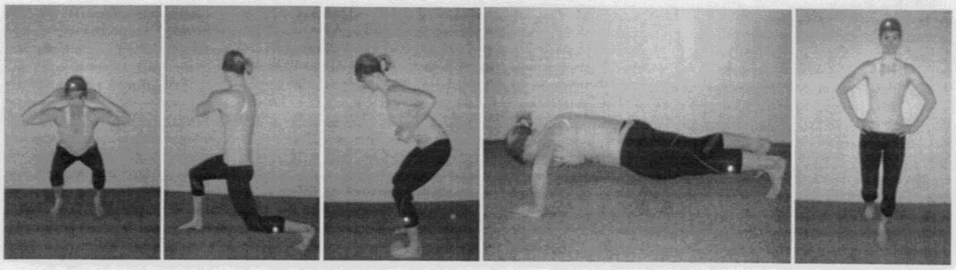
Oral presentation

Once all data has been collected and the research study is complete, you will be invited to attend an oral presentation by the researcher.

Should you have any questions or concerns with regards to this research project, please feel free to contact the researcher directly at 14412721@sun.ac.za or at +264812793045.

I thank you for your time and interest in taking part in this research project.

APPENDIX D



Squat

Feet hip distance apart, hands behind head. Squat down as deep as possible and return to the starting position.

Lunge and twist

Arms crossed over the body. Lunges the back knee down and then twist towards the forward leg. Return to starting position.

Bend and Pull

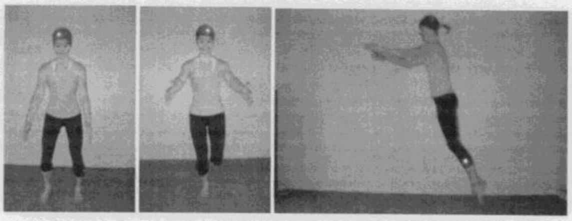
Feet hip distance apart, very small bend in the knees. Bend forward through the hips then pull elbows back in a rowing motion retracting the scapula. .

Push up

Start with hands under shoulders and up on toes. Lower chest as close to the floor as possible and then push up to return to starting position.

Single leg squat

Hands behind head, standing on one leg, perform a single leg squat as deep as able and return to starting position.



Vertical Jump A

Hands on hips, jump up vertically as high as possible and land on both feet.

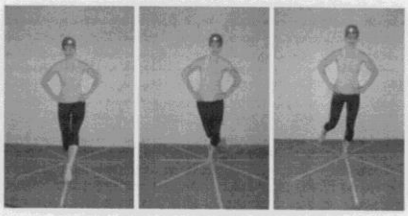
Vertical Jump B

Hands on hips, jump up vertically as high as possible and land on one foot only. Perform on left and right sides.

Broad jump

Standing feet hip width, jump forward off both legs as far as possible and lands on one leg only. Perform on left and right sides

Star Excursion Balance Test



Four pieces of tape are laid down on the ground 45 degrees apart from each other, forming eight rays. The eight rays are named for the reach direction they represent based on their anatomical alignment from the midpoint (anterior, anteromedial, anterolateral, lateral, medial, posterior, posterolateral and posteromedial). For the purposes of the NMST test, only the anterior (A), posteromedial (PM) and posterolateral (PL) reach directions utilised. The midpoint is marked where the four pieces of tape intersect and is where the test foot must remain throughout testing.

The arch of the test foot is placed on the midpoint of the star and hands are on hips. The subject is instructed to reach the opposite foot along the chosen reach direction as far as possible and lightly touch it down. The point on the line where the athletes touches down is marked. Each direction is repeated three times and the furthest reach direction is recorded. If reach foot is used for considerable support at any time, support foot is moved, hands come off the hips or subject loses balance, the trial is disregarded and repeated.

Leg length (LL) is measured from distal aspect of anterior superior iliac spine to the distal end of the lateral malleolus. SEBT score is calculated using the following score calculation:

$$\frac{[(A + PL + PM)]}{(LLx3)} \times 100$$

Active Straight Leg Raise

Starting position is supine on the floor. The test leg is actively straightened then lifted up into the air as far as possible keeping the test leg straight and the non-test leg in contact with the ground throughout the entire testing procedure. Hips are to remain in neutral rotation throughout testing. Prior to testing two lines are marked on the subject's leg to divide the leg into three zones for scoring. One line is drawn at mid patella and one at mid-thigh (half way between the ASIS and mid patella). Zone 1 was demarcated as distal to mid patella, Zone 2 between mid-patella and mid-thigh and Zone 3 superior to mid-thigh. The ASLR is scored by aligning a ski pole vertically with the medial malleolus of the test leg and recording which zone of the non-test leg the ski pole was situated in. A three was scored if the pole was situated in Zone 3, a two was scored if the pole was situated in Zone 2 and a one was scored if the pole was situated in Zone 1.

Vanweerd, R. (2013). *The inter- and intra-rater reliability of the Netball Movement Screening Tool.* MPhil, Auckland University of Technology.

APPENDIX E

Pattern	Head	Shoulder/Thoracic Spine	Lumbar Spine	Hips	Knees	Ankles	Feet	Balance	Depth
Squat	Held in neutral position, appears centrally aligned	Thoracic extension evident, shoulders kept down and away from ears. Elbows are in-line with ears during movement	Neutral curve position	Horizontally aligned and mobile. Move back and down during flexion	Aligned with hips and feet during flexion	Mobility allows adequate dorsiflexion during hip and knee flexion	Stable with heels grounded during lower limb flexion	Evenly distributed	Tops of thighs appear parallel with floor
Lunge and Twist	Held in neutral position, appears centrally aligned	Held down and away from ears. Majority of rotation appears to occur through the thoracic spine	Held in a neutral curve position. Rotation and/or lateral flexion does not occur during trunk twisting	Mobile and stable to prohibit elevation and depression during rotation	Aligned with hips and feet during flexion and do not move laterally with rotation	Mobility allows adequate dorsiflexion during hip and knee flexion	Heel of lead leg in contact with the floor, trail foot flexed and balanced on forefoot	Maintained for each leg	Lead thigh parallel with the ground
Bend and Pull	Held in neutral position, appears centrally aligned	Held down and away from ears. Scapulae move balanced and rhythmic. During arm flexion scapulae protract. Scapulae are not excessively abducted during arm extension	Held in a neutral curve position throughout trunk flexion	Facilitate trunk flexion	Extended	N/A	Pointing straight	Maintained	75-90 degrees of trunk flexion acheived
Push Up	Held in neutral position, appears centrally aligned	Held down and away from ears. Scapulae move balanced and rhythmic and are not excessively abducted during arm extension	Held in a neutral curve position	Held in line with the body during arm flexion and extension	Extended	N/A	Straight, not falling out or in	N/A	Chest touches floor
Single leg squat	Held in neutral position, appears centrally aligned	Held down and away from ears. Elbows in line with ears	Held in neutral curve position	Mobile and facilitate flexion and stable to minimise weight shift over stance leg	Aligned with hips and feet during flexion	Mobility allows adequate dorsiflexion during hip and knee flexion	Stable with heels grounded during lower limb flexion	Maintained on each leg	Top of thighs appear parallel with floor
Vertical Jump A	Held in neutral position, appears centrally aligned	Shoulder held down and away from ears, thoracic spine stable	Held in neutral curve no hyper-extension	Neutral rotation flexed on landing	Aligned over second toe. Flexion greater than 30 degrees	Aligned with knee and hip	Aligned, lands on toes	Remains balanced during take-off and landing. Holds landing for two seconds	Hips and knees are flexed 30-45 degrees at landing
Vertical Jump B	Held in neutral position, appears centrally aligned	Shoulder held down and away from ears, thoracic spine stable	Held in neutral curve no hyper-extension	Neutral rotation flexed on landing	Aligned over second toe. Flexion greater than 30 degrees	Aligned with knee and hip	Aligned, lands on toes	Remains balanced during take-off and landing. Holds landing for two seconds	Hips and knees are flexed 30-45 degrees at landing
Broad Jump	Held in neutral position, appears centrally aligned	Shoulder held down and away from ears, thoracic spine stable	Held in neutral curve no hyper-extension	Neutral rotation flexed on landing	Aligned over second toe. Flexion greater than 30 degrees	Aligned with knee and hip	Aligned, lands on toes	Remains balanced during take-off and landing. Holds landing for two seconds	Hips and knees are flexed 30-45 degrees at landing

Vanweerd, R. (2013). *The inter and intra-rater reliability of the Netball Movement Screening Tool.* MPhil, Auckland University of Technology.

APPENDIX F

Movement Competency Screen

Pattern	Primary	Secondary	Score	Comments
Squat	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Lunge (left)	O Balance O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth	1 2 3	
Lunge (right)	O Balance O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth		
Twist (left)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Twist (right)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance		
Bend	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Pull	O Shoulders O Lumbar O Hips O Depth	O Head O Knees O Ankles / Feet O Balance	1 2 3	
Push Up	O Head O Shoulders O Lumbar O Depth	O Hips O Knees O Ankles / Feet O Balance	1 2 3	
Single Leg Squat (left)	O Depth O Lumbar O Hips O Ankles / Feet	O Head O Shoulders O Knees O Balance	1 2 3	
Single Leg Squat (right)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance		

Jump Patterns

Pattern	Primary	Secondary	Score	Comments
Vertical Jump A	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Vertical Jump B (left)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Vertical Jump B (right)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance		
Broad Jump (left)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance	1 2 3	
Broad Jump (right)	O Shoulders O Lumbar O Hips O Ankles / Feet	O Head O Knees O Depth O Balance		

Considerations: The numbers in the PRIMARY and SECONDARY columns depict the number of areas that were marked during the screen. Select the 1, 2 or 3 in the Score columns after adding up the checked areas for each pattern. For the vertical jump B and broad jump, the lower of the two scores is recorded.

Scoring Instructions		
Score	**Primary**	**Secondary**
1	**2+ and / or 4**	
2	**1 and / or 0-3**	
3	**0 and / or 0**	

Star Excursion Balance Test

Scoring	Left	Right
Measurement A		
Measurement PL		
Measurement PM		
Leg length		
Score		

Score is equated by the following: $\frac{[(A + PL + PM)]}{(LLx3)} \times 100$

Active straight leg raise

Scoring	
Left	1 2 3
Right	1 2 3

Scoring Summary

Screening Test	Score
MCS	
Jumping Patterns	
SEBT	
ASLR	
Total Score:	

Nb: The SEBT score is not included in the overall NMST score due to the continuous nature of it's scoring compared to the ordinal ranking used in the other tests. Further research needs to be undertaken to ascertain a way to rank the SEBT in an ordinal fashion.

Vanweerd, R. (2013). *The inter and intra-rater reliability of the Netball Movement Screening Tool.* MPhil, Auckland University of Technology.

APPENDIX G

AUTHOR GUIDELINES FOR THE JOURNAL OF PHYSICAL THERAPY IN SPORT

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by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. EU Directive 2010/63/EU for animal experiments http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm; Uniform Requirements for manuscripts submitted to Biomedical journals http://www.icmje.org. The manuscript should contain a statement that has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that participants gave informed consent to the work. Studies involving experiments with animals must state that their care was in accordance with institution guidelines. Patients' and volunteers' names, initials, and hospital numbers should not be used.
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New guidance for randomised controlled trials

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2. Livesley, R.K., Matrix Methods of Structural Analysis, 2nd edn., Pergamon Press, Oxford, 1975.
3. Davies, R.M., ed., Space Structures: Proceedings of the First International Conference on Space Structures, Blackwell Scientific Publications, Oxford, 1967.
4. Mollaert, M., De Wilde, W. and Van Damme, F., Modular Design of Tension Structures, in: Heki, K., ed., Shells, Membranes and Space Frames (vol. 2): Proceedings of the IASS Symposium on Membrane Structures and Space Frames, Elsevier Science Publishers, Amsterdam, 1986, 133-140.
5. Sanchez-Alvarez, J.S., Formex Formulation of Structural Configurations, PhD Thesis, University of Surrey, 1980.

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APPENDIX I

The ANOVA revealed a statistical result of $F(1, 37) = 0.36$, $p = 0.55$ ($\alpha = 0.05$), meaning that there is no significant difference in the BMI (kg/m^2) values of players and their injury history in the past 12 months.

The relationship between the total NMST components and the individual Bunkie test results.

Table I.1 The relationship between each Bunkie test and all total scores for the NMST components represented as Spearman correlation (rho)

BUNKIE TEST	APL L	APL R	PPL L	PPL R	PSL L	PSL R	LSL L	LSL R	MSL L	MSL R
MCS TOTAL	0.00	0.14	0.20	0.12	0.17	0.01	0.33 †	0.19	0.02	0.29
JUMP TOTAL	-0.01	0.14	0.10	0.08	0.24	-0.02	0.26	0.17	-0.11	0.12
NMST TOTAL	-0.08	0.10	0.16	0.10	0.17	0.06	0.38 †	0.15	0.08	0.26
SEBT TOTAL L	0.22	0.25	0.30	0.42 ‡	0.29	0.45 ‡	0.45 ‡	0.29	0.37 †	0.02
SEBT TOTAL R	0.19	0.35 †	0.27	0.36 †	0.19	0.39 †	0.42 ‡	0.41 ‡	0.42 ‡	0.18

† $p \leq 0.05$ ‡ $p \leq 0.01$

The abbreviations L or R in this table represent the Left or Right side tested.

The abbreviations APL, PPL, PSL, LSL and MSL refer to the Anterior Power Line, Posterior Power Line, Posterior Stabilising Line, Lateral Stabilising Line and Medial Stabilising Line.

The relationship between the individual modified SEBT directions and the individual Bunkie test results.

Table I.2 The relationship between each Bunkie test and each individual SEBT direction represented as Spearman correlation (rho)

BUNKIE TEST	APL L	APL R	PPL L	PPL R	PSL L	PSL R	LSL L	LSL R	MSL L	MSL R
SEBT ANT L	0.25	0.04	0.32 †	0.31	0.31	0.17	0.20	0.14	0.10	0.01
SEBT ANT R	0.35 †	0.39 †	0.59 ‡	0.49 ‡	0.34 †	0.35 †	0.44 ‡	0.56 ‡	0.17	0.31
SEBT PM L	0.16	0.28	0.20	0.35 †	0.18	0.38 †	0.42 ‡	0.33 †	0.36 †	0.02
SEBT PM R	0.09	0.29	0.16	0.32 †	0.13	0.36 †	0.35 †	0.28	0.41 ‡	0.11
SEBT PL L	0.22	0.33 †	0.23	0.38 †	0.32 †	0.46 ‡	0.40 ‡	0.30	0.38 †	0.09
SEBT PL R	0.08	0.29	0.08	0.18	0.10	0.26	0.32 †	0.32 †	0.35 †	0.18

† p ≤ 0.05 ‡ p ≤ 0.01

Again L and R represent the test results on the Left (L) and Right (R) sides.

SEBT refers to the modified Star Excursion Balance Test and ANT, PM and PL refer to the reach directions, namely Anterior, Posteromedial and Posterolateral.