

**The effect of anthropometric parameters,
biomechanical malalignments and
flexibility of the lower extremities on the
prevalence of Medial Tibial Stress
Syndrome in rugby players of the North-
West University Rugby Institute**



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Declaration

AUTHORS' CONTRIBUTION

The study reported in this dissertation was planned and executed by a team of researchers. The contribution of each of the researchers is depicted in the table below. Also included in this section is a statement from the co-authors confirming their individual roles in this study and giving their permission that the articles may be part of the dissertation.

NAME	ROLE IN THE STUDY
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This dissertation is submitted in article, as approved by the Senate of North West University (Potchefstroom Campus) and, is presented in four, main parts, namely an introductory chapter (Chapter 1), a literature review (Chapter 2) and two research articles (Chapters 3 and 4). A summary with conclusions and recommendations follows (Chapter

5). In the first chapter, a problem statement, research questions and hypotheses are presented. Chapter 2 comprises, *Intrinsic risk factors contributing to MTSS in rugby union players: A review of the literature* by Horn, H, De Ridder, J.H. and Moss, S.J. The chapter firstly presents the reader with the literature format of this article by means of an introduction. A section comprising the intrinsic risk factors contributing to MTSS in rugby union players follows the introduction. This is followed by a summary of studies investigating the effect of the risk factors on the prevalence of injuries.

The research articles, Chapter 3 and 4, are written according to the instructions to authors of the British Journal of Sports Medicine to which the article will be submitted. The research article (Chapter 3) is entitled: *Selected components affecting the prevalence of MTSS in rugby union players: ana analysis of anthropometrical and biomechanical parameters* by Horn, H, De Ridder, J.H., Moss, S.J. and Du Plessis, J.L. Its main purpose was to determine whether anthropometrical and biomechanical risk factors contribute to MTSS. Chapter 4 is entitled: *The effect of static and dynamic foot motion on the incidence of MTSS in Rugby Union Players* by Horn, H, De Ridder, J.H., Moss, S.J. and Du Plessis, J.L. Its purpose was to determine the effect of static and dynamic foot motion and foot type on the prevalence of MTSS. The results of the study are presented and interpreted and summarised in Chapter 5, together with conclusions and recommendation, followed by a list of appendices.

I declare that I have approved the above mentioned articles and that my role in the study as indicated above is representative of my actual contribution and that I hereby give my consent that they may be published as part of the M.A dissertation of H. Horn.

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Summary

With the general increase in Rugby union's popularity the past decade, there has been an increase in sport injuries, both from acute and overuse trauma. Approximately half of all sport injuries may be attributed to overuse or repetitive micro trauma rather than a single traumatic event. Although very few overuse injuries have an established aetiology, the fact that over 80% of these injuries occurs at or below the knee suggests that there may be some common mechanisms in the aetiology. It could only be stated with certainty that the aetiology of these injuries is multifactorial and diverse, with both extrinsic and intrinsic factors contributing.

Many intrinsic factors (personal) predispose athletes to develop overuse injuries. Intervention of intrinsic injury risk factors is more problematic, as intrinsic risk factors are often difficult to examine and even more difficult to rehabilitate than external factors. Extrinsic risk factors (environmental) that are independent of the injured person can be influenced through the intervention of the extrinsic factors. Main attention should be paid not to the treatment of the site of injury but to the possible cause of the symptoms. It is therefore vital that coaches and medical teams have a complete understanding of the incidence, nature, severity, and causes of injuries in order to review the adequacy of their injury prevention, treatment and rehabilitation.

The objectives of this study were to determine the effect of selected anthropometric parameters, biomechanical malalignment and flexibility on the prevalence of Medial tibial stress syndrome (MTSS) in U/19 university rugby players of the 2006 season of the North-West University (NWU) Rugby Institute (RI).

A prospective once-off subject availability study was performed that included U/19 rugby union players of the RI of the NWU (n=91). Selected biomechanical and anthropometrical assessments were made. Biomechanical and anthropometrical assessments were performed on all subjects before the start of the season. All existing injuries were recorded by means of an injury history questionnaire. Descriptive statistics (e.g. mean and standard deviations) and contingency tables were used to analyse the data. Effect sizes were used to decide on the practical significance of the findings. A cut-off point of 0.8 (large effect) was set for practical significance of differences between means.

Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were leg length differences for both players with and without MTSS for Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length. Iliospinale- and Trochanterion-Tibiale lateral length differences presented with the largest length difference. Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length difference had a small effect. Only Bi-iliocrystal width presented with a medium effect.

Hamstrings, Gastrocnemius and Plantaris as well as Soleus and Popliteus flexibility of players without MTSS were tighter than those of players who suffered from MTSS. Only Hamstring tightness had a small effect. Gastrocnemius and Plantaris as well as Soleus and Popliteus presented with a medium effect. Players without MTSS had a more flexible TFL on their right side. All the other flexibility measurements of the Thomas test presented that players without MTSS had a more inflexible profile. Effect size was not analysed because of the small sample sizes in some of the cells. Players without MTSS presented with an overall more inflexible profile than those with MTSS.

More players without MTSS supinated at heel contact on both their feet, compared to the players with MTSS. Players without MTSS supinated more on both their feet during mid stance. A small percentage of players with and without MTSS supinated during the propulsion phase. More players without MTSS had a neutral right foot mid stance compared to players with MTSS who had a more neutral mid stance on their right foot. Players with MTSS pronated more with both their feet during propulsion. Players with MTSS pronated mostly during the propulsion phase and mostly had flatter and higher arched feet than players without MTSS.

More players with MTSS had a light flat foot, flat foot as well as a high arched foot than players without MTSS. Most of the players with MTSS had normal right arched foot type. None of the players with MTSS had either a light high right foot or a high arched left foot.

Keywords

Biomechanics, overuse injuries, malalignments, lower limb injuries, medial tibial stress syndrome, flexibility

Opsomming

Met die Rugbyunie se toenemende gewildheid die afgelope dekade het die aantal sportbeserings ook toegeneem, as gevolg van akute sowel as oorgebruikstrauma. Ongeveer die helfte van alle sportbeserings kan toegeskryf word aan oorgebruik of herhaalde mikrotrauma eerder as 'n enkele traumatiese gebeurtenis. Alhoewel baie min oorgebruiksbeserings 'n bevestigde etiologie het, suggereer die feit dat meer as 80% van hierdie beserings by of onder knie voorkom, dat daar sekere gemeenskaplike meganismes in die etiologie kan wees. Dit kan slegs met sekerheid gestel word dat die etiologie van hierdie beserings deur veelvuldige faktore veroorsaak word en dat die beserings divers is, en dat ekstrasieke sowel as intrinsieke faktore daartoe bydra.

Baie intrinsieke (persoonlike) faktore veroorsaak dat atlete geneig is om oorgebruiksbeserings te ontwikkel. Intervensie van intrinsieke beserings-risikofaktore is meer problematies, omdat intrinsieke risikofaktore dikwels moeilik is om te ondersoek en selfs nog moeiliker om te rehabiliteer as eksterne faktore. Ekstrasieke (omgewings-) faktore kan maklik beïnvloed word deur die intervensie faktore. Aandag moet nie in die eerste plek gegee word aan die behandeling van die area van die besering nie, maar aan die moontlike oorsaak. Daarom is dit noodsaaklik dat afrigters en mediese spanne beskik oor 'n volledige begrip van die voorkoms, aard, graad en oorsake van beserings, om die toereikendheid van hulle beseringsvoorkoming, -behandeling en -rehabilitasie te evalueer.

Die doelwitte van hierdie studie was om vas te stel wat die effek is van geselekteerde antropometriesse parameters, biomeganiese wanbelyning en soepelheid op die voorkoms van mediale tibiale stressindroom (MTSS) by onder 19-universiteitsrugbyspelers van die 2006-seisoen van die Noordwes-Universiteit (NWU) Rugbyinstituut (RI).

'n Prospektiewe eenmalige beskikbaarheidstudie is gedoen, wat onder 19-rugby-

uniespelers van die RI van die NWU (n=91) geselekteer het. Geselekteerde biomeganiese en antropometriese assesserings is gedoen. Biomeganiese en antropometriese evaluering is gedoen op alle proefpersone voor die begin van die seisoen. Alle bestaande beserings is aangeteken deur middel van 'n beseringsgeskiedenis-vraelys. Beskrywende statistiek (bv. gemiddelde en standaard-afwykings) en gebeurlikheidstabelle is gebruik om die data te ontleed. Effekgroottes is gebruik om te besluit oor die praktiese beduidendheid van die bevindings. 'n Afsnypunt van 0.8 (groot effek) is gestel vir praktiese beduidendheid van die verskille tussen gemiddeldes.

Spelers met MTSS het 'n breër Bi-iliocristale breedte gehad as dié sonder MTSS. Beenlengteverskille is waargeneem by spelers met MTSS sowel as dié sonder MTSS met betrekking tot Iliospinale, Trochanterium-Tibiale laterale en Tibiale laterale lengte. Iliospinale en Trochanterium-Tibiale laterale lengteverskille het gepresenteer met die grootste lengteverskil. Iliospinale, Trochanterium-Tibiale laterale en Tibiale laterale lengteverskil het 'n klein effek gehad. Slegs Bi-iliokristale breedte het met 'n medium effek gepresenteer.

Hampese-, Gastrocnemius- en Plantaris-, sowel as Soleus- en Popliteus-soepelheid van spelers sonder MTSS was minder as dié van spelers met MTSS. Slegs Hampese-onsoepelheid het 'n klein effek gehad. Gastrocnemius en Plantaris sowel as Soleus en Popliteus het gepresenteer met 'n medium effek. Spelers sonder MTSS het 'n soepeler Tensor Fasciae Latae (TFL) aan hulle regterkant gehad. Al die ander soepelheidsmetings van die Thomas-toets het getoon dat spelers sonder MTSS 'n soepeler profiel gehad het. Effekgrootte is nie ontleed nie as gevolg van die klein steekproefgroottes in party van die selle. Spelers sonder MTSS het gepresenteer met 'n algeheel minder soepel profiel as diegene met MTSS.

Meer spelers met MTSS het gesupineer met hakkontak by albei voete, in vergelyking met die spelers sonder MTSS. Spelers sonder MTSS het meer op albei voete gesupineer tydens middel-afstand. 'n Klein persentasie spelers met en sonder MTSS het tydens die wegspringfase gesupineer. Meer spelers sonder MTSS het 'n neutrale regtervoet middelstand gehad as spelers met MTSS, wat 'n meer neutrale middelstand op hulle regtervoet gehad het. Spelers met MTSS het die meeste geproneer tydens die wegspringfase en het meestal platter en hoër geboë voete gehad as spelers sonder MTSS.

Meer spelers met MTSS het 'n ligte plat voet, plat voet sowel as 'n hoog-geboë voet gehad as spelers sonder MTSS. Die meeste spelers met MTSS het 'n normale regter geboë voettipe gehad. Nie een van die spelers met MTSS het 'n ligte hoë regtervoet of 'n hoog-geboë linkervoet gehad nie.

Sleutelwoorde

Biomeganika, oorgebruiksbeserings, wanbelyning, onderlyf beserings, mediale tibiale stres sindroom, soepelheid

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List of Abbreviations

C

cm = Centimeter

D

° = Degree

M

MTSS = Medial Tibial Stress Syndrome

N

n = Number of subjects

NWU = North-West University

R

RI = Rugby Institute

S

SD = Standard deviation

T

TFL = Tensor Fasciae Latae

U

U/19 = Under 19

1 Problem statement and aim of the study

1. INTRODUCTION
2. PROBLEM STATEMENT
3. OBJECTIVES
4. HYPOTHESES
5. STRUCTURE OF THE DISSERTATION
6. REFERENCES

1. INTRODUCTION

There is an extensive risk of injury when playing sport (Neely, 1998a:395; Lysens *et al.*, 1989:612; Matheson *et al.*, 1987:46). The diagnosis and treatment of overuse injuries are major problems in sport medicine. Overuse injuries are becoming more common not only because participation in sport is increasing, but also because the duration and intensity of the training are intensifying (Sandelin *et al.*, 1987:61; Renstrom & Johnson, 1985:316). Numerous injuries occur each year caused by sport, resulting in decreased physical activity and work time lost (Murphy *et al.*, 2003:13). Rugby, which is one of the most popular worldwide team contact sports, has one of the highest levels of injury of all team sports (Brooks *et al.*, 2005:288).

2. PROBLEM STATEMENT

Research in sport biomechanics may take the form of describing movement from a performance enhancement to an injury reduction perspective. Biomechanics research may also play an integral role in reducing the incidence and severity of sport injuries (Elliott, 1998:1). Approximately half of all sport injuries in both adults and children may be attributed to overuse or repetitive micro trauma (chronic weight-bearing activities) rather than to a single traumatic event (Beck, 1998:265; Elliott, 1998:1; Krivickas, 1997:132). Given the instantaneous and repetitive demands put on all the supporting tissue, it is not surprising that injury to the lower extremity is not uncommon (Winter & Bishop, 1992:149).

The theoretical link between skeletal malalignments and lower quarter overuse problems appears more plausible when interventions designed to address the malalignments are successful (Gross, 1995:401). Abnormal biomechanics of the lower limb have been implicated as causative factors for injury (Neely, 1998a:395), but although anatomical misalignment is frequently given as the cause of overuse injuries in runners, definite evidence of such a relationship is hard to come by (Watson, 1995:293). Sporting injuries may generally be divided into those caused by an impact, where there is a sudden increase in the force applied to the body or those produced by overuse (Watson, 1995:290). Overuse injuries are generally due to overload or repetitive micro trauma of the musculoskeletal system, where a number of repetitive force each lower than the critical limit of selected tissues produce a combined fatigue effect in that tissue over a period. Damages to tissue are at a greater rate than at which the body can repair itself (Elliott, 1998:3; Krivickas, 1997:140). More recent investigations suggest that tibial stress injuries are a consequence of the repetitive strain imposed by loading during chronic weight-bearing activity (Elliott, 1998:3; Beck, 1998:267, Twellaar *et al.*, 1997:68; Krivickas, 1997:140). Awareness of anatomical factors that may be predisposed to overuse injuries allows clinicians to develop individual pre-rehabilitation programmes designed to decrease the risk of overuse injury.

Exercise induced pain along the border of the tibia has been referred to in the literature using a variety of terms. Authors have described this condition in different ways - stress fractures,

tibial periostitis, posterior compartment syndrome (Detmar, 1986:436) and 'shin soreness' (Muburgh *et al.*, 1988:129). However, the term Medial Tibial Stress Syndrome is the preferred term to describe exercise induced tibial pain along its medial border (Mubarek *et al.*, 1982:201). Detmar (1986:437) proposed a clinical classification and management system for Medial Tibial Stress Syndrome (MTSS). MTSS is classified according to the primary tissue in which the pathology occurs. The tissue that could be involved in a pathological process associated with exercise is bone (Type 1), periosteum (Type 2) and fascia and muscle (Type 3) (Detmar, 1986:438).

The site of injury in MTSS (Type 2) is the periosteal-fascial junction (Detmar, 1986:439). It is a periostitis at the posterior medial border of the tibia (Bennet *et al.*, 2001:505), which is also the site of attachment of the Soleus muscle (Kendall *et al.*, 2005:414). Periostitis has been described as the tearing away of the muscle fibres at the muscle-bone interface causing inflammation (Bennet *et al.*, 2001:505). The pathological mechanism of this syndrome is believed to be traumatic disruption of the periosteum by ballistic avulsion due to powerful contraction of the Soleus muscle (Detmar, 1986:441). More recent studies have also identified the Soleus muscle as the likely contributor to the development of posterior-medial shin pain (Bennet *et al.*, 2001:505; Beck, 1998:1057). Pain presents with palpation over the lower half of the medial tibia localized to the periosteal-fascial junction (Detmar, 1986:440). Pain may be described as a dull ache to intense pain that is exacerbated with repetitive weight-bearing activities and may be continuous or intermittent. Symptoms of this problem typically resolve quickly with rest and improved training technique (Detmar, 1986:440).

Awareness of anatomical factors that may be predisposed to overuse injuries allows a clinician to develop individual pre-rehabilitation programmes designed to decrease the risk of overuse injury. The theoretical link between skeletal malalignments and lower quarter overuse problems appears more plausible when interventions designed to address the malalignments are successful (Gross, 1995:389). Abnormal biomechanics of the lower limb have been implicated as a causative factor for injury (Neely, 1998a:395), but although anatomical misalignment is frequently given as the cause of overuse injuries in runners, definite evidence of such a relationship is hard to come by (Watson, 1995:293).

The causes of overuse injury are generally of two types (Elliott, 1998:1; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:207). A combination of extrinsic factors (environmental) such as training errors, excessive weekly running distances and terrain, are of great importance in the prevalence of lower extremity injuries, but the focus of this study will be on intrinsic factors (anatomical) factors, such as bony alignment of the extremities, flexibility deficits, calf tightness, leg discrepancy, limb girth, muscle imbalance, postural stability and foot morphology which predispose athletes to develop overuse injuries (Cimbiz & Bayazit, 2004:111; Burne *et al.*, 2002:441; Neely, 1998b:253; Krivickas, 1997:132). The clinician can advise the athlete on the importance of avoiding extrinsic factors that may also predispose to overuse injuries (Krivickas, 1997:144). Lower extremity malalignment is less amenable to intervention. Muscle inflexibility aggravates and predisposes to the development of a variety of overuse injuries (Beck, 1998:1057; Krivickas, 1997:134). An appropriate stretching programme may improve flexibility deficits. Prospective studies have reported an association between overpronation and medial tibial pain (Burne *et al.*, 2002:441). It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the Soleus origin, commonly attributed to MTSS pathology. According to Lysholm and Wiklander (1987:168), intrinsic risk factors are involved with 40% of injuries.

Few studies have made a contribution to the effect of anthropometric parameters and biomechanical malalignments on the prevalence of MTSS in rugby players. It is within this framework that the proposed research will be undertaken. The research questions that will be answered by the investigation are as follows:

- What is the effect of selected anthropometric parameters and biomechanical malalignments of the lower extremities on the incidence of MTSS in rugby players of the North-West University Rugby Institute?
- What is the effect of static and dynamic foot motion on the prevalence of MTSS in university rugby players of the North-West University Rugby Institute?

This study could make a contribution by investigating the effect of selected anthropometric parameters and biomechanical malalignments of the lower extremities on the prevalence of

MTSS in rugby players of the North-West University Rugby Institute in order to contribute to possible further studies in correcting malalignments. Abnormal biomechanics of the lower limb have been implicated as a causative factor for injury (Neely, 1998a:253), but although anatomical malalignment is frequently given as the cause of overuse injuries in runners, definite evidence of such a relationship is hard to come by (Watson, 1995:293).

3. OBJECTIVES

The specific aims of this study are derived from the above-mentioned research questions and are as follows:

- To investigate the effect of selected anthropometric parameters and biomechanical malalignment of the lower limb on the incidence of MTSS in rugby players of the North-West University Rugby Institute.
- To investigate the effect of static and dynamic foot motion on the prevalence of MTSS in university rugby players of the North-West University Rugby Institute.

4. HYPOTHESES

For this investigation the following hypotheses are made:

- MTSS is prevalent in university rugby players of the North-West University Rugby Institute. Anthropometrical parameters such as leg length discrepancies, abnormal leg lengths or breadths and limb girth and biomechanical malalignment and inflexibility cause an increase on the incidence of MTSS in university rugby players of the North-West University Rugby Institute.
- An insufficient static and dynamic foot motion and flat or high arched feet is the reason for the increase on the prevalence of MTSS in university rugby players of the North-West University Rugby Institute.

5. STRUCTURE OF THE DISSERTATION

This dissertation is submitted in article form and is presented in four main parts namely an introductory chapter (Chapter 1), a literature review (Chapter 2) and two research articles (Chapters 3 & 4). A summary with conclusions and recommendations will follow (Chapter 5). In the first chapter, a problem statement, research questions and hypotheses are presented. The research articles, Chapter 3 & 4, were written according to the instructions to authors of the British Journal of Sports Medicine to which the article will be submitted. The literature review is based on the intrinsic risk factor's contributing to MTSS in Rugby Union. The one research article (Chapter 3) is entitled: *Selected components affecting the prevalence of MTSS in Rugby Union Players: An analysis of anthropometrical and biomechanical parameters*. The second research article (Chapter 4) is entitled: *The effect of static and dynamic foot motion on the prevalence of MTSS in Rugby Union Players*. The results of the study are presented, interpreted and summarised in Chapter 5, together with conclusions and recommendations, followed by a list of appendices.

When the literature was studied it became clear that more information on the prevalence of overuse injuries on Rugby union players is needed.

The structure of the dissertation is shown in Figure 1.

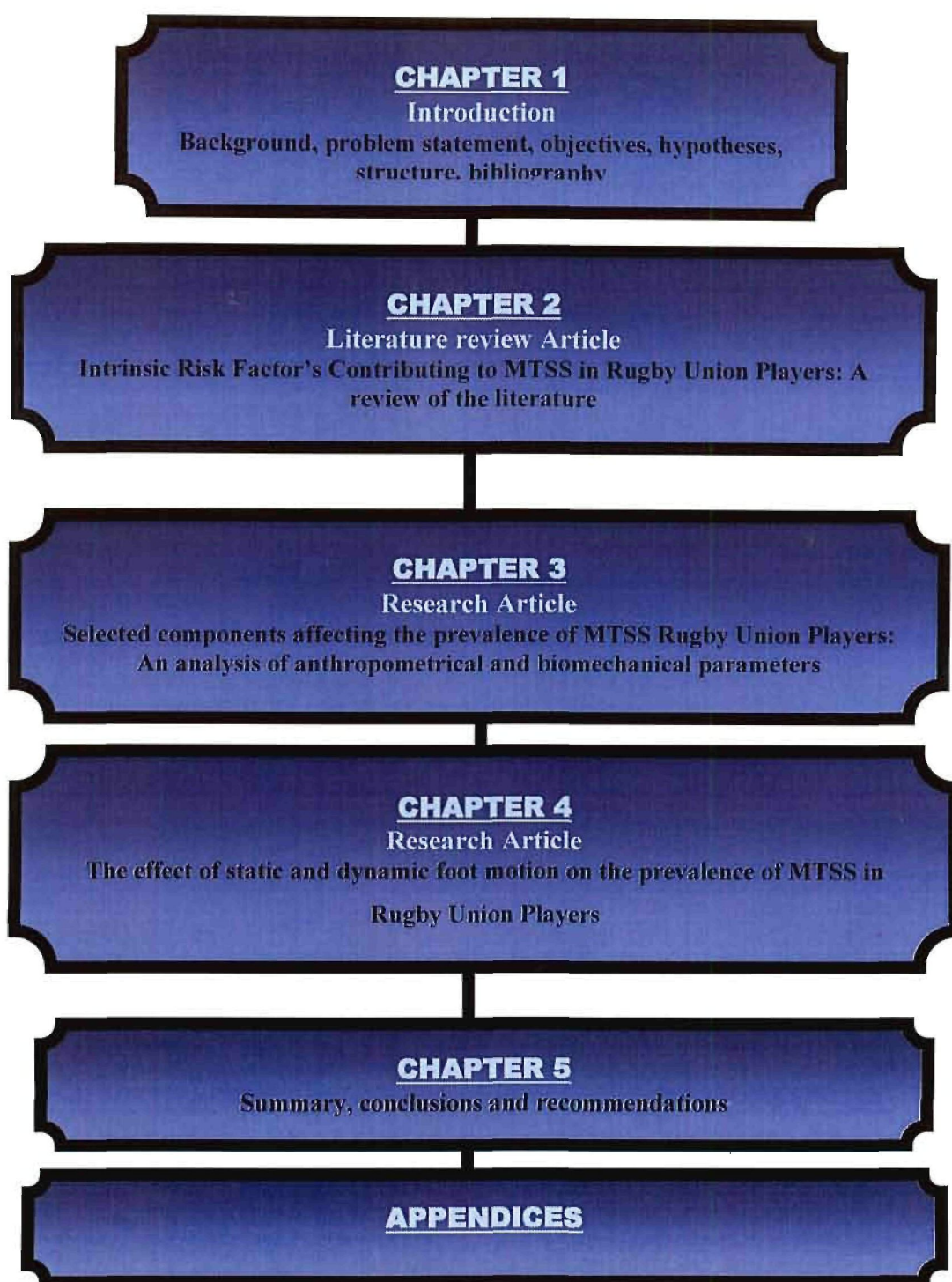


Figure 1: Structure of the dissertation

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2 Intrinsic Risk Factors Contributing to MTSS in Rugby Union Players: A review of the literature

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1. INTRODUCTION

There is an extensive risk of injury when undertaking physical activities (Lysens *et al.*, 1989:612; Neely, 1998a:395; Matheson *et al.*, 1987:46). Numerous sport injuries occur each year, resulting in decreased physical activity and loss of work time (Murphy *et al.*, 2003:13). Treating sport injuries is often difficult, expensive and time consuming, and thus, preventative strategies and activities are justified on medical as well as economic grounds (Parkkari *et al.*, 2001:985). Successful management of sport injuries must involve consideration of the mechanism of tissue injury (Kelly, 2004:4).

Approximately half of all sport injuries in both adults and children may be attributed to overuse or repetitive micro trauma (chronic weight-bearing activities) rather than to a single traumatic event (Beck, 1998:265; Elliott, 1998:1; Krivickas, 1997:132). Overuse injuries are becoming more common, not only because participation in sport is increasing, but also because the duration and intensity of the training are intensifying (Sandelin *et al.*, 1987:61; Renstrom & Johnson, 1985:316). Overuse injuries tend to be related with endurance and jumping sport (Courtture & Karlson, 2002:29; Watson, 1995:289; Detmar, 1986:439; Mubarek *et al.*, 1982:202). Overuse injuries are blamed on “running too much” when in fact, running incorrectly is the cause of the problem (Beck & Day, 1985:553). Rugby is the team sport with the highest level of injury. (Brooks *et al.*, 2005b:288).

The interactions of a variety of physical characteristics of athletes are proposed to be related to the risk to sustain a sport injury. Injury risk factors can be divided into extrinsic (environmental) and intrinsic (personal) risk factors (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206).

In the past, most epidemiologic studies have focused attention on the extrinsic factors (Neely, 1998b:253; Lysens *et al.*, 1991:281). More recently, emphasis has been put on the role of intrinsic risk factors, which are possibly responsible for the majority of sport injuries (Neely, 1998b:253; Lysens *et al.*, 1991:281). Many intrinsic and extrinsic risk factors have been implicated for lower extremity injury; however at present there is little agreement (Murphy *et al.*, 2003:13). Lysholm and Wiklander (1987:169) identified

intrinsic risk factors as being involved in 40% of the injury cases. The knee is the most common site of overuse running injuries. Injuries to the foot, ankle and lower leg, such as Plantar fasciitis, Achilles tendinitis and MTSS account for almost 40% of the injuries according to a clinical study about over 2000 injured runners (Taunton *et al.*, 2002:97). Other researchers have reported a fairly similar breakdown for the location of overuse running injuries (Rolf, 1995:181; Clement *et al.*, 1981:47) although very few running injuries have an established aetiology (Rolf, 1995:185), the fact remains that over 80% of these injuries occur at or below the knee, which suggests that there may be some common mechanisms in the aetiology. There are several risk factors that may be associated with a variety of running injuries (Hreljac & Ferber, 2006:100).

Medial Tibial Stress Syndrome (MTSS) is the clinical syndrome of inflammatory pain along the posterior medial border of the tibia (Kelly, 2004:4; Beck, 1998:266). There are 3 mayor types of chronic MTSS, depending on the primary structure involved: Type I: (bone); Type II (Periosteal-fascial junction) Type III (muscles) (Detmar, 1986:438).

2. MEDIAL TIBIAL STRESS SYNDROME (MTSS)

2.1 Physiology of MTSS

Medial Tibial Stress Syndrome is a condition comprising periostitis (periosteum- a thin sheath of tissue that wraps around the tibia, or shin bone) or symptomatic periosteal modelling (Beck, 1998:266) and usually occurs closer to the ankle. According to a study by Beck *et al.*, (1994:1060), the structures where the symptoms of MTSS occur, are the Soleus and Flexor digitorum longus muscles and the deep Crural fascia. The origin of the Tibialis posterior is not associated with this location. During the stance phase of running, the medial fibres of the Soleus eccentrically contract as the foot goes into pronation. This results in stress at the fascial origin of the Soleus. The Soleus muscle is most commonly strained or damaged in MTSS (Kelly, 2004:4; Beck *et al.*, 1994:1057; Detmar, 1986:441; Michael & Holders, 1985:87). Detmar (1986:440) observed that in patients with MTSS, who were operated on, that the tibial periosteum had been avulsed by the Soleus.

A muscle fiber will fail if the tensile or shear stress induced in a structural component exceeds its yield strength. This stress may be the result of a single mechanical event or a

cumulative, repetitive, mechanical event, and this leads to inflammation (Kelly, 2004:6). Although inflammation is required for proper healing of injuries, an excessive or prolonged inflammatory response can become self-perpetuating and destructive. Therefore, controlling or suppressing inflammation is one of the primary goals of treatment for overuse injuries such as MTSS (Kelly, 2004:7).

High-injury sports, such as running, are a good model for considering the prevention of injuries such as MTSS. The frequency of high injury and subsequent absence from participation in sport may be significantly reduced, if runners were more aware of the causes of injuries and relevant prevention strategies. Both extrinsic and intrinsic factors contributing to MTSS need to be considered when assessing injured patients. Many of the risk factors are modifiable, thus giving ample opportunity for injury prevention (Kelly, 2004:7).

2.2 Aetiology of MTSS

According to Touloupoulou and Hershman (1999:193) leg pain in athletes has a lot of different aetiology. The clinician must strive to specifically define the clinical problem in order to administer the appropriate treatment for the athlete's condition. MTSS is one of many overuse lower leg injuries found under the umbrella term of exercise-induced leg pain or shin splints (Yates & White, 2004:772), and commonly occurs in athletes participating in jumping and endurance sport (Courtney & Karlson, 2002:29; Detmar, 1986:439; Mubarek *et al.*, 1982:202).

The motion in the knee together with controlled pronation of the foot helps to absorb the impact of the body striking the ground (Kelly, 2004:4). The ground reaction force at the time of the mid-stance phase in running is equivalent to a vertical force equal between two to five times the person's bodyweight (Kelly, 2004:4; Van Mechelen, 1995:268). It is not only the ground reaction (i.e. external) force at impact that is thought to produce running injuries, bending forces and actively induced muscle (i.e. internal) forces are also thought to play a role (Van Mechelen, 1995:268). Even small biomechanical abnormalities could therefore result in a significant concentration of stress and load (Renstrom & Johnson, 1985:316). Many of the anatomic factors that cause problems for runners are very subtle, and would not cause any difficulty, were it not for the extreme stress that is applied to the

extremity in long distance running (James *et al.*, 1978:41). The cumulative effect of this repetitive stress on the muscles and connective tissues in the shin area is believed to be the origin of MTSS. For that reason, MTSS is often called an overuse injury (Kelly, 2004:4; Beck, 1998: 265).

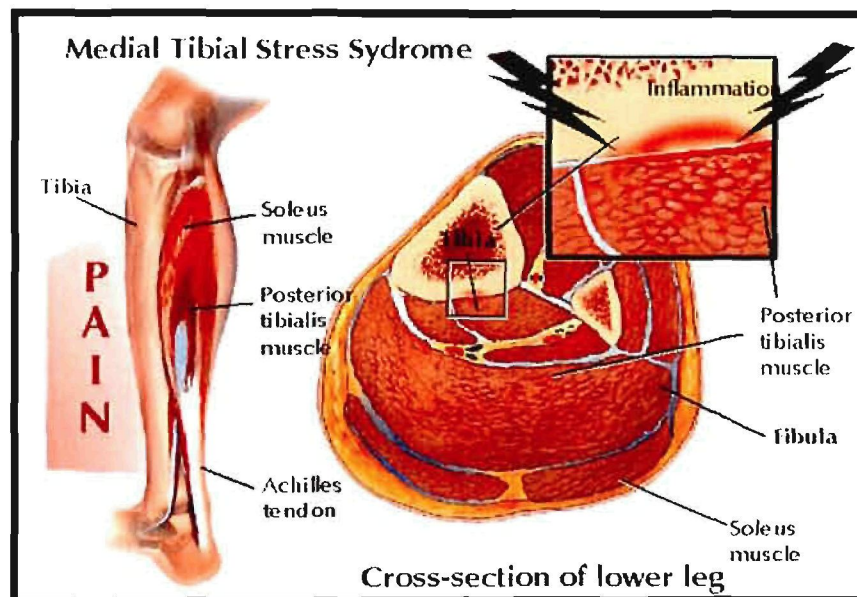


Figure 2.1: Cross-section of the lower leg and site of MTSS
(Below:www.hughston.com/hha/a_15_1_4.htm).

It is hypothesised that the periosteum is traumatically detached from the bone by ballistic avulsion of the periosteum off the bone. Less frequently, the periosteum is detached by subperiosteal bone stress on the tibial edge resulting in sufficient subperiosteal haemorrhage or inflammation to lift the periosteum away from the bone caused by the chronic and repetitive strain. The powerful Soleus muscle most probably causes these avulsions of periosteum, since it partially attaches medially into the fascia (Touliopolous & Hershman, 1999:196; Beck, 1998:268; Detmar, 1986:441) or the periosteum beneath the origin of the Tibialis posterior muscle (Touliopolous & Hershman, 1999: 196).

According to Kelly (2004:8) MTSS occurs because the ankle dorsiflexors do not function adequately. High plantar flexor strength and decreased range of motion have been demonstrated in patients with tibial stress injuries. A weak or fatigued muscle cannot dissipate mechanical stress effectively, so the stress is transmitted to the bone, thereby

increasing the risk of injury. In athletes with anatomic malalignment this may occur sooner.

2.3 Classification of MTSS

The proposed classification refers to chronic MTSS (Detmar, 1986:437). A patient is defined as having a chronic condition when they experience precisely located pain which regularly reappears following at least one or more periods of rest sufficient to produce complete resolution of symptoms. When pain recurs despite a program of graded exercise and rehabilitation with proper equipment including orthotics, and despite the application of standard conservative therapeutic modalities such as icing then an athlete is diagnosed as having chronic MTSS (Detmar, 1986:437).

The normal cross-sectional anatomy of the medial tibia is bone, periosteum (a thin sheath of tissue that wraps around the tibia or shinbone), fascia and muscle (Detmar, 1986:437).

There are 3 major types of chronic MTSS, depending on the primary structure involved:

- 1) The primary problem is the bone itself (Detmar, 1986:438);
- 2) The symptoms are typically noted just adjacent to the bone at the periosteal-fascial junction (Detmar, 1986:438);
- 3) Involves the distal posterior compartment musculature, typically the distal deep compartment muscles or, rarely, the soleus (Detmar, 1986:438).

Although medial, distal tibial stress fracture and MTSS constitute different pathologies, it may, for management purposes, be considered as a condition on a 'one stress-failure continuum' (Courtine & Karlson, 2002:29; Beck, 1998:266), on which MTSS is a relatively mild expression and stress fracture is a severe extreme injury. MTSS represents a stress reaction within the bone, wherein the usual remodelling process becomes maladaptive (Courtine & Karlson, 2002:29). These conditions do not necessarily occur concurrently, nor in temporal sequence; however, it is likely that stress fracture and MTSS are invoked by similar mechanisms. This continuum probably comprises most of the conditions that are typically called "shin splints" (Courtine & Karlson, 2002:29). The most common site of tibial stress fracture, are at or near the junction of the middle and distal thirds (Beck, 1998:266).

2.4 Clinical characteristics of MTSS

The following are clinical characteristics of MTSS:

1. Pain is induced by exercise and relieved by rest particularly after an unaccustomed increase in activity or at the start of the season (Kelly, 2004:6; Courture & Karlson, 2002:29; Kues, 1990:115; Allen & Barnes, 1986:818; Detmar, 1986:439; Michael & Holders, 1985:87; Mubarek *et al.*, 1982:202).
2. Enhanced training techniques and the use of gym equipment can reduce the features of MTSS (Detmar, 1986:439).
3. When palpated, tenderness at the posterior medial border of the tibia is present (Kelly, 2004:6; Courture & Karlson, 2002:29; Touliopolous & Hershman, 1999:198; Beck *et al.*, 1994:1057; Michael & Holders, 1985:87; Kues, 1990:115; Mubarek *et al.*, 1982:202) and some subjects may have visible swelling at the painful site (Kues, 1990:115).
4. A dull ache to intense pain is experienced at the posterior medial border of the tibia during exercise (Michael & Holders, 1985:87).
5. No sensory, motor, or vascular abnormalities are present (Michael & Holders, 1985:87).
6. Symptoms often subside after a few weeks of training; in some instances, however, they symptoms persist and become more severe until exercise becomes either extremely painful or impossible. Symptoms particularly occur after an unaccustomed increase in activity or at the start of the sporting season (Allen & Barnes, 1986:818).
7. The leg pain develops gradually during walking, running or jumping (Kues, 1990:115). However once this type of pain becomes well-established chronic prolonged trails of rest, orthotics, heat, cold, stretching, anti-inflammatory agents, and even local injections of steroids can prove successful in alleviating the symptoms during exercise (Detmar, 1986:439).

8. Occasionally pain can also be elicited by manoeuvres that contract or stretch the soleus, such as active ankle plantar flexion against resistance, passive ankle dorsiflexion, standing on tiptoe, or jumping in place (Kelly, 2004:6; Courture & Karlson, 2002:30).
9. The pain is recurrent and associated with repetitive, strenuous activity (Mubarek *et al.*, 1982:202).
10. During later stages the pain becomes more severe, sharper and more persistent. In advanced stages of MTSS, the pain complicates activities of daily living or can occur at rest (Courture & Karlson, 2002:29).

Shin pain accounts for an estimated 10–20 % of all injuries in runners and up to 60% of all overuse injuries of the leg (Courture & Karlson, 2002:29).

2.5 Diagnoses of MTSS

According to a study by Allen and Barnes (1986:818) the diagnoses of MTSS was much more difficult to assess as the diagnosis depended solely on the patient's history and the clinical finding of tenderness at the medial border of the tibia. Allen & Barnes (1986:818) stated that diagnosing MTSS is difficult because there are no specific clinical signs.

In order to make a definite diagnosis it is recommended that the patient presenting with exercise pain in the leg should first be treated conservatively, that is, with a period of rest, followed by physiotherapy and by shoe inserts if these are indicated. If there is no improvement and symptoms have persisted for at least six months, then intracompartmental pressure should be measured during exercise (Allen & Barnes, 1986:823). A careful history, physical examination, compartment pressure measurement (Touliopolous & Hershman 1999:197; Detmar, 1986:445) and triple-phase bone scan (Courture & Karlson, 2002:29; Touliopolous & Hershman, 1999:197; Detmar, 1986:445) will allow for precise diagnosis of nearly all cases.

The physical examination must include a thorough assessment of the entire lower extremity from the hip to the toes. It should include evaluation of extremity alignment in

the frontal and transverse planes, extremity length for discrepancies, knee function, ankle dorsiflexion with the knee extended and flexed, configuration of the weight-bearing foot, heel-leg alignment, and an assessment of footwear or shoes running (James *et al.*, 1978:40). Gross abnormalities are not always present on examination nor should they be expected. Many of the anatomical factors that cause problems for runners are very subtle, and would not cause any difficulty were it not for the extreme stress that is applied to the extremity in long distance running (James *et al.*, 1978:40). Plain x-rays of patients who have MTSS are almost invariably normal, although posterior cortical widening consistent with chronic remodelling may be seen (Touliopolous & Hershman, 1999:197). Triple-phase bone scintigraphy is an easy way to differentiate MTSS from tibial stress fracture (Courtoure & Karlson, 2002:30).

3. PREVALENCE OF MTSS IN RUGBY

Rugby union's popularity has increased internationally in recent times (Brooks *et al.*, 2005a:757; McManus, 2004:438; Holtzhausen, 2001:1; Hughes & Fricker, 1994:249), and is one of the most professional team sport in the world (Brooks *et al.*, 2005b:757). With the increased profile of rugby players, it is foreseen that there will also be an influx of players to the sport, particularly in the junior ranks (McManus, 2004:438; Holtzhausen, 2001:1; Hughes & Fricker, 1994:249). Rugby is a very physical sport and has therefore attracted the attention of sport medicine practitioners. This raises the concern of injury associated with participation (McManus, 2004:438; Holtzhausen, 2001:1; Hughes & Fricker, 1994:249). Little is known about the level and pattern of injuries in professional rugby (Holtzhausen, 2001:1). It is documented that there is a high incidence of injury (Brooks *et al.*, 2005a:757; McManus, 2004:438; Holtzhausen, 2001:1). It is therefore vital that the national and international governing bodies for rugby union together with the team coaches and medical teams have a complete understanding of the incidence, nature, severity, and causes of injuries in order to review the adequacy of their injury prevention, treatment and rehabilitation strategies (Brooks *et al.*, 2005a: 757; McManus, 2004:438).

Incidence is expressed as the number of injury incidents per 1000 player hours. According to Holtzhausen (2001:8), the mean incidence of all recorded injuries in professional rugby union is 86.4 injuries per 1000 player game hours, ranging between 67.8 and 150 injuries per 1000 player game hours. The highest rate of injury was recorded in the lower limb,

where the knee and ankle were the most commonly injured structures (Holtzhausen, 2001:8). According to a study (2006:58) on rugby union u/21 players the combined average injury rate for forwards and backs were 61.8 per 1000 game hours and 8.6 injuries per 1000 training hours. The most injured body region for forward players was the ankle (18%) followed by the knee (13%).

The incidence of injuries in 1 squad of 25 Super-12 players during the 1997 Super-12 Competition was 150 injuries per 1000 playing hours (Targett, 1998:282). This represents the highest injury rate reported in rugby union to date. Three Super-12 squads suffered 84 injuries per 1000 player hours during the 1999 Super 12 competition (Holtzhausen *et al.*, 2006:1261). The period prevalence of injuries among 30 professional rugby players in the Scottish Border Reivers club competition was 67.8 injuries per 1000 player hours (Holtzhausen, 2001:5).

A low incidence of chronic-overuse-type injuries was reported in professional rugby, possibly because of definitions of injury more suited to acute injuries (Holtzhausen, 2001:8), only two studies discussed chronic-overuse-type injuries. During the 1999 Super-12 Competition, the cohort of 3 squads reported 6 chronic overuse injuries that fit the definition of injury used in that study (Holtzhausen *et al.*, 2006:1262). These injuries could not be expressed in terms of 1000 hours exposure because of the chronic nature of conditions. Most were carried over from the previous season. The 1997 Super-12 squad reported 2 chronic-overuse injuries that did not prevent training, thus not qualifying as “injuries” in the study design. Both injuries required surgery after the Super-12 Competition, which underscores their serious nature (Holtzhausen *et al.*, 2006:1262). This type of injury might have been underreported because of the definitions of injury used in most rugby surveys, which are more suited to describing acute injuries.

During a study on all 20 teams competing in the 2003 Rugby World Cup, an overall injury rate of 98 injuries per 100 player game hours were found, and in comparison with other datasets it is high, probably owing to the different protocols applied in sport injury surveillance research (Best *et al.*, 2005:815).

In amateur rugby, the highest injury rates were reported in the lower limb, the head and face, and shoulder with musculoskeletal injuries such as muscle strains and ligament

sprains were the most common types of injury (Holtzhausen, 2001:8). During the 1997 Junior Rugby Union National campaign an injury incidence rate of 13.26 per 1000 player hours were found. Of these, 44% of the injuries were sustained during training (McManus, 2004:439). The most common site of injury were the lower limb (37%), followed by the head and neck (McManus, 2004:440). According to a study by Hughes and Fricker (1994:255) on first grade rugby union players, injuries occurred once every 741.8 training hours (Hughes & Fricker, 1994:250). The head was the most common site of injury (17.3%). The lower leg accounted for 11.3% of all injuries (Hughes & Fricker, 1994:251).

The different injury rates in the studies could be the cause of the different definitions of injury that have been used. It is clear that there are not a lot of research performed on overuse injuries as well as injury prevalence of amateur rugby and therefore more studies contributing to this could be helpful in the prevention and rehabilitation of these injuries.

4. RISK FACTORS OF MTSS

Prevention of injury remains an important goal for clinicians and researchers. However, to prevent lower extremity injury, the risk factors and aetiology of injuries must be established (Murphy *et al.*, 2003:13; Neely, 1998b:253). Preventative strategies can then be specifically targeted (Neely, 1998b:253). The interactions of a variety of physical characteristics of athletes are proposed to be related to the risk to sustain a sport injury. Injury risk factors can be divided into extrinsic and intrinsic risk factors (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206).

Many intrinsic factors (personal, individual biological and psychosocial characteristics), such as bony alignment of the extremities, flexibility deficits, calf tightness, leg length discrepancy, limb girth, muscle imbalance, postural stability, foot morphology and previous injury predispose athletes to develop overuse injuries (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206). Intervention of intrinsic injury risk factors

is more problematic, as intrinsic risk factors are often difficult to examine and even more difficult to change than external factors (Taimela *et al.*, 1990:213).

Extrinsic (environmental) risk factors such as training errors, excessive weekly running distances and uneven terrain have been implicated for lower extremity injuries (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206). Extrinsic risk factors are independent of the injured person and are principally related to the type of activity during the incident of injury and can obviously be influenced (Taimela *et al.*, 1990:212) through the intervention of the extrinsic factors, such as changing training distances, intensity or terrain. Intrinsic factors are far more difficult to intervene because it takes longer to rehabilitate and to examine the specific cause of injury. This study will focus on intrinsic risk factors because of the lack of research available on intrinsic risk factors related to rugby union injuries

Extrinsic factors are of great importance in the prevalence of lower extremity injuries, but the focus of this study will be on intrinsic factors. The measuring of muscle strength and muscle imbalances is excluded in this study but is of great importance in the rehabilitation of lower extremity injuries.

4.1 INTRINSIC RISK FACTORS OF MTSS

4.1.1 Anthropometry

Considering the influence of anthropometric characteristics on the risk of injury it is hypothesized that the skeletal and muscular system of tall and obese/heavy persons are more vulnerable to injuries because of the high mechanical stress put on the body (Twellaar *et al.*, 1996:68).

The physiological cross sectional area of muscle is proportional to the maximum magnitude of force that it can develop. Therefore, limb girth has received interest as a potential risk factor for lower extremity injury with regard to muscles' ability to stabilize and control the joint. Several studies have reported a relation between limb girth and lower extremity injury (Murphy *et al.*, 2003:22; Bennel *et al.*, 1996:814). Limitations of these

studies are small sample sizes, different location at which limb circumference was measured and uneven sex distribution (Murphy *et al.*, 2003:22).

4.1.2 Biomechanics

Although functional biomechanical findings are clinically more accurate predictors of injury and a diagnostic tool, than static findings, a correlation between the two is essential. Biomechanics can be defined as the mechanics of the living systems, and the biomechanics of the structure and function of living systems are investigated by using the knowledge and methods of mechanics. It has been suggested that biomechanical principles can be applied to distinguish between inner and outer forces, i.e. forces originating within the body itself and external forces like gravity and resistance, which influence the body from the outside. Running is considered to be a learned skill and it has been shown that, at a given speed, muscular activity for the strong runner is lower than that for the weak runner (Subotnick, 1985:147). Abnormal biomechanics of the lower limb has been implicated as a causative factor for injury as a result of exercise (Neely, 1998a:395). The more biomechanics are understood, the better musculoskeletal disorders in sport and the workplace can be appreciated.

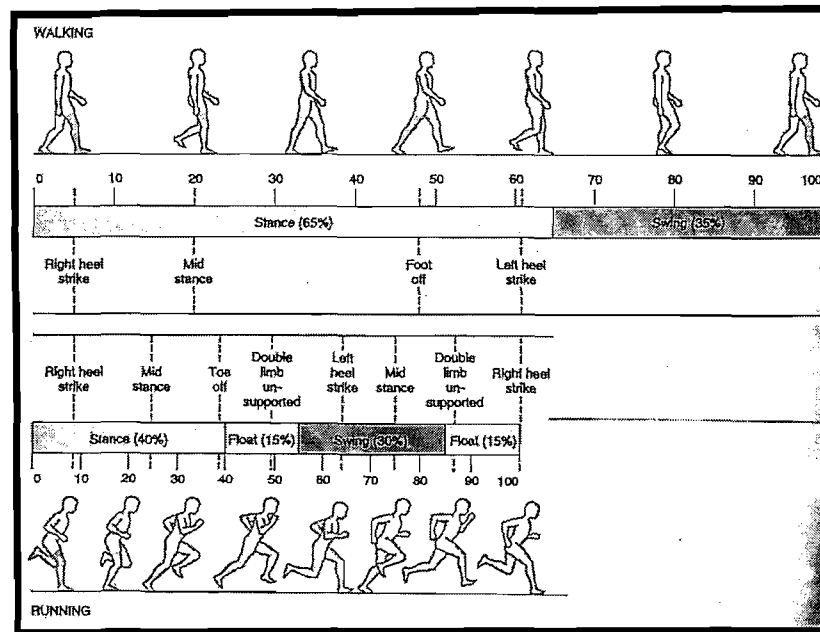


Figure 2.2: Comparison of the phases of the walking and running cycles (Magee, 2002:562).

Anatomical alignment is the intersegmental joint forces and the structures that must resist these forces are related through anatomical alignment of the joints and skeletal system (e.g., articular surfaces, ligaments, and musculature). Therefore, alignment of the hip, knee, and ankle has received substantial interest as a potential risk factor for lower extremity injury (Murphy *et al.*, 2003: 14).

Lower extremity malalignment is less amenable to intervention (Beck, 1998:1057; Krivickas, 1997:134). The theoretical link between skeletal malalignments and lower quarter overuse problems appears more plausible when interventions designed to address the malalignments are successful (Gross, 1995:389). Abnormal biomechanics of the lower limb has been implicated as a causative factor for injury (Neely, 1998a: 395), but although anatomical malalignment is frequently given as the cause of overuse injuries in runners, although definite evidence of such relationship is hard to come by (Watson, 1995:293).

Table 2.1: Joint motions at the hip, knee, tibia, foot and ankle during the stance phase of gait (Magee, 2002:620).

PHASE	HIP	KNEE	TIBIA
HEEL STRIKE	20° to 40° of hip flexion, moving toward extension	In full extension before heel contact, flexing as heel strikes floor	Slight lateral rotation
	Slight adduction and lateral rotation		
FOOT FLAT	Hip moving into extension, adduction and medial rotation	In 20° flexion moving toward extension	Medial rotation
MIDSTANCE	Moving through neutral position	In 15° flexion moving toward extension	Neutral
	Pelvis rotating posteriorly		
HEEL OFF	10° to 15° extension of hip, abduction, lateral rotation	In 4° flexion moving toward extension	Lateral rotation
TOE OFF	Moving toward 10° extension, abduction, lateral rotation	Moving from near full extension, to 40° flexion	Lateral rotation

PHASE	FOOT	ANKLE	
HEEL STRIKE	Supination (rigid) at heel contact	Moving into plantar flexion	
FOOT FLAT	Pronation	Plantar flexion to dorsiflexion	
	(adapting to support surface)	(over a fixed foot)	
MIDSTANCE	Neutral	3° dorsiflexion	
HEEL OFF	Supination,	15° dorsiflexion,	
	as foot becomes rigid for push-off	toward plantar flexion	
TOE OFF	Supination	20° plantar flexion	

A runner's feet "collide" with the ground 800 to 2000 times per mile, or 50 – 70 times per minute for each foot, at a force 3 to 8 times body weight. The impact at the foot-surface interface is absorbed by the running shoe or transmitted directly to the leg and back. While a person is running, minor anatomic and biomechanical abnormalities that are of no functional significance in walking can produce injury. During pronation the tibia rotates internally. At heel strike the tibia is externally rotated and the patellar tendon is angulated laterally. When the foot pronates, the Q angle is reduced, indicating a significant amount of internal tibial rotation. Any interference with the sequential timing and extent of pronation and supination places abnormal stress on the lower extremity. If pronation is excessive or prolonged, the ankle sags medially and the obligatory internal tibial rotation increases, straining the structures of the knee and foot. Excessive pronation also prevents the foot from returning to the more stable, supinated position for toe-off. Hyperpronation is a compensatory mechanism for Tibia vara (bow leg) tight Achilles tendon, tight Gastrocnemius and Soleus muscle, and Hindfoot and Forefoot varus (Brody, 1980:2).

It has been suggested that high arch feet are inflexible, while flat feet are hyper mobile and susceptible to a large degree of pronation. The literature is contradictory regarding the relationship between foot structure and exercise-related overuse injuries (Subotnick, 1985:144). Cowan *et al.* (1993:773) suggested that a greater percentage of athletic injuries occur with people with flat feet. Cowan *et al.* reported an increase in exercise related injuries with increased arch height in US Army recruits. According to Kaufman *et al.*, (1999:773) subjects with either Pes cavus (high arched feet) or Pes planus (low arched feet/flat), measured statically and dynamically, had twice the incidence of stress fractures compared to those subjects with average foot height.

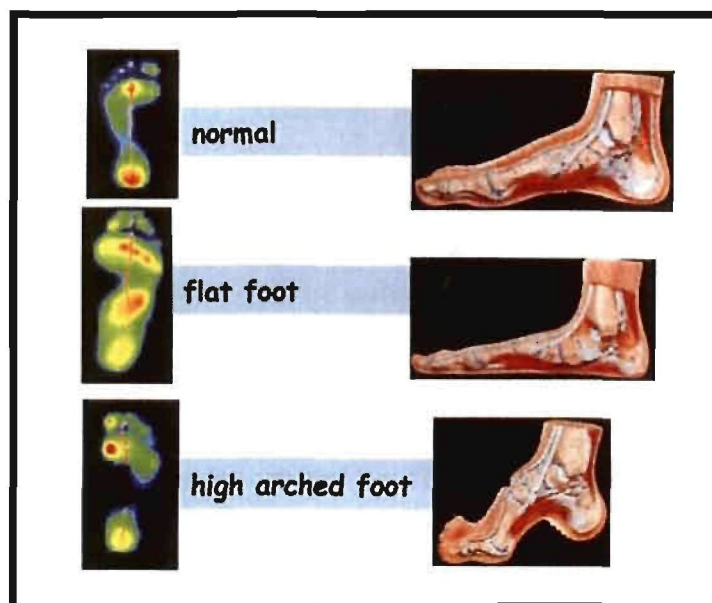


Figure 2.3: Plantar and dorsal view of a normal, flat and high arched foot (Wilsens, <http://rsscan.com>).

Prospective studies have reported an association between overpronation and medial tibial pain. It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the soleus origin, commonly attributed to MTSS pathology (Burne et al., 2002:441).

4.1.2.1 Flexibility

Flexibility is the amount of movement of a joint through its normal plane of motion. Hyper mobility is an aspect of flexibility where joints are moved in their normal plane of

motion but beyond some predefined point. A flexibility imbalance involves a difference in the range of motion between the right and left side of the body (Knapik *et al.*, 1992:278).

Poor flexibility might be associated with an increased density and decreased length of collagen fibres in connective tissue of ligaments, tendons, muscles and joint capsules increasing the vulnerability to injury (Beck, 1998:1057; Krivickas, 1997:134; Corbin 1984:102). In the majority of studies no relation was found between flexibility and sport injuries (Twellaar *et al.*, 1996:66; Jackson *et al.*, 1978: 8). According to a study by Twellaar *et al.* (1996) the range of motion (ROM) of various joints did not show any significant relation to the total number of injuries sustained. This is not surprising, as the relation between flexibility and injuries are more joint specific (Twellaar *et al.*, 1996:69). According to Kelly (2004:9), athletes are advised to maximize their Gastrocnemius flexibility and soleus complexes with focused stretching. Any activity that improves ankle coordination in various planes of motion and adequate strength of both posterior and anterior muscle groups of the lower legs will limit the risk of MTSS.

Most studies reported an association between muscle tightness and injury (Krivickas & Feinberg, 1996:1142; Knapik *et al.*, 1992:280), whereas Twellaar *et al.* (1996:69) found no significant relation. The findings of general injury studies and studies of the influence of muscle tightness on ligament sprains are confounding because of research designs using various methods of measuring muscle tightness, diverse injury types, and a variety of sport with different inherent risks (Murphy *et al.*, 2003:21). It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the Soleus origin, commonly attributed to MTSS pathology (Burne *et al.*, 2002:444).

MTSS occurs because the ankle dorsiflexors are not functioning adequately (Kelly, 2004:6). High plantar flexion strength and decreased range of motion in dorsiflexion have been demonstrated in patients with tibial stress injuries (Kelly, 2004:6; Neely, 1998a:395).

A weak or fatigued muscle cannot dissipate mechanical stress effectively, so the stress is transmitted to the bone, thereby increasing the risk of injury (Kelly, 2004:6). Limitation of ankle dorsiflexion may be caused by a tight Gastrocnemius when the knee is extended, as the muscle spanned two joints. Other causes for a paucity of movement of the ankle joint are a tight Soleus, tight capsular tissue or abnormal osseous formation of the ankle. A tight

Soleus is relatively uncommon but will limit movement with the knee in flexion or extension, as the muscle only spans one joint (Neely, 1998a:395). Scarring from previous injury may cause tight capsular tissue and abnormal osseous formation may be congenital or caused by acute or repetitive trauma. Both will limit movement of the ankle joint, regardless of whether the knee is extended or flexed (Neely, 1998a:395).

The knee never reaches full extension during running and, in fact, with an increase in running speed (and therefore an increase in forces on the lower limb) the degree of extension becomes progressively smaller. Restrictions on the movement of the ankle joint which are present only with the knee in full extension are unlikely to be a cause of lower limb injuries (Neely, 1998a:396). There are different ways to compensate for insufficient dorsiflexion. Some might compensate by decreasing step length, other compensation is an increase in the toe out foot placement angle, so that dorsiflexion demands during the terminal stance of gait are decreased. This has been shown to cause excessive and prolonged pronation (Gross, 1995:389).

The evidence to suggest that the range of either dorsiflexion or plantar flexion plays a significant role in the aetiology of lower limb injuries is limited. Limitation of dorsiflexion would appear to be a more convincing risk factor than that of plantar flexion (Neely, 1998a:396).

4.1.2.2 Malalignment

The intersegmental joint forces and the structures that must resist them (articular surfaces, ligaments, and musculature) are related through anatomical alignment of the joint and skeletal system. Therefore, alignment of the hip, knee and ankle has received substantial interest as a potential risk factor for lower extremity injury (Murphy *et al.*, 2003:22).

According to Twellaar *et al.*, (1996:66) malalignment of the lower extremities may cause abnormal stress in the joint and muscles involved. When the stress brings about micro traumatic damage, typical overuse injuries are the result. Suggested malalignment of the lower extremities associated with sport injuries are leg length discrepancy, abnormal knee and rear foot position, and deviating configuration of the feet. Several studies reported an association between abnormal anatomical alignment and injury (Krivickas, 1997: 142;

Milgrom *et al.*, 1987:326; Lysholm & Wiklander, 1987:169; James *et al.*, 1978:43). Two found no association (Wen *et al.*, 1997:1295; Twellaar *et al.*, 1996:66). Limitations are that there is little agreement in the literature about the characterization of abnormal alignment (Murphy *et al.*, 2003:27).

The problems and symptoms resulting from leg length discrepancy may be severely depending on the degree of inequality. Leg length discrepancy can be structural (anatomical shortening or lengthening of the bone), functional (the result of soft tissue shortening or relaxation causing compensatory changes in the lower limb) or environmental (often caused by the chamber of the road when running). Other reported problems have been degenerative changes of the lumbar spine, hip, knee joints and muscular imbalances throughout the lower extremities and trunk (Neely, 1998a:399).

Like anatomical alignment of a joint, foot morphology has an important effect on the relation between the ground reaction force and the axes of rotation of the ankle, knee and lower extremity as well as the corresponding forces developed on these structures. The methods of quantifying an abnormally high or low arch differ greatly and, consequently, disparate results exist. Most of the studies have reported a relation between foot morphology (Krivickas, 1997:142; Wen *et al.*, 1997:1295; Twellaar *et al.*, 1996:66; Milgrom *et al.*, 1987:326), and injury whereas studies which have found no relation (Murphy *et al.*, 2003:27). The most commonly used measures of foot type are: arch height, pronation/supination, Pes cavus/Pes planus, fore foot/rear foot position and subtalar joint range of motion (Neely, 1998a:401).

The foot needs to re-supinate and the subtalar joint to become locked once again during the final phase of the stance, to balance the body, conserve muscular activity and establish a rigid lever to push off from (Neely, 1998a:402). If the foot is pronated during the push-off phase of gait, stability is lost producing trauma to the foot, and through a closed chain, the resultant forces are transmitted to the leg, knees and hips. The same principle applies to the heel strike, when the foot should be supinated; the foot is already pronated, mobile and unprepared to absorb the ground reaction forces. The foot must then rely on ligaments and muscle for stability, the muscle working out of phase and inefficiently to maintain balance. Such forces have a large part to play in the aetiology of lower extremity injuries (Neely, 1998a:402).

4.1.3 Other risk factors

With regard to muscle strength, several studies found an association between muscular imbalance and injury (Taimela *et al.*, 1990:209), where fewer studies show no association. It is difficult to compare the findings of these investigations because of different planes of motion and testing speeds. Isokinetic dynamometers used to measure strength in terms of torque generated about a specific joint provide important information; however, these tests are performed with the subject non-weight bearing, and cannot duplicate the speeds of physical activity and injury mechanism (Murphy *et al.*, 2003:21).

Excessive height and weight have been shown to predispose athletes to stress injuries in physical training and a similar relationship between height and weight and accidental injuries has been reported in high school football. The relationship between body size and injuries may be due to the high position of the centre of gravity or to the length of the limbs greater mechanical loading or perhaps to the relative clumsiness associated with height (Taimela *et al.*, 1990:208). Greater limb length could produce greater leverage and thus more stress on the limb joints in situations that require rapid change of direction (Taimela *et al.*, 1990:208). However, this disagrees with the result of many studies cited above which did not find any relationship between height and the risk of injury (Neely, 1998b:253).

4.2 Injury history

Previous injury may lead to an increased risk of sustaining future injury by contributing to muscular weakness and imbalance, proprioceptive defects (functional stability), impairment of ligaments, diminished muscle flexibility and fear of re-injury that could cause the athlete to use altered muscle recruitment strategies and lose focus causing an inability to maintain attention to appropriate visual cues (Murphy *et al.*, 2003:18; Neely, 1998a:253; Taimela *et al.*, 1990:208).

There is strong evidence that previous injury, especially followed by inadequate rehabilitation, places an athlete at increased risk of suffering a re-occurring injury (Murphy *et al.*, 2003:18).

5. SUMMARY

Injury is an unfortunate fact in the world of sport; some individuals sustain injuries of greater severity more frequently than others. The risk when undertaking physical activity is significant and even more so when it involves rugby union. Rugby union is a popular sport played in more nations than any other sport, except soccer (Hughes & Fricker, 1994:249). Sport that involves running, jumping or other ballistic movements is often subjected to overuse injuries (Courtture & Karlson, 2002:29; Watson, 1995:289; Detmar, 1986:439; Mubarek *et al.*, 1982:202). Overuse injuries occur when the human body is subjected to a degree of physical demands that it is not capable to tolerate or to adapt to. The prevention of injuries is an important goal for the coaches, medical team and players (Murphy *et al.*, 2003:14). However, to ensure prevention of these injuries the risk factors and aetiology of injuries must be established (Murphy *et al.*, 2003:13; Neely, 1998b:253).

Injury risk factors can be divided into extrinsic (environmental) and intrinsic (personal) factors (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206). The intervention of intrinsic factors is far more difficult than extrinsic factors because of the longer time needed for the intervention of biomechanical rehabilitation. Intrinsic factors include bony alignment of the extremities, flexibility deficits, calf tightness, leg length discrepancy, limb girth, muscle imbalance, postural stability, foot morphology and previous injury (Cimbiz & Bayazit, 2004:111; Murphy *et al.*, 2003:13; Burne *et al.*, 2002:441; Elliott 1998:1; Neely, 1998b:253; Krivickas, 1997:132; Twellaar *et al.*, 1996:66; Lysens *et al.*, 1991:281; Winter & Bishop, 1992:149; Taimela *et al.*, 1990:206). These are some of the factors that predispose athletes to develop overuse injuries. There is a lack of consistency in the research about these risk factors.

The anthropometric characteristics of tall and heavy persons are at a higher risk of injury because of the high mechanical stress. Malalignment of the lower extremities may cause abnormal stress in the joint and muscles involved (Twellaar *et al.*, 1996:68). When the stress brings about micro traumatic damage, typical overuse injuries are the result. Suggested malalignments of the lower extremities associated with sport injuries are leg length inequality, abnormal knee and rear foot position, and deviating configuration of the

feet. Awareness of anatomical factors that may be predisposed to overuse injuries allows a clinician to develop individual pre-rehabilitation programmes designed to decrease the risk of overuse injury.

Like anatomical alignment of a joint, foot morphology has an important effect on the relation between the ground reaction force and the axes of rotation of the ankle, knee and lower extremity as well as the corresponding forces developed on these structures. This has served as the rationale for studying the relation between the biomechanical behaviour of the medial longitudinal arch and the incidence of lower extremity injury (Murphy *et al.*, 2003: 14).

Previous injury may lead to an increased risk of sustaining future injury by contributing to muscular weakness and imbalance, proprioceptive defects (functional stability), impairment of ligaments, diminished muscle flexibility and fear of re-injury that could cause the athlete to use altered muscle recruitment strategies and lose focus causing an inability to maintain attention to appropriate visual cues.

Muscle inflexibility aggravates and predisposes to the development of a variety of overuse injuries. An appropriate stretching programme may improve flexibility deficits.

Currently, in rugby union, not much research has been done on the effect of intrinsic risk factors on injuries or the occurrence of overuse injuries, especially MTSS. Further research in this area may contribute in the form of the prevention, recurrence or rehabilitation of MTSS. Extensive research has been carried out over the last few years and the research focus was predominantly on extrinsic risk factors. Research on the role of intrinsic risk factors on injuries is scarce, not to mention the role of certain intrinsic risk factors on overuse injuries. The identification of these risk factors and mechanism of injuries can facilitate specific interventions. There is a need for accurate and current data on this subject.

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3 Selected components affecting the prevalence of MTSS in Rugby Union Players: An analysis of anthropometrical and biomechanical parameters

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1. ABSTRACT

Objectives: The objective of this research is to investigate the effect of selected anthropometric and biomechanical parameters of the lower extremities on the incidence of MTSS in U/19 rugby union players.

Design: A prospective once-off subject availability study was performed. Anthropometrical and biomechanical assessments were performed on all subjects. All previous and current injuries were recorded by an injury history questionnaire. Independent sample tests and cross tabulation were used. The effect size was determined, where $d \geq 0.8$ was set for practical significance.

Participants: Only players of the U/19 squad were eligible for this study (n=91).

Results: Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were leg length differences for both players with and without MTSS. Iliospinale and Trochanterion-Tibiale lateral length differences presented with the largest length difference. Hamstrings, Gastrocnemius and Plantaris as well as Soleus and Popliteus flexibility of players without MTSS were lower than those of players who suffered from MTSS.

Conclusions: Players without MTSS have an inflexible profile compared to those with MTSS. Players without MTSS as well as those who suffer from MTSS present with a difference in leg length. Players with a larger Bi-iliocrystal width as well as a larger calf girth are more prone to MTSS.

Keywords: Malalignments, lower limb overuse injuries, rugby union, medial tibial stress syndrome, flexibility, biomechanics

2. INTRODUCTION

Although rugby union has one of the highest levels of injury of all team sport, little is known about the level and pattern of injuries in professional rugby.[1-3] It is therefore vital that the national and international governing bodies for rugby union, together with the team coaches and medical team, have a complete understanding of the incidence, nature, severity, and causes of injuries in order to review the adequacy of their injury prevention, treatment and rehabilitation strategies.[2-4]

The interactions of a variety of physical characteristics of athletes are proposed to be related to the risk of sustaining a sport injury. Injury risk factors can be divided into extrinsic (environmental) and intrinsic (personal) risk factors.[6-15] More recently, emphasis has been put on the role of intrinsic risk factors, which are possibly responsible for the majority of sport injuries.[10, 13] Many risk factors have been implicated for lower extremity injury; however at present there is little agreement.[7] Lysholm and Wiklander [16] identified intrinsic risk factors as being involved in 40% of the injury cases.

Sport medicine professionals have long suspected that particular deficits in strength or flexibility are risk factors for athletic injuries. It has been assumed that stronger and/or more flexible athletes are less likely to get injured.[17] According to Twellaar *et al.* [12] malalignment of the lower extremities may cause abnormal stress in the joint and muscles involved. Several studies have reported a relation between limb girth and lower extremity injury.[7]

Medial Tibial Stress Syndrome (MTSS) is the clinical syndrome of inflammatory pain along the posterior medial border of the tibia.[4-5] By increasing the understanding of players and coaches to the risk factors pre-disposing them to MTSS, and through the implementation of preventions strategies, the incidence and reappearance of MTSS should be significantly reduced. Preventative measures should be based on the outcome of research that has identified risk factors for injuries. Only if such research into risk factors has been performed can adequate preventative measures then be proposed. Few studies have made a contribution to

the effect of anthropometric parameters, biomechanical malalignments and flexibility on the prevalence of MTSS in rugby players.

The purpose of this study is to make a contribution to sport science by investigating the effect of selected anthropometric parameters, malalignment and flexibility of the lower extremities on the prevalence of MTSS in rugby players of the North-West University Rugby Institute in order to contribute to possible further studies in identifying risk factors and correcting these malalignments.

3. METHODS

3.1. Subjects and study design

Ninety one (n=91) U/19 university rugby players of the North-West University Rugby Institute participated in this study. Ninety five players were recruited for this study, but not all of the participants gave consent to participate in this study. The inclusion criteria were that the players had to be 18 years of age and part of the U/19 squad of the North West University Rugby Institute. All subjects were informed of the test procedures by the means of both a verbal and written explanation. An informed consent form was signed by participants themselves, as well as by their parents if they were under aged, before they took part in this study. Ethical approval was obtained from the Ethics Committee of the North-West University (Ethics number: 06M15). A prospective once-off subject availability study comprised an evaluation to determine the anthropometrical and flexibility parameters that contribute to MTSS in U/19 rugby union players.

3.2. Measuring procedure and equipment

3.2.1 Demographic information

All the subjects completed a demographic information questionnaire. Information on age, playing position and shoe insertions were obtained through the questionnaire.

3.2.2. Anthropometry measurements

Maximum calf girth was taken at the marked medial calf skinfold site with a flexible steel tape. A segmometer was used for the height measurements. Length and height measurements included: Iliospinale height, Trochanterion-Tibiale laterale length and Tibiale lateral height. The Large sliding calliper was used for the breadth measurement: Bi-iliocristal. Weight was measured with an electronic scale and height with a stadiometer.[18]

3.2.3 Lower extremity flexibility measurements

Goniometric measurements explained by Norkin and White [19] were used to determine the flexibility of selected muscle groups. The flexibility measurements included Hamstring suppleness, Thomas test (Hip Flexor Muscles), Soleus and Popliteus (one-joint plantar flexor) as well as Gastrocnemius and Plantaris (two-joint plantar flexors). The protocol described by Kendall *et al.*[20] was used for hip and plantar flexor flexibility.

3.2.4 Injury history questionnaire

A validated rugby union injury report questionnaire was used to determine the previous injury history and new injury data of all players. The questionnaire was explained to all the subjects by the researchers. Injuries were classified as “minor” if the player was able to return to the game or training session in which he became injured, “mild” if one week of training was missed, “moderate” if two weeks were missed and “severe” if more than two weeks were missed. The questionnaire included the site of injury, type of injury, when the injuries occurred and the number of games or training sessions missed.[21]

3.3. Data analysis

Statistical analysis was carried out with the SPSS program.[22] Descriptive statistics (e.g. mean and standard deviations) and contingency tables were used to analyze the data. Effect

sizes were used to decide practical significance of the findings. A cut-off point of 0.8 (large effect) was set for practical significance between means.[23]

4. RESULTS

The purpose of this study was to make a contribution by investigating the effect of selected anthropometric parameters, malalignment and flexibility of the lower extremities on the prevalence of MTSS in rugby union players in order to contribute to possible further studies in identifying risk factors and correcting these malalignments. Out of a total of 91 players participating in this study, 13 of the U/19 squad were diagnosed with MTSS. Only the players with MTSS in both legs were examined in this study. Nine of the players had MTSS in both legs. According to Table 1, the majority of the subjects played flanker (17.1%), the second most played positions by the subjects was scrumhalf while 10.8%, and 9.9% of the players were locks and wings. Only 9% of the players wore shoe insertions. The mean height of players was 180.8cm and the weight was 89.0kg.

Table 3.1: Demographic information of players: Playing positions, shoe insertions, age, weight and length of players

POSITION	% OF PLAYERS	N
Flanker	17.1	91
Scrumhalf	10.8	91
Wing	9.9	91
Lock	9.9	91
Prop	9	91
SHOE INSERTIONS	% OF PLAYERS	N
Yes	9	90
No	72.1	90
	MEAN	n
AGE (years)	18	91
LENGTH (cm)	180.8	91
WEIGHT (kg)	89	91

Anthropometrical characteristics contributing to MTSS

According to Table 2, players without MTSS had a smaller calf girth of 39.2 cm compared to 39.9 cm. Players with MTSS had a wider Bi-iliocrystal mean width of 32.7 cm to those without MTSS of 29.9 cm. There were leg length differences for both players with and without MTSS for Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length. Iliospinale and Trochanterion-Tibiale lateral length differences presented with the largest length difference.

A practical significance is present for $d \geq 0.8$. According to Table 2 Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length difference and calf girth had a small effect. Only Bi-iliocrystal width presented with a medium effect.

Table 3.2: Anthropometrical characteristics contributing to MTSS

VARIABLES	UNINJURED		INJURED		EFFECT SIZE
	n	MEAN $\pm$ SD	N	MEAN $\pm$ SD	
Calf girth (cm)	76	39.2 $\pm$ 3.39	9	39.9 $\pm$ 2.39	0.218
Iliospinale length difference (cm)	73	0.2 $\pm$ 1.83	7	-0.9 $\pm$ 3.32	0.35
Trochanterion-Tibiale lateral length difference (cm)	73	-0.3 $\pm$ 1.83	7	0.6 $\pm$ 3.32	0.46
Tibial lateral length difference (cm)	73	0.2 $\pm$ 1.91	7	0.3 $\pm$ 1.58	0.07
Bi-iliocrystal width (cm)	73	29.9 $\pm$ 5.15	7	32.7 $\pm$ 4.33	-
VARIABLES	N	Mean			
Height (cm)	88	180.8			
Weight (kg)	88	88.6			

$d \geq 0.8$

Flexibility characteristics contributing to MTSS

In Table 3, Hamstring tightness of players without MTSS was 84.2°, where players with MTSS had a mean of 88.5°. The “two-joint” plantarflexors, Gastrocnemius and Plantaris of players injured with MTSS, were 8.5°, and those who were not injured were 7.1°. With Soleus and Popliteus, the “one-joint” plantar flexor’s mean was 9.2° for players with MTSS, compared to 7.3° for players without MTSS.

A practical significance is present for $d \geq 0.8$. According to Table 3, Hamstring tightness had a small effect. Gastrocnemius and Plantaris as well as Soleus and Popliteus presented with a medium effect.

Table 3.3: Flexibility characteristics contributing to MTSS

VARIABLES	INJURED		UNINJURED		EFFECT SIZE
	n	MEAN $\pm$ SD	n	MEAN $\pm$ SD	
Hamstrings(°)	8	88.5 $\pm$ 11.47	73	84.2 $\pm$ 8.88	0.375
Gastrocnemius and Plantaris(°)	8	8.5 $\pm$ 2.2	69	7.1 $\pm$ 2.18	0.647
Soleus and Popliteus(°)	8	9.2 $\pm$ 2.39	69	7.3 $\pm$ 1.68	0.761

According to Figure 1, 62.5% of the players who suffered from MTSS had a tight Sartorius on both their left and right legs. None of the players with MTSS had a tight TFL on their left leg, and only 12.5% on their right leg. Only half of the players suffering from MTSS had a tight Iliopsoas on their left leg compared to 62.5% on their right leg. In players without MTSS 64.4% had tight left Iliopsoas compared to 68.5% on their right leg. Of the players with MTSS, 75% had a tight left Rectus Femoris compared to 93.2% of players without MTSS. Players without MTSS had 93.2% tight Rectus Femoris on their left side compared to 89% on their right side.

Effect size was not analysed because of the small sample sizes in some of the groups.

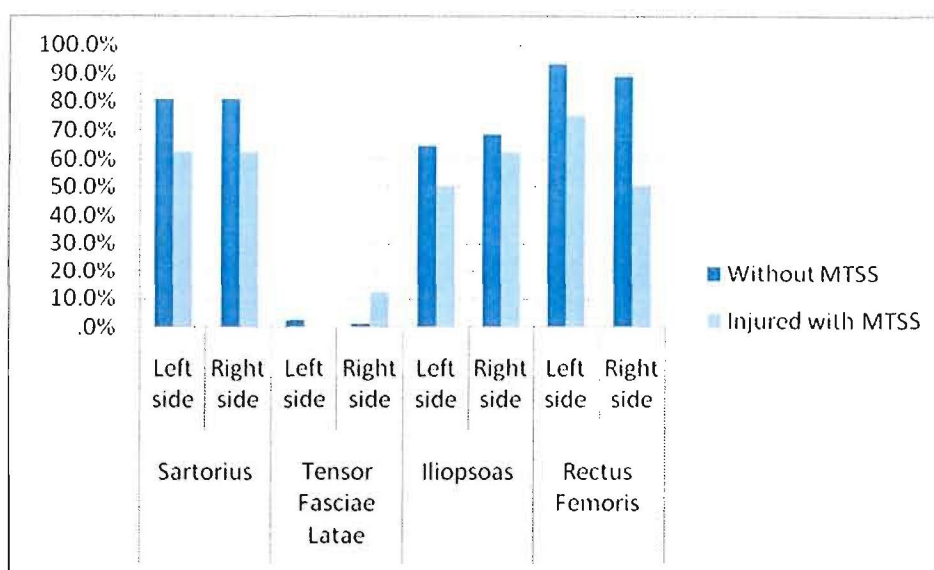


Figure 3.1: Thomas test: Sartorius, Tensor Fasciae Latae, Iliopsoas and Rectus Femoris tightness

5. DISCUSSION

In this study anthropometrical and flexibility measurements were taken on the participating rugby union players to analyse the contribution of selected intrinsic risk factors on the prevalence of MTSS. Out of a total of 91 players participating in this study, 13 of the U/19 squad were diagnosed with MTSS. Only the players with MTSS in both legs were examined in this study. Nine of the players had MTSS in both legs. According to Table 1, the majority of the subjects played flanker (17.1%), the second most played positions by the subjects was scrumhalf while 10.8%, and 9.9% of the players were locks and wings. Only 9% of the players wore shoe insertions. The mean height of players was 180.8cm and weight was 89.0kg.

The players without MTSS had a smaller calf girth than players with MTSS. Calf girth presented with a small effect between players with MTSS and those without MTSS. Several studies have reported a relation between limb girth and lower extremity injury.[7,19]

Limitations of these studies are small sample sizes, different location at which limb girth was measured as well as uneven gender distribution.[7]

Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were a leg length differences for both players with and without MTSS for Iliospinale-, Trochanterion-Tibiale lateral- and Tibial lateral length. Iliospinale- and Trochanterion-Tibiale lateral length differences presented with the largest length difference. Iliospinale-, Trochanterion-Tibiale lateral- and Tibial lateral length difference had a small effect. Only Bi-iliocrystal width presented with a medium effect.

Several studies reported an association between abnormal anatomical alignment and injury.[11,16,20-21] Two studies found no association.[12,22] Limitations are that there is little agreement in the literature about the characterization of abnormal alignment.[7] The problems and symptoms resulting from leg length discrepancy may be severe, depending on the degree of inequality like muscular imbalances throughout the lower extremities and trunk.[10]

Hamstrings, Gastrocnemius and Plantaris as well as Soleus and Popliteus flexibility of players without MTSS were tighter than players who suffered from MTSS. Only Hamstring tightness had a small effect. Gastrocnemius and Plantaris as well as Soleus and Popliteus presented with a medium effect. Players without MTSS had a more flexible TFL on their right side. All the other flexibility measurements of the Thomas test presented that players without MTSS had a more inflexible profile. Effect size was not analysed because of the small sample sizes in some of the cells.

The majority of studies showed no relation between flexibility and sport injuries.[12,24] According to a study by Twellaar *et al.*[12] the range of motion (ROM) of various joints did not show any significant relation to the total number of injuries sustained. This is not surprising, as the relation between flexibility and injuries are more joint specific.[12] Most studies reported an association between muscle tightness and injury,[17,25] whereas Twellaar *et al.*[12] found no significant relation. The findings of general injury studies and studies of

the influence of muscle tightness on ligament sprains are confounding because of research designs using various methods of measuring muscle tightness, diverse injury types, and a variety of sport with different inherent risks.[7] It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the Soleus origin, commonly attributed to MTSS pathology.[8]

Limitation of ankle dorsiflexion may be caused by a tight Gastrocnemius when the knee is extended, as the muscle spans two joints. Other causes for a paucity of movement of the ankle joint are a tight Soleus, tight capsular tissue or abnormal osseous formation of the ankle. A tight Soleus is relatively uncommon but will limit movement with the knee in flexion or extension, as the muscle only spans one joint.[10]

The evidence to suggest that the range of either dorsiflexion or plantar flexion plays a significant role in the aetiology of lower limb injuries is limited.[10]

6. CONCLUSION

Sport, such as rugby union, is injury prone, due to several factors. Overuse syndrome occurs more frequently due to the increase in frequency of training and the increase in exercise intensity.

The players without MTSS had a smaller calf girth than players with MTSS. Calf girth presented with a small effect between players with MTSS and those without MTSS.

Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were leg length differences for both players with and without MTSS for Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length. Iliospinale and Trochanterion-Tibiale lateral length differences presented with the largest length difference. Iliospinale, Trochanterion-Tibiale lateral and Tibial lateral length difference had a small effect. Only Bi-iliocrystal width presented with a medium effect.

Hamstrings, Gastrocnemius and Plantaris as well as Soleus and Popliteus flexibility of players without MTSS was tighter than those of players who suffered from MTSS. Only Hamstring tightness had a small effect. Gastrocnemius and Plantaris as well as Soleus and Popliteus presented with a medium effect. Players without MTSS had a more flexible TFL on their right side. All the other flexibility measurements of the Thomas test presented that players without MTSS had a more inflexible profile. Effect size was not analysed because of the small sample sizes in some of the cells. Players without MTSS presented with an overall more inflexible profile than those with MTSS.

The conclusion can be drawn from this study that players without MTSS had an inflexible profile compared to those with MTSS. Players without MTSS as well as those who suffered from MTSS presented with a difference in leg length. Players with a larger Bi-iliacristal width and calf girth were more prone to MTSS. The study highlights the need for pre-season anthropometrical and flexibility assessments to correct certain malalignments and inflexibility to protect players from sustaining MTSS.

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4

The effect of static and dynamic foot motion on the prevalence of MTSS in Rugby Union Players

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1. ABSTRACT

Objectives: The objective of this research is to investigate the effect of static and dynamic foot motion on the incidence of MTSS in U/19 rugby union players.

Design: A prospective once-off subject availability study was performed. Biomechanical assessments of the feet were performed on all subjects. All previous and current injuries were recorded by an injury history questionnaire. Independent sample tests and cross tabulation were used. The effect size was determined, where $d \geq 0.8$ was set for practical significance.

Participants: Only players of the U/19 squad were eligible for this study (n=91).

Results: More players without MTSS supinated at heel contact on both their feet, compared to the players with MTSS. Players without MTSS supinated more on both their feet during mid stance. A small percentage of players with and without MTSS supinated during the propulsion phase. More players without MTSS had a neutral right foot mid stance compared to players with MTSS who had a more neutral mid stance on their right foot. Players with MTSS pronated more with both their feet during propulsion. More players with MTSS had a light flat foot, flat foot or a high arched foot than players without MTSS. Most of the players with MTSS had normal right arched foot type. None of the players with MTSS had either a light high right foot or a high arched left foot.

Conclusions: Players with MTSS had a more sufficient heel contact than players without MTSS. Neither group had a sufficient mid stance. Players with MTSS pronated mostly during the propulsion phase and mostly have flatter and higher arched feet than players without MTSS.

Keywords: Biomechanics, lower limb overuse injuries, rugby union, medial tibial stress syndrome

2. INTRODUCTION

There is a significant risk of injury when undertaking physical activities. Abnormal biomechanics of the lower limb have been implicated as a causative factor for injury.[1-3] Applied biomechanics is the application of the practical principles of mechanics (the study of forces and their effects) to the body in movement and at rest. From a pure musculoskeletal standpoint, the human body is a mechanical device. All mechanical devices are subject to wear during use that reflects their history of destructive forces.[4]

It has been suggested that high arch feet are inflexible, while flat feet are hyper mobile and susceptible to a large degree of pronation. The literature is contradictory regarding the relationship between foot structure and exercise-related overuse injuries.[5] Cowan *et al.*[6] suggest that a greater percentage of athletic injuries occur in people with flat feet. Cowan *et al.*[6] report an increase in exercise related injuries with increased arch height in US Army recruits. According to Kaufman *et al.*,[7] subjects with either Pes cavus (high arched feet) or Pes planus (low arched feet/flat), measured statically and dynamically, have twice the incidence of stress fractures compared to those subjects with average foot height.

A runner's feet "collide" with the ground 800 to 2000 times per mile, or 50 – 70 times per minute for each foot, at a force 3 to 8 times body weight. The impact at the foot-surface interface is absorbed by the running shoe or transmitted directly to the leg and back. While a person is running, minor anatomical and biomechanical abnormalities that are of no functional significance in walking can produce injury. During pronation the tibia rotates internally. At heel strike the tibia is externally rotated and the patellar tendon is angulated laterally.[8] When the foot pronates, the Q-angle is reduced, indicating a significant amount of internal tibial rotation. Any interference with the sequential timing and extent of pronation and supination places abnormal stress on the lower extremity. If pronation is excessive or prolonged, the ankle sags medially and the obligatory internal tibial rotation increases, straining the structures of the knee and foot.[8] Excessive pronation also prevents the foot from returning to the more stable, supinated position for toe-off. Hyperpronation is a

compensatory mechanism for Tibia vara (bow leg), tight Achilles tendon, tight Gastrocnemius and Soleus muscle, and Hindfoot and Forefoot varus.[8]

Table 4.1: Joint motions at the foot during the stance phase of gait.[9]

PHASE	FOOT
Heel strike	Supination (rigid) at heel contact
Foot Flat	Pronation (adapting to support surface)
Mid stance	Neutral
Heel off	Supination, as foot becomes rigid for push-off
Toe-off	Supination

Like anatomical alignment of a joint, foot morphology has an important effect on the relation between the ground reaction force and the axes of rotation of the ankle, knee, and lower extremity as well as the corresponding forces developed on these structures.[10] Prospective studies have reported an association between overpronation and medial tibial pain. It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the Soleus origin, commonly attributed to MTSS pathology.[11]

Malalignment of the lower extremities may cause abnormal stress on the joints and muscles involved. When the stress brings about micro traumatic damage, typical overuse injuries are the result.[12] Leg length discrepancies have been linked to excessive pronation and subsequent overuse injuries. The common view is that excessive pronation occurs on the side of the short leg.[13] The more biomechanics is understood, the better musculoskeletal disorders in sports and the workplace can be appreciated and corrected.

The purpose of this study was to determine the effect of static and dynamic foot motion on the prevalence of MTSS in rugby players of the North-West University Rugby Institute.

3. METHODS

3.1. Subjects and study design

Ninety one (n=91) U/19 university rugby players of the North-West University Rugby Institute participated in this study. Ninety five players were recruited for this study, but not all of the participants gave consent to participate. The inclusion criteria were that the players had to be 18 years of age and part of the U/19 squad of the North West University Rugby Institute. All subjects were informed of the test procedures by the means of both a verbal and written explanation. An informed consent form was signed by participants themselves, as well as by their parents if they were under aged, before they took part in this study. Ethical approval was obtained from the Ethics Committee of the North-West University (Ethics number: 06M15). A prospective once-off subject availability study comprised an evaluation to determine the anthropometrical and flexibility parameters that contribute to MTSS in U/19 rugby union players.

3.2. Measuring procedure and equipment

3.2.1 Demographic information

All the subjects completed a demographic information questionnaire. Information on age, playing position and shoe insertions was obtained through the questionnaire.

3.2.2. Biomechanical measurements

The Scientific RS footscan® (0, 5 meter plate) was used for the foot analysis. Static and dynamic pressure measurements of the foot were made. Foot shape, foot size and foot movements were automatically calculated and an analysis was made.[14]

3.2.3 Injury history questionnaire

A validated rugby union injury report questionnaire was used to determine the previous injury history and new injury data of all players. The questionnaire was explained to all the subjects by the researchers. Injuries were classified as “minor” if the player was able to return to the game or training session in which he became injured, “mild” if one week of training was missed, “moderate” if two weeks were missed and “severe” if more than two weeks were missed. The questionnaire included the site of injury, type of injury, when the injuries occurred and the number of games or training sessions missed.[15]

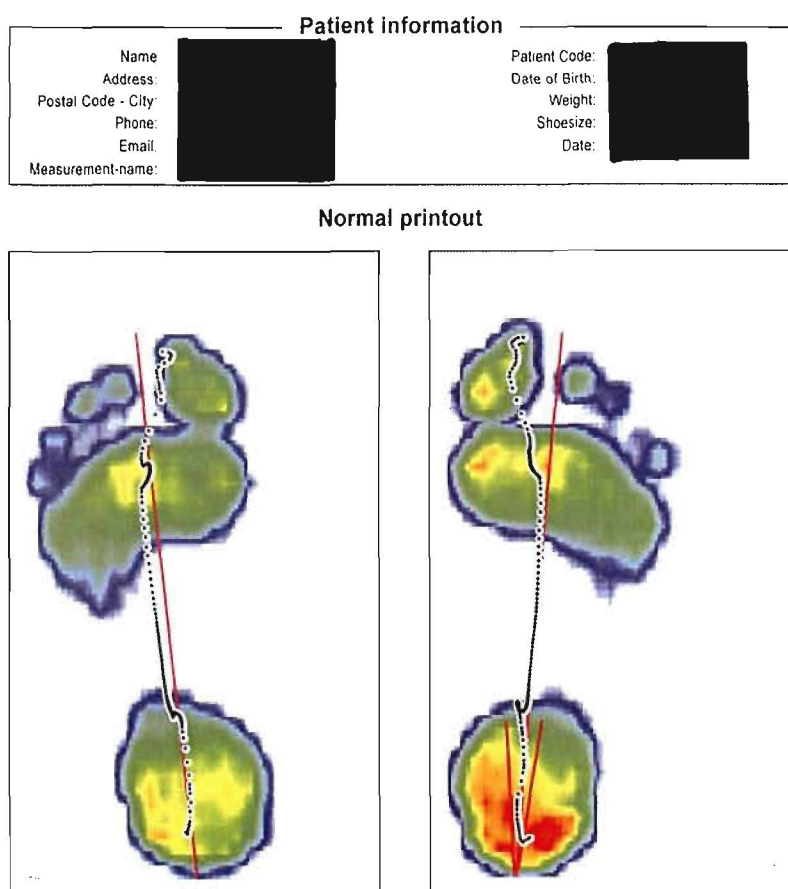


Figure 4.1: Foot analysis: Foot type and static and dynamic foot motion.[14]

3.3. Data analysis

Statistical analysis was carried out with the SPSS program.[16] Descriptive statistics (e.g. mean and standard deviations) and contingency tables were used to analyze the data. Effect sizes were used to decide the practical significance of the findings. A cut-off point of 0.8 (large effect) was set for practical significance between means.[17]

4. RESULTS

The purpose of this study is to investigate the effect of static and dynamic foot motion on the prevalence of MTSS in rugby union players in order to contribute to possible further studies in identifying risk factors and correcting these malalignments. Out a total of 91 players participating in this study, 13 of the U/19 squad were diagnosed with MTSS. Only the players with MTSS in both legs were examined in this study. Nine of the players had MTSS in both legs. According to Table 2, the majority of the subjects played flanker (17.1%), the second most played positions by the subjects was scrumhalf while 10.8%, and 9.9% of the players were locks and wings. Only 9% of the players wore shoe insertions. The mean length of players was 180.8cm and weight was 89.0kg.

Table 2: Demographic information of players: Playing positions, shoe insertions, age, length and weight of players

POSITION	% OF PLAYERS	N
Flanker	17.1	91
Scrumhalf	10.8	91
Wing	9.9	91
Lock	9.9	91
Prop	9	91
SHOE INSERTIONS	% OF PLAYERS	N
Yes	9	90
No	72.1	90
MEAN		n
AGE (years)	18	91
LENGTH (cm)	180.8	91
WEIGHT (kg)	89	91

Biomechanical characteristics contributing to MTSS

Figure 2 presents the foot analysis of the left foot. There were a total of 91 players who participated in the study. Nine of the players suffered from MTSS in both their legs. Of the players without MTSS, 48% had a supinated heel contact, whereas 75% of the players with MTSS had a supinated foot position on their left feet. During mid stance, 24% of the uninjured group had a neutral foot position on their left feet in relation to the 37.5% of the group with MTSS. Most of the players supinated during mid stance. During the propulsion phase of walking, 97.3% of the players without MTSS pronated in relation to the whole uninjured group. Only 1.3% of the uninjured group supinated during propulsion compared to the 0% of the injured group.

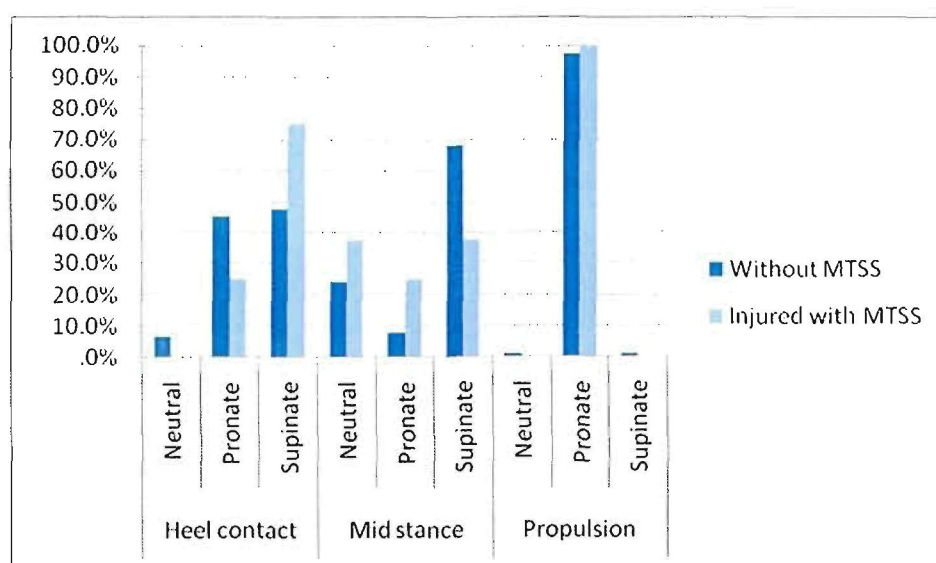


Figure 4.2: Analysis of the left foot: Heel contact, mid stance and propulsion

According to Figure 3, 65.3% of the players without MTSS had a supinated heel contact, where 75% of the players injured with MTSS had a supinated foot position on their right feet. During mid stance, 25% of the injured group had a neutral foot position on their right feet in relation to the 26.7% of the group without MTSS. Most of the players supinated during mid stance. During the propulsion phase of walking 97.3% of the players without MTSS pronated

in relation to the whole uninjured group. Only 1.3% of the uninjured group supinated during propulsion compared to the 0% of the injured group.

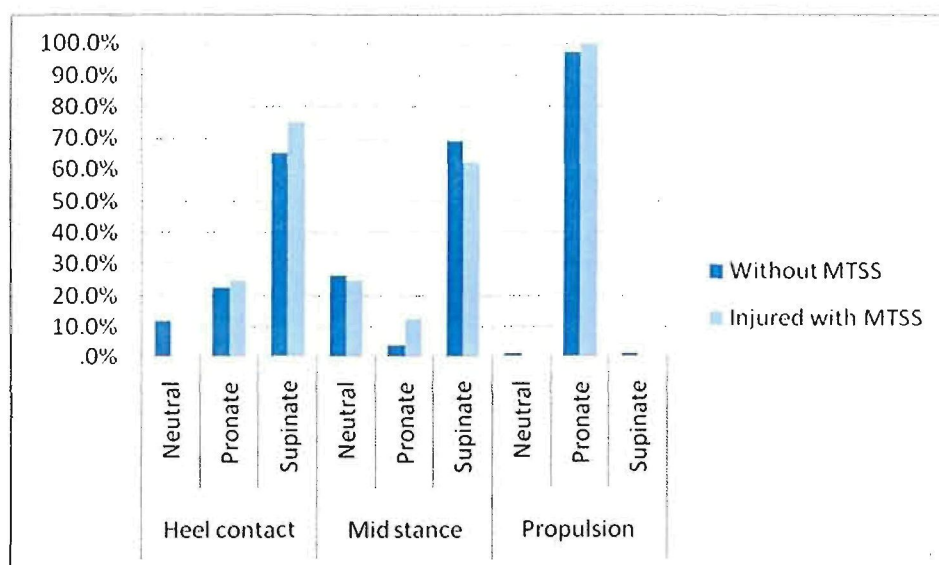


Figure 4.3: Analysis of the right foot: Heel contact, mid stance and propulsion

According to figure 4, 29.7% of the players without MTSS had a light flat left foot type, compared to the 44.4% of the players with MTSS. Of the players with MTSS, 11.1% had a flat right foot in relation with the 10.8% of players without MTSS. More than half of the players without MTSS had a normal right foot type (55.4%) in comparison with 66.7% of players with MTSS. None of the players with MTSS had a flat right high arched foot or a high arched left foot. Effect size was not analysed because of the small sample sizes in some of the cells.

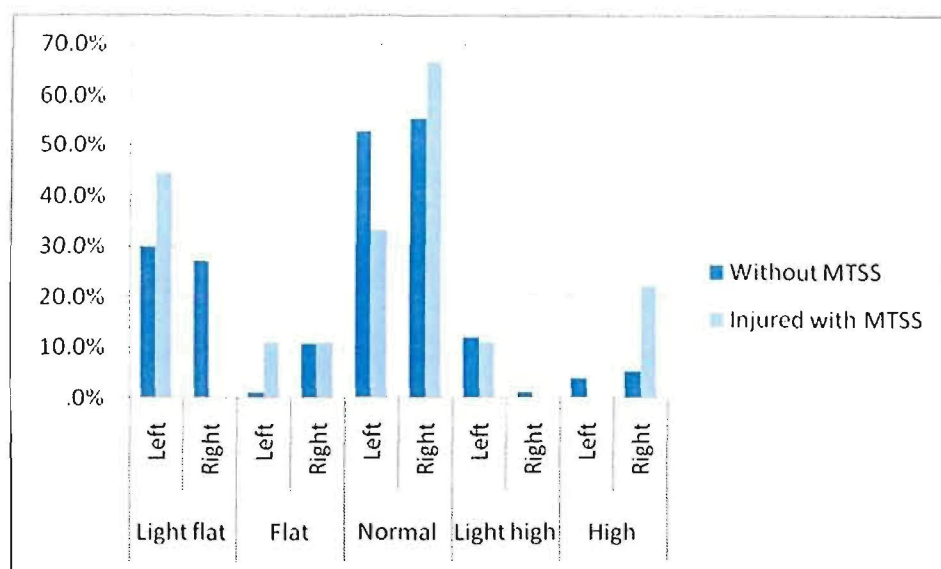


Figure 4.4: Foot type: Light flat, Flat, Normal, Light high and high arched feet

5. DISCUSSION

In this study selected biomechanical measurements were taken of the participating rugby union players to analyse the contribution of this risk factors on the prevalence of MTSS. Out a total of 91 players participating in this study, 13 of the U/19 squad were diagnosed with MTSS. Only the players with MTSS in both legs were examined in this study. Nine of the players had MTSS in both legs. According to Table 1, the majority of the subjects played flanker (17.1%), the second most played positions by the subjects was scrumhalf while 10.8%, and 9.9% of the players were locks and wings. Only 9% of the players wore shoe insertions. The mean length of players was 180.78cm and weight was 89.0kg.

During heel contact the foot is suppose to be in a supinated position.[9] Of the players without MTSS, 48% had a supinated heel contact on their left foot, compared to 75% of the players with MTSS. Players without MTSS had a 65.3% supinated heel contact, where 75% of the players injured with MTSS had a supinated foot position on their right feet

During mid stance the foot should be in a neutral position.[9] During mid stance 24% of the uninjured group had a neutral foot position on their left feet in relation to the 37.5% of the group with MTSS. Most of the players supinated during mid stance. During mid stance 25% of the injured group had a neutral foot position on their right feet in relation to the 26.7% of the group without MTSS.

At the propulsion phase, the foot should be in the more stable, supinated position.[9] During the propulsion phase of walking 97.3% of the players without MTSS pronated on both their feet in relation to the whole uninjured group

A total of 29.7% of the players without MTSS had a light flat left foot type, compared to the 44.4% of the players with MTSS. Of the players with MTSS, 11.1% had a flat right foot in relation to the 10.8% of players without MTSS. More than half of the players without MTSS had a normal right foot type (55.4%) in comparison with 66.7% of players with MTSS. None of the players with MTSS had a flat high arched right foot or a high arched left foot. Effect size was not analysed because of the small sample sizes in some of the cells.

It has been suggested that high arch feet are inflexible, while flat feet are hyper mobile and susceptible to a large degree of pronation.[5] The literature is contradictory regarding the relationship between foot structure and exercise-related overuse injuries.[9]. Cowan *et al.*[6] suggest that a greater percentage of athletic injuries occur with people with flat feet. Cowan *et al.* report an increase in exercise related injuries with increased arch height in US Army recruits. According to Kaufman *et al.*,[7] subjects with either Pes cavus (high arched feet) or Pes planus (low arched feet/flat), measured statically and dynamically, have twice the incidence of stress fractures compared to those subjects with average foot height.

6. CONCLUSION

Not many studies have investigated the effect of intrinsic risk factors on the prevalence of MTSS in rugby union players. The purpose of this study was to investigate the effect of static

and dynamic foot motion on the prevalence of MTSS to assist coaches and the medical team in recognizing these factors in order to put preventative strategies in place.

More players without MTSS supinated at heel contact on both their feet, compared to the players with MTSS. Players without MTSS supinated more on both their feet during mid stance. A small percentage of players with and without MTSS supinated during the propulsion phase. More players without MTSS had a neutral right foot mid stance compared to players with MTSS who had a more neutral mid stance on their right foot. Players with MTSS pronated more with both their feet during propulsion.

More players with MTSS had a light flat foot, flat foot or a high arched foot than players without MTSS. Most of the players with MTSS had normal arched right foot type. None of the players with MTSS had either a light high right foot or a high arched left foot.

The conclusion can be made that players with MTSS had a more sufficient heel contact than players without MTSS. Neither group had a sufficient mid stance. Players with MTSS pronated mostly during the propulsion phase and mostly have flatter and higher arched feet than players without MTSS. Future studies should attempt to assess the influence of biomechanical malalignment on the rest of the lower extremities of rugby union players.

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5 Summary, Conclusion and Recommendations

-
1. SUMMARY
 2. CONCLUSIONS
 3. STUDY LIMITATIONS
 4. RECOMMENDATIONS
-

1. SUMMARY

The objectives of this study (Chapter 1) were to investigate the effect of selected anthropometric parameters, biomechanical malalignment and inflexibility on the incidence of MTSS within the U/19 squad of the North-West University Rugby Institute.

The review article (Chapter 2) focused on the intrinsic risk factors contributing to MTSS in rugby union players because of the lack in research available on intrinsic risk factors contributing to MTSS in rugby union players. Over the last few years there has been an increase in various musculoskeletal sport injuries, especially chronic overuse injuries, due to an increase in the duration as well as the intensity of exercise. Various risk factors, intrinsic and extrinsic, have been identified as the cause of these injuries. The literature has controversial views about the intrinsic risk factors contributing to lower limb injuries. Bony alignment of the extremities, flexibility deficits, calf tightness, leg length discrepancy, limb girth, muscle imbalance, postural stability, foot morphology and previous injury predispose athletes to develop overuse injuries. Several studies have reported a relation between limb

girth and lower extremity injury. Leg length discrepancies have been linked to excessive pronation and subsequent overuse injuries. The common view is that excessive pronation occurs on the side of the short leg. It has been suggested that high arch feet are inflexible, while flat feet are hyper mobile and susceptible to a large degree of pronation. The literature is contradictory regarding the relationship between foot structure and exercise-related overuse injuries. Most studies found no relation between flexibility and sport injuries because the relation between flexibility and injuries are more joint specific. This review highlights already identified intrinsic risk factors to help coaches and the medical team to have a complete understanding of the incidence, nature, severity, and causes of injuries in order to review the adequacy of their injury prevention, treatment and rehabilitation strategies

The first research article, *Selected components affecting the prevalence of MTSS in rugby union players: An analysis of anthropometrical and biomechanical parameters* is presented in Chapter 3. The players without MTSS had a smaller calf girth than players with MTSS. Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were leg length differences for both players with and without MTSS. Iliospinale and Trochanterion-Tibiale lateral length differences presented with the largest length difference. Players without MTSS presented with an overall more inflexible profile than those with MTSS. In the majority of studies, no relation was found between flexibility and sport injuries. Several studies reported an association between abnormal anatomical alignment and injury. Limitation of ankle dorsiflexion may be caused by a tight Gastrocnemius when the knee is extended, as the muscle spans two joints. Other causes for a paucity of movement of the ankle joint are a tight Soleus, tight capsular tissue or abnormal osseous formation of the ankle. A tight Soleus is relatively uncommon but will limit movement with the knee in flexion or extension, as the muscle only spans one joint. The evidence to suggest that the range of either dorsiflexion or plantar flexion plays a significant role in the aetiology of lower limb injuries is limited.

The second research article comprises Chapter 4: *The effect of static and dynamic foot motion and foot type on the prevalence of MTSS in Rugby Union Players*. The findings indicated that more players with MTSS supinated at heel contact on both their feet, compared to the players without MTSS. Players without MTSS supinated more on both their feet during mid stance. A small percentage of players with and without MTSS supinated during the propulsion phase. More players without MTSS had a neutral right foot mid stance compared to players with MTSS who had a more neutral mid stance on their right foot. Players with MTSS pronated more with both their feet during propulsion. More players with MTSS had a light flat foot, flat foot or a high arched foot than players without MTSS. Most of the players with MTSS had normal arched right foot type. None of the players with MTSS had either a light high right foot or a high arched left foot. It has been suggested that high arch feet are inflexible, while flat feet are hyper mobile and susceptible to a large degree of pronation. The literature is contradictory regarding the relationship between foot structure and exercise-related overuse injuries.

2. CONCLUSIONS

The conclusions that are drawn from this study are presented in accordance with the hypotheses set in Chapter 1.

Hypothesis 1:

MTSS is prevalent in university rugby players of the North-West University Rugby Institute. Anthropometrical parameters such as leg length discrepancies, abnormal leg lengths or breadths and limb girth and biomechanical malalignment and inflexibility cause an increase on the incidence of MTSS in university rugby players of the North-West University Rugby Institute.

Players with MTSS had a wider Bi-iliocrystal width than those without MTSS. There were leg length differences for both players with and without MTSS for Iliospinale,

Trochanterion-Tibiale lateral and Tibial lateral length. Iliospinale and Trochanterion-Tibiale lateral length differences presented with the largest length difference. This part of the hypothesis is accepted. Several studies reported an association between abnormal anatomical alignment and injury. This part of the hypothesis is accepted. The players without MTSS had a smaller calf girth than players with MTSS. Players without MTSS presented with an overall more inflexible profile than those without MTSS. The majority of studies showed no relation between flexibility and sport injuries. Hamstring tightness had a small effect. Gastrocnemius and Plantaris as well as Soleus and Popliteus and Bi-iliocrystal width presented with a medium effect. This part of the hypothesis is not accepted.

Hypothesis 2:

An insufficient static and dynamic foot motion and flat or high arched feet are the reasons for the increase on the prevalence of MTSS in university rugby players of the North-West University Rugby Institute.

During heel contact the foot is supposed to be in a supinated position. In mid stance the foot should be in a neutral position and during the propulsion phase the foot should be in the more stable, supinated position. More players without MTSS supinated at heel contact on both their feet, compared to the players with MTSS. Players without MTSS supinated more on both their feet during mid stance. A small percentage of players with and without MTSS supinated during the propulsion phase. More players without MTSS had a neutral right foot mid stance compared to players with MTSS who had a more neutral mid stance on their right foot. Players with MTSS pronated more with both their feet during propulsion. More players with MTSS had a light flat foot, flat foot or a high arched foot than players without MTSS. Most of the players with MTSS had normal right arched foot type. None of the players with MTSS had either a light high right foot or a high arched left foot. This part of the hypothesis is accepted based on the findings in the study.

3. STUDY LIMITATIONS

The limitations that were experienced during the study were the following:

1. The small sample size resulted in a loss of statistical power. A study where more clubs are used would have increased the number of subjects.
2. All the subjects recruited were from the same institution, namely the Rugby Institute of the North-West University, and the findings cannot be generalized to all U/19 rugby union players.

4. RECOMMENDATIONS

The limited research available on the contribution of intrinsic risk factors to rugby union players emphasizes the importance of research regarding this matter. Future studies should attempt to assess the influence of anthropometrical and biomechanical parameters over a complete season or more than one season. Larger sample sizes should be used, by including various clubs.

The inconsistency in the literature regarding potential risk factors for rugby injuries highlights the need for uniformity in the research data method collections and injury definition. Follow-up studies should be implemented to investigate the effectiveness of preventative strategies. Very few prospective studies have been published on injury rates in rugby, and a comparison between them is difficult because of differing definitions of injury and data collection methods.

Appendix A

Guidelines for Authors

British Journal of Sports Medicine

SCIENTIFIC RELIABILITY

1. **Abstract/summary** – does it reflect accurately what the paper says.
2. **Research question** – is it clearly defined and appropriately answered?
3. **Overall design of study** – is it adequate?
4. **Participants studied** – are they adequately described and their conditions defined?
5. **Methods** – are they adequately described? For randomized trials: CONSORT style?
Ethical?
6. **Results** – does it answer the research question? Credible? Well presented?
7. **Tables and figures** – useful? Is the quality good enough? Can some be eliminated?
Are the data correct in the tables?
8. **Interpretation and conclusions** – are they warranted by and sufficiently derived
from/focused on the data? Message clear?
9. **References** – are they up to date and relevant? Any glaring omissions?

MANUSCRIPT PREPARATION

Review articles

Review articles should provide concise in-depth reviews of both established and new areas in sports medicine.

Word count: up to 4000 words.

Research letters

Letters containing original research should be submitted via Bench>Press. They must be typed in double line spacing and are published online only. [Articles published online only are exactly the same as articles also published in print. They are edited and typeset, fully searchable and citable. They are treated exactly the same as "print" articles by indexing services such as PubMed.]

Coverletter

Your cover letter should inform the editor of any special considerations regarding your submission, including but not limited to:

1. Details of related papers published or submitted for publication.
2. Copies of related papers should be submitted as supplementary data to help the editor decide how to handle the matter.
3. Details of previous reviews of the submitted article.
4. The previous editor's and reviewers' comments should be submitted as supplementary data along with your responses to those comments. Editors encourage authors to submit these previous communications and doing so may expedite the review process.
5. Whether any of the material could be published as data supplements rather than in the print version of the article.

MANUSCRIPT FORMAT

Title page

The title page **must** contain the following information:

1. The title.
2. The name, postal address, e-mail, telephone, and fax numbers of the corresponding author.
3. The full names, institutions, city, and country of all co-authors.
4. Up to five keywords or phrases suitable for use in an index (it is recommended to use MeSH terms).
5. Word count - excluding title page, references, figures and tables.

Manuscript format

The manuscript format must be presented in the following order:

1. Title page
2. Abstract (or summary for case reports)
3. Main text (tables should be inserted where cited in the text; images must be uploaded as separate files)
4. Acknowledgments • Competing interests • Funding
5. References
6. Appendices

Do not use the automatic formatting features of your word processor such as endnotes, footnotes, headers, footers, boxes etc.

Provide appropriate headings and subheadings as in the journal. We use the following hierarchy: BOLD CAPS, bold lower case, Plain Text, *Italics*.

Cite illustrations in numerical order (fig 1, fig 2 etc) as they are first mentioned in the text.

Tables must be embedded where cited in the text.

Images must not be embedded in the text file, but submitted as individual files (view further details in [File Formats](#).)

Abstracts

Articles containing original data concerning the course (prognosis), cause (aetiology), diagnosis, treatment, prevention, or economic analysis of a clinical disorder or an intervention to improve the quality of healthcare must include a structured abstract of no longer than 250 words. The structured abstract should appear on the page following the title page, using the following headings and information.

Objective: State the main question or objective of the study and the major hypothesis tested, if any.

Design: Describe the design of the study, indicating, as appropriate, use of randomization, blinding, criterion standards for diagnostic tests, temporal direction (retrospective or prospective), and so on.

Setting: Indicate the study setting, including the level of clinical care (e.g., primary or tertiary, private practice or institutional).

Patients (or Participants): State selection procedures, entry criteria, and numbers of participants entering and finishing the study.

Interventions (or Assessment of Risk Factors): Describe essential features of any interventions, including their method and duration of administration. For observational studies, clearly outline the independent variables.

Main Outcome Measurements: The primary study outcome measures (dependent variables) should be indicated as planned before data collection began. If the hypothesis being reported was formulated during or after data collection, this fact should be clearly stated.

Results: Report the main findings of the study.

Conclusions: State only those conclusions of the study that are directly supported by data, along with their clinical application (avoiding overgeneralization) or whether additional study is required before the information should be used in usual clinical settings.

Please note: Equal emphasis must be given to positive and negative findings of equal scientific merit.

File naming convention

Where possible, please name your manuscript and image files as shown below. (Please note: the manuscript ID # appears at the top of each submission page as soon as you start your submission; author refers to the corresponding author's last name.)

1. Your manuscript file should be named as: yr_manuscript id number_author
(for example: 2005_001234_clark)

Your image file should be named as: yr_manuscript id number_F#
(for example: 2005_001234_F1)

Statistics

Statistical analyses must explain the methods used.

Guidelines on presenting statistics.

Statistical checklist.

Statistical advice for contributors (PDF).

Guidelines on RCTs: CONSORT, QUORUM, MOOSE, STARD, and Economic submissions

Abbreviations and symbols must be standard and SI units used throughout except for blood pressure values which are reported in mm Hg.

Whenever possible, drugs should be given their approved generic name. Where a proprietary (brand) name is used, it should begin with a capital letter.

Acronyms should be used sparingly and fully explained when first used.

View more [detailed style guidelines](#)

Black and white images (photographs, line drawings, graphs, pie charts etc.)

All black and white images should be saved and supplied as TIFF, GIF, EPS, PowerPoint or high quality JPEG files to a minimum of 300 dpi.

Further instructions on [converting your PowerPoint images](#).

Images should be mentioned in the text.

During the submission when you upload the figure files you should label them as Figure 1, Figure 2 etc.

Further assistance on [conversion of your images](#)

Color images

Please note: Do not submit color figures unless you are willing to pay the cost of publishing your figures in color. If you do not wish to pay the color charges please submit your figures in black and white.

Color images should be saved and supplied as TIFF, GIF, EPS, PowerPoint or high quality JPEG files to a minimum of 600 dpi. Color images should not exceed 2MB at a minimum resolution of 600 dpi. If you choose a higher resolution your image dimension should be

reduced accordingly to keep the file under 2MB.
NB. Scanners may automatically increase image size at a higher resolution.

Alternatively PowerPoint files can be saved as JPEG, GIF, or TIFF files and submitted as a standard image file. Images should be mentioned in the text. Further instructions on converting your PowerPoint images.

Images should be mentioned in the text.

During the submission when you upload the figure files you should label them as Figure 1, Figure 2 etc.

Please note: The journal charges for the cost of reproducing color images on all unsolicited articles. This charge is heavily subsidized by the journal and covers origination costs only. If an image is supplied as a composite figure that contains numerous parts (for example, fig 1A-D), the image will be considered as a single image, provided that all the parts are supplied within a single file that prints out at an overall size no larger than A4 (210 mm x 297 mm). The charge for color processing will be £100 +VAT for the figure. Parts of color images supplied as separate files will be charged at £100 + VAT for each file.

Care should be taken in planning composites because combining different images with widely varying colors can lead to contamination or loss of color and poor quality results. When submitting your manuscript, please ensure you include a name and address where the manuscript should be sent. If one is not included, the invoice will be sent to the corresponding author.

Further assistance on conversion of your images

Tables

Tables should be submitted in the same format as your article and embedded in the main body of the article. Please note: Bench>Press cannot accept Excel files. If your table(s) are in Excel, copy and paste them into the manuscript file (where cited is preferable). In extreme circumstances, Excel files can be uploaded as supplementary files; however, we advise against this as they will not be acceptable if your article is accepted for publication.

Tables should be self-explanatory, and the data they contain must not be duplicated in the text or figures.

Further assistance on [conversion of your tables](#)

Unacceptable file formats

Any file using OLE (Object Linking and Embedding) technology to display information or embed files, Bitmap (.bmp), PICT (.pict), Photoshop (.psd), Canvas (.cnv), CorelDRAW (.cdr); Excel (.xls); and locked or encrypted PDFs are not acceptable

REFERENCES

Authors are responsible for the accuracy of references cited: these should be checked against the original documents before the paper is submitted. It is vital that the references are styled correctly so that they may be hyperlinked.

More guidance on [editing references for optimum conversion on Bench>Press](#)

In the text

References must be numbered sequentially as they appear in the text. References cited in figures or tables (or in their legends and footnotes) should be numbered according to the place

in the text where that table or figure is first cited. Reference numbers in the text must be given in square brackets immediately after punctuation (with no word spacing) - for example,[6] not [6].

Where more than one reference is cited, separate by a comma - e.g. [1, 4, 39]. For sequences of consecutive numbers give all numbers without spaces - for example, [22-25]. References provided in this format are translated during the production process to superscript type, which act as hyperlinks from the text to the quoted references in electronic forms of the article.

In the reference list

References must be double spaced (numbered consecutively in the order in which they are mentioned in the text) in the [slightly modified] Vancouver style. Only papers published or in press should be included in the reference list. (Personal communications or unpublished data must be cited in parentheses in the text with the name(s) of the source(s) and the year. Authors should get permission from the source to cite unpublished data.)

Punctuation of references must follow the [slightly modified] Vancouver style:

12 Surname AB, Surname CD. Article title. *Journal abbreviation*. Year; **Vol**:Start page
End page.

Use one space only between words up to the year and then no spaces. The journal title should be in italic and abbreviated according to the style of Medline. If the journal is not listed in Medline then it should be written out in full.

Check journal abbreviations using PubMed.

List the names and initials of all authors if there are 3 or fewer; otherwise list the first 3 and add *et al*

Example references:

Journal

13 Koziol-McLain J, Brand D, Morgan D, *et al.* Measuring injury risk factors: question reliability in a statewide sample. *Inj Prev* 2000;**6**:148-50.

Chapter

in

book

14 Nagin D. General deterrence: a review of the empirical evidence. In: Blumstein A, Cohen J, Nagin D, eds. *Deterrence and incapacitation: estimating the effects of criminal sanctions on crime rates*. Washington, DC: National Academy of Sciences 1978:95-139.

Book

(personal author or authors) (all book references should have specific page numbers)

15 Howland J. Social norms and drunk driving countermeasures. In Graham JD, ed. *Preventing automobile injury: new findings from evaluative research*. Dover, MA: Auburn House Publishing Company 1988:163-96.

Abstract/supplement

16 Roxburgh J, Cooke RA, Deverall P, et al. Haemodynamic function of the carbomedics bileaflet prosthesis [abstract]. *Br Heart J* 1995;**73** (suppl 2):P37.

Electronic citations

Basically, websites are referenced with their URL and access date, and as much other information is given as is available. Access date is important, as websites can be updated and URLs change. The "date accessed" can be later than the acceptance date of the paper, and it can be just the month accessed. See the 9th edition of the AMA Manual of Style for further examples.

electronic journal articles: Morse SS. Factors in the emergency of infectious diseases. *Emerg Infect Dis* 1995 Jan-Mar;**1**(1). www.cdc.gov/nciod/EID/vol1no1/morse.htm (accessed 5 Jun 1998).

Use as much information as the author gives. The volume/number information in the URL

will take the user to the start of the individual document; ask the author to supply or confirm. Also ask authors to supply the date they accessed the file.

Online First

Each Online First article has a unique Digital Object Identifier (DOI). This should be included in all citations.

BEFORE the article has appeared in an issue use the citation format: Sabin MA, Ford AL, Holly JMP, Hunt LP, Crowne EC, Shield JPH. Characterisation of morbidity in a UK, hospital based, obesity clinic. *Arch Dis Child*. Published Online First: 24 October 2005. doi:10.1136/ad.2005.083485

AFTER the article has appeared in an issue use the citation format: Sabin MA, Ford AL, Holly JMP, Hunt LP, Crowne EC, Shield JPH. Characterisation of morbidity in a UK, hospital based, obesity clinic. *Arch Dis Child* 2006; 91:126-130 doi:10.1136/ad.2005.083485 [published Online First: 24 October 2005].

Electronic

Letters

Author. Title of letter. Journal name Online [eLetter] Date of publication. url eg: Krishnamoorthy KM, Dash PK. Novel approach to transseptal puncture. Heart Online [eLetter] 18 September 2001. <http://heart.bmjournals.com/cgi/eletters/86/5/e11#EL1>

Digital Object Identifiers (DOIs)

DOIs are a unique string created to identify a piece of intellectual property in an online environment; particularly useful for articles which have been published online before appearing in print (therefore the article has not yet been assigned the traditional volume, issue, and page number reference).

The DOI is a permanent identifier of all versions of an article, whether raw manuscript or edited proof, online or in print. Thus the DOI should ideally be included in the citation even if you want to cite a print version of an article.

How to cite articles before they have appeared in print

To cite an electronic article that has not yet appeared in print please use the following citation format:

1. Alwick K, Vronken M, de Mos T, *et al.* Cardiac risk factors: prospective cohort study. *Ann Rheum Dis*. Published Online First: 5 February 2004. doi:10.1136/ARD.2003.001234

How to cite articles once they have appeared in print

Once the article has been printed the citation should also include the traditional year, volume, and page numbers, as well as the DOI and original date of publication.

1. Vole P, Smith H, Brown N, *et al.* Treatments for malaria: randomised controlled trial. *Ann Rheum Dis* 2003;327:765-8 doi:10.1136/ARD.2003.001234 [published Online First: 5 February 2004].

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PLEASE NOTE: RESPONSIBILITY FOR THE ACCURACY AND COMPLETENESS OF REFERENCES RESTS ENTIRELY WITH THE AUTHORS.

Supplementary material

You may submit supplementary material which may support the submission and review of your article. This could include: papers in press elsewhere, published articles, appendices, etc.

Online only material

Additional figures and tables, methodology, references, video clips, raw data etc. may be published online only to supplement the printed article. If your paper exceeds the word count

you should consider if any of the article could be published online only as a "data supplement". These files will not be copyedited or typeset.

Bench>Press

All supplementary data files should be uploaded to Bench>Press using the supplementary file section. These files are not converted to PDF but will be provided to reviewers and editors in the format in which you supply them.

Appendix B

Recruitment Letter

INLIGTINGSBRIEF RAKENDE RUGBY-PROJEK

Geagte Rugbyspeler

Hierdie studie handel oor die effek van antropometriese parameters, biomeganiese wanbelyning en soepelheid van die onderste ledemate op die voorkoms van Mediale Tibiale Stres Sindroom by Rugbyspelers van die Noordwes- Universiteit se Rugby Instituut (Potchefstroomkampus). Die O/19-span (2006-seisoen) van NWU Rugby Instituut word hierby betrek.

Die voorkoms van Mediale tibiale stress sindroom (MTSS) of “Shints Splints” is van groot belang vir afrigters en mediese spesialiste aangesien dit ‘n groot rol speel by prestasie. Die doel van hierdie studie is om die risiko faktore te bepaal wat ‘n effek het op die voorkoms van MTSS om sodoende afrigters, biokinetikuste en sportwetenskaplikes van raad te bedien oor hoe om voorkomend op te tree. Die riskofaktore waarop gefokus word in hierdie studie, is verskeie antropometriese parameters, biomeganiese wanbelyning, en soepelheid van die onderste ledemate. Hierdie studie word onderneem deur die Skool vir Biokinetika, Rekreasie en Sportwetenskap (BRS) by die Noordwes Universiteit (Potchefstroom kampus).

Inligting rakende die studie

1. Die doel van hierdie studie is drieledig: (1) Om die effek van verskeie antropometriesse parameters, (2) biomeganiese wanbelying, en (3) soepelheid van die onderste ledemate op die voorkoms van MTSS te bepaal.
2. Beseringsgeskiedenis sal deur middel van 'n vraelys gemeet word.
3. Privaatheid en konfidensialiteit is essensieël. Geen speler se data sal individueel aand die PRI bekend gemaak word nie.
4. Die meetprosedure vereis dat die rugbyspeler in oefenklere en kaalvoet is.
5. Kuitomtrek, beenlengtes van die onderste ledemate (Iliospinale hoogte, Trochanterion-tibiale laterale hoogte en Tibiale laterale hoogte), beenbreedte (Bi-Iliocristale breedte), soepelheid (Heupfleksore, Hampese en Plantaarfleksore) en voetmorfologie (voethoogte en breedte) gaan geneem word.
6. U samewerking en ondersteuning in die verband sal waardeer word
7. Vir enige verdere navae, kontak Hannalize Horn by 299 1824.

Byvoorbaat dankie.

Hannalize Horn
(Biokinetikus & M-student)

Professor Hans de Ridder
(Studieleier: Skool vir BRS, NWU)

Dr. Hanlie Moss
(Hulpleier: Skool vir BRS, NWU)

Appendix C

Informed Consent

INGELIGTE TOESTEMMING

Ek, die ondergetekende _____ (volle name)
het die voorafgaande gegewens in verband met die projek hierbo genoem gelees en ook die mondelinge weergawe daarvan aangehoor en ek verklaar dat ek dit verstaan. Ek was die geleentheid gegun om tersaaklike aspekte van die projek met die projekteier te bespreek en ek verklaar hiermee dat ek vrywillig aan die projek deelneem. Ek gee hiermee my toestemming om as deelnemer in bogenoemde projek op te tree.

Ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my, in die loop van die projek mag ontstaan.

Ek onderneem verder om geen eise teen die Universiteit in te stel weens skade of persoonlikheidsnadeel wat ek weens die projek/proef of die toedoen van ander proefpersone mag ly nie, tensy dit aan die nalatigheid van die Universiteit, sy werknemers of studente te wyte is.

(Handtekening van proefpersoon)

Onderteken te _____ op _____.

GETUIES

1. _____
2. _____

Onderteken te _____ op _____.

Vir alle navorsing en intervensies op deelnemers onder die ouderdom van 21 jaar is die skriftelike toestemming van die ouer of wettige voog nodig.

Hiermee gee ek _____ (volle name)
ouer of wettige voog van die deelnemer hierbo genoem toestemming dat hy/sy aan hierdie projek mag deelneem en ek vrywaar hiermee die Universiteit asook enige werknemer of student van die Universiteit, teen enige aanspreeklikheid wat teenoor my in die loop van die projek mag ontstaan tensy sodanige besering, skade of dood veroorsaak is deur die nalatigheid van die Universiteit, sy personeel of sy studente.

Handtekening: _____ Datum: _____

Verwantskap: _____

Appendix D

Assessment Form

ANTHROPOMETRICAL/FLEXIBILITY ASSESSMENT FORM

	LEFT			RIGHT		
	TRAIL			TRAIL		
	1	2	3	1	2	3
1. Girth (cm)						
· Calf						
2. Length & Height measurements (cm)						
· Iliospinale height						
· Trochanterion-tibiale laterale						
· Tibiale lateral						
· Navicular height						
·						
3. Breadth measurement (cm)						
· Bi-iliocrystal						
·						
4. Flexibility measurements						
· Thomas test (Hip Flexor Muscles)						
· Sartorius						
· Tensor Fasciae Latae						
· Rectus Femoris						
· Iliopsoas						
· Hamstring length						
· Plantar flexors - Soleus and Popliteus (90)						
· Plantar flexors - Gastrocnemius and Plantaris						

Appendix E

Injury History Questionnaire

LOWER EXTREMITY INJURIES

SITE	DESCRIPTION	LEFT / RIGHT	CHRONIC / ACUTE	PREVIOUS INJURY (YEAR/REHAB)	CURRENT INJURY (REHAB)	SEVERITY
HIP	LIGAMENTS	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	FRACTURE					MILD (If missed one week)
		RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
UPPER LEG	HAMSTRINGS	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	GROIN					MILD (If missed one week)
	QUADRICEPS	RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
KNEE	LIGAMENTS	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	PATELLA					MILD (If missed one week)
	MENISCIS	RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
LOWER LEG	"SHINTS SPLINTS"	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	CALF MUSCLE					MILD (If missed one week)
		RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
ANKLE	LIGAMENTS	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	FRACTURE					MILD (If missed one week)
		RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
FOOT	CALCANEUS	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
	FRACTURE					MILD (If missed one week)
		RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)
TOES	FRACTURE	LEFT	ACUTE			MINOR (If Able To Return To Game Or Training In Which Injured)
						MILD (If missed one week)
		RIGHT	CHRONIC			MODERATE (If missed two weeks)
						SEVERE (If missed more than 2 weeks)

Appendix F

Demographic/Personal Information

DEMOGRAPHIC INFORMATION

DATE: ____ / ____ / 2007 CODE: _____

DATE OF BIRTH: ____ / ____ / 19__

POSITION:	PROP(1&3)	HOOKE(2)	LOCK(4&5)	FLANKER(6&7)	8TH MAN(8)	SCRUMHALF(9)
	FLYHALF(10)	WING(11&14)	CENTER(12&13)	FULLBACK(15)		
DOMINANT SIDE:	LEFT	RIGHT				
SHOE INSERSIONS:	YES	NO				
WEIGHT (kg)						
HEIGHT (cm)						