The contribution of selected biomechanical, postural and anthropometrical factors on the nature and incidence of injuries in rugby union players

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DECLARATION

This dissertation is submitted in article format and includes a review article (Chapter 2) on intrinsic risk factors contributing to sport injuries as well as a research article (Chapter 3) entitled "Injury incidence and selected biomechanical, postural and anthropometrical characteristics contributing to musculoskeletal injuries in rugby union players". The co-authors of these articles, Dr. S.J. Moss and Ms S. Stroebel, hereby give permission to the candidate, Ms E.J. Bruwer, to include the two articles as part of a Masters dissertation. The contribution (advisory and supportive) of these co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as partial fulfilment of the requirements for the M.A. degree in Human Movement Science within the School for Biokinetics, Recreation and Sport Science in the Faculty of Health Sciences at the North-West University (Potchefstroom Campus).

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SUMMARY

Background

The incidence of injuries in rugby union has increased on both professional and amateur levels since the introduction of professionalism in 1995. Although rugby union is a body contact sport with an expected high injury rate, limited research has been done regarding the postural and biomechanical characteristics of the players and the effect these variables have on the incidence and nature of rugby union injuries. Large body size is a significant predictor of success in rugby union and the body mass and mesomorphy of players has increased over the last years. It has, however, not been thoroughly investigated whether changes in body composition have any effect on the incidence of rugby union injuries. Intrinsic risk factors that have been identified to contribute to rugby union injuries are hypermobility of joints, lack of dynamic mobility and core stability, previous injuries, aerobic and anaerobic fitness as well as the personalities and characteristics of players which affect their on-field awareness. The findings of studies investigating the relation between player characteristics and rugby union injuries are inconsistent because of the differences in player characteristics under investigation and playing conditions, different research methodologies used as well as differences in the way injury is defined. Therefore, the need exists to determine the differences in the biomechanical, postural and anthropometrical characteristics of injured and uninjured rugby union players by making use of a prospective design and a standardized injury definition.

Objectives

The objectives of this study were firstly, to determine the incidence and nature of injuries among U/21 rugby union players at the Rugby Institute (RI) of the North-West University (NWU) (South Africa) and secondly, to determine which of the selected biomechanical, postural and anthropometrical characteristics contributed to musculoskeletal injuries obtained during the first five months of the 2005 season.

Methods

A prospective once-off subject availability study was performed that included forty-nine U/21-rugby union players of the RI of the NWU. Biomechanical, postural and anthropometrical assessments were performed on all subjects before the start of the 2005-season. All the injuries sustained during the first five months of the 2005 season were recorded by means of a validated rugby union injury report questionnaire. A stepwise discriminant analysis identified the independent variables that discriminated mostly between the players with and without injuries within the different body regions. Back-classification by means of the "Jack-knife method" determined whether the independent characteristics that were selected to contribute to injuries was valid and the effect size, I ("better than chance"), was then determined, with I > 0.3 accepted as practically significant.

Results

A total of 66 injuries with an injury rate of 8.6/1000 training hours and 61.8/1000 game hours were reported. Severe injuries accounted for 53% of all injuries to forward players with the ankle being the most injured anatomical region. In the backline severe injuries accounted for 11% with the shoulder being the most injured region. The tackle was the phase of play in which most injuries occurred. The statistical analysis identified uneven hips, pronated feet, tight hamstrings, anatomical leg length differences, gait pronation and a tall stature to be practically significant predictors for lower extremity injuries (I>0.3). No practical significance was obtained for the selected biomechanical, postural and anthropometrical characteristics related to shoulder girdle as well as back or spine injuries.

Conclusions

The conclusions that can be drawn from this study are that the injury incidence of rugby union players of the U/21-squad of the RI of the NWU is high in comparison with those of other club level players and that postural and biomechanical imbalances of the lower extremities may increase the risk for injury in this area.

Keywords

Rugby union injuries; intrinsic risk factors; biomechanical abnormalities; postural faults; body composition

OPSOMMING

Agtergrond

Die voorkoms van rugbybeserings het, na die instelling van rugby as 'n beroepsport in 1995, in beide professionele- en amateurrugbyspelers toegeneem. Alhoewel 'n hoë beseringsinsidensie in 'n kontaksport soos rugby verwag word, is daar steeds beperkte navorsing beskikbaar rakende die biomeganiese- en postuureienskappe van spelers en die bydrae wat hierdie eienskappe tot die voorkoms en aard van beserings lewer. Die liggaamsmassa en mesomorfie van rugbyspelers het oor die jare toegeneem omdat liggaamsgrootte 'n baie belangrike rol in die sukses van rugby speel. Die effek van veranderinge in liggaamsamestelling op die beseringsinsidensie van rugbyspelers moet egter nog deeglik ondersoek word. Intrinsieke risikofaktore wat reeds geïdentifiseer is as bydraend tot rugbybeserings, sluit in: hipermobiele gewrigte, tekortkominge in dinamiese mobiliteit en kernstabiliteit, 'n geskiedenis van vorige beserings, aërobiese- en anaërobiese fiksheid, asook die persoonlikhede en karaktereienskappe van spelers wat hul bewustheid vir risiko's tydens spelsituasies beïnvloed. Die bevindinge van studies wat die verwantskappe tussen eienskappe van spelers en beserings in rugby ondersoek, is egter teenstrydig as gevolg van verskille in die spelereienskappe wat getoets word en die toestande waarin die studies plaasvind, verskille in die definisies wat gebruik word om beserings te beskryf, asook variasies in die navorsingsmetodologie wat gebruik word. Die doel van hierdie studie is om die biomeganiese, postuur en antropometriese eienskappe van beseerde en onbeseerde rugbyspelers te identifiseer om sodoende te bepaal watter intrinsieke faktore 'n potensiële risiko vir beserings in rugby inhou deur gebruik te maak van 'n prospektiewe studie-ontwerp en 'n gestandaardiseerde definisie van besering.

Doelstellings

Die doelstellings van hierdie studie was eerstens om die voorkoms en aard van beserings van die O/21-rugbyspelers van die Rugby Instituut (RI) van die Noordwes-Universiteit (NWU) (Suid Afrika) te bepaal en tweedens om te bepaal watter biomeganiese, postuur en antropometriese eienskappe 'n bydrae lewer tot muskulo-skeletale beserings wat gedurende die eerste vyf maande van die 2005 seisoen opgedoen is.

Metode

'n Prospektiewe eenmalige proefpersoon beskikbaarheidstudie, wat nege-en-veertig O/21-rugbyspelers van die RI van die NWU insluit, is uitgevoer. Alle spelers het voor die begin van die 2005-seisoen biomeganiese, postuur en antropometriese metings ondergaan. 'n Gevalideerde rugbybeseringsvraelys is gebruik om al die beserings wat gedurende die eerste vyf maande van die 2005-seisoen opgedoen is te rapporteer. 'n Stapsgewyse diskriminant analise het die onafhanklike veranderlikes wat tussen beseerde en onbeseerde spelers onderskei het, geïdentifiseer. Terugklassifikasie is deur middel van die "Jack-knife-metode" gedoen om te bepaal of die onafhanklike veranderlikes wat geselekteer is om 'n bydrae tot beserings te lewer, geldig is. Die effekgrootte ("better than chance") het die praktiese betekenisvolheid van geselekteerde veranderlikes bepaal ($I > 0.3$).

Resultate

'n Totaal van 66 beserings met 'n beseringsvoorkoms van 8.6 beserings per 1000 oefenure en 61.8 per 1000 wedstrydure is gerapporteer. Ernstige beserings het onderskeidelik 53% en 11% van die totale hoeveelheid beserings in die voor- en agterspelers uitgemaak. Die enkelgewrig was die mees beseerde anatomiese deel onder voorspelers en die agterspelers het die meeste beserings aan die skouergordel opgedoen. Veranderlikes wat deur die statistiese analise geïdentifiseer is om 'n bydrae tot besering in die onderste ledemate te lewer ($I > 0.3$) sluit is: onewe heupe, voetpronasie, stywe hampese, anatomiese beenlengteverskille, pronasie tydens draf en 'n langer lengte. Geen van die biomeganiese-, postuur- en antropometriese veranderlikes het 'n prakties betekenisvolle bydrae tot skouergordelbeserings en rugbeserings gelewer nie.

Gevolgtrekking

Die gevolgtrekking wat uit hierdie studie gemaak kan word, is dat die voorkoms van beserings van die O/21-span van die RI van die NWU hoog is in vergelyking met die beseringsvoorkoms ander klubspanne en dat sekere postuur en biomeganiese wanbalanse in die onderste ledemate die risiko vir beserings in hierdie area kan verhoog.

Sleutelterme

Rugbybeserings; intrinsieke risikofaktore; biomeganiese abnormaliteite; postuur wanbalanse; liggaamsamestelling

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LIST OF ABBREVIATIONS

A	ACL	= Anterior cruciate ligament
	AC joint	= Acromioclavicular joint
B	BMI	= Body mass index (kg/m^2)
C	cm	= centimetre
D	d	= delta (effect size)
I	I	= Effect size index ("better than chance")
	ISAK	= International Society for the advancement of Kinanthropometry
K	kg	= kilogram
M	m	= meter
	mm	= millimetre
N	N	= Number of subjects
	NWU	= North-West University
R	RI	= Rugby Institute
S	SD	= Standard deviation
U	U/21	= Under 21

CHAPTER 1

Problem statement and aim of the study

- INTRODUCTION
- PROBLEM STATEMENT
- OBJECTIVES
- HYPOTHESES
- STRUCTURE OF THE DISSERTATION
- REFERENCES

1.1 INTRODUCTION

Rugby union is a dangerous body contact sport that enjoys worldwide popularity, with the major rugby-playing countries being the United Kingdom, Australia, New Zealand and South Africa (Quarrie *et al.,* 2001:157; Nicholas, 1997:376; Noakes & Du Plessis, 1996:3). The increased incidence of rugby union injuries is a growing concern in most rugby playing countries (Brooks *et al.,* 2005:757; Barthgate *et al.*, 2002:265; Holtzhauzen, 2001:1; McManus, 2000:342; Targett, 1997:280).

The frequent powerful contact in rugby imposes high intensity extrinsic forces on the body which potentially exposes players to a large number of injuries (Bottini *et al.*, 2000:94; Bird et al., 1998:319). Epidemiological studies on injuries in rugby union, of which many were retrospective, used different methods of data collection as well as injury definition (Bird *et al.*, 1998:319; Targett, 1997:280). This makes comparison between study outcome measures impossible. A few studies investigated possible risk factors that may contribute to injuries and usually only players who sustained injuries were screened for associated risk factors (Waller *et al.*, 1994:223). Previously identified risk factors are also mostly extrinsic factors such as level of play, years of rugby participation and the playing position (Quarrie *et al.,* 2001:157).

Need exists for research on the relationship of intrinsic risk factors to the incidence of rugby union injuries. The identification of intrinsic factors contributing to injuries will enable researchers to develop successful preventative programmes. These programmes could be incorporated in off-season training to decrease the incidence of injuries.

1.2 PROBLEM STATEMENT

Since the introduction of professionalism in 1995, injuries in rugby union have increased on professional as well as amateur levels (Bathgate *et al.*, 2002:265; Garraway *et al.*, 2000:351). The proportion of rugby union players in the Scottish Borders who were injured almost doubled from 27% in the 1993-1994 season to 47% in the 1997-1998 season (Garraway, 2000:350). The overall injury rate recorded during the 1995 Rugby World Cup was 32 injuries per 1000 player hours (Jakoet & Noakes, 1998:46), while during the 2003 Rugby World Cup the overall injury rate increased to 97.9 injuries per 1000 player hours (Best & McIntosh, 2005:812). A possible reason for the lower injury rate during the 1995 Rugby World Cup could be the introduction of the professional era after the 1995 World Cup. The highest injury rate reported in rugby union to date was that of one Super 12 squad during the 1997 Super 12 competition, which was 150 injuries per 1000 player hours (Holtzhauzen, 2001:1). A report by Jakoet and Noakes (1998:48) indicated that the frequency of injury in international rugby is less than at lower levels of the game, suggesting that fitness and experience reduce the injury rate in rugby players significantly, however, a study by Bathgate *et al.* (2002:265) on elite Australian rugby union players found contradicting results.

The contact phases of rugby implicate extrinsic forces which are commonly associated with soft-tissue contusions, joint strains, fractures, dislocations, lacerations, grazes as well as head or spinal injuries (Gerrard *et al.,* 1994:232). Studies recording injuries among professional rugby union players indicate that the lower limbs were the most injured body region, particularly the knee and ankle and these were mainly ligament sprains and musculotendinous tears (Junge *et al.*, 2004:169; Bird *et al.*, 1998:319). A low incidence of chronic overuse-type injuries is usually reported (Holtzhausen, 2001:8), however, Hatting (2003:181) reported a high incidence of chronic overuse type-injuries in a study on rugby union players between the ages 15 and 20 years in the North West Province of South Africa. Most injuries in modern rugby occur during the tackle phase, either tackling or being tackled. Loose play or open play is the second most common cause of injury, closely followed by the ruck and maul (Bathgate *et al.,* 2002:267; Holtzhausen, 2001:9; Bottoni *et al.,* 2000:96; Jakoet & Noakes, 1998:46; Addley & Farren, 1988:23). According to Bathgate *et al.* (2002:266), the lock position was the most injured forward player and the flyhalf the most injured backline player. In the 1995 World Cup the loose forwards were the most commonly injured players, followed by the scrumhalf and flyhalf. A study recording injuries during the 1997 Super-12 competition showed that the eighth man was the most commonly injured position (Targett, 1997:281), while the hooker, fullback and center were the most commonly injured during the 1999 Super 12 competition (Holtzhausen, 2001:11). It is evident from the above studies that controversy exists in the relation between player position and rate of injury. Multiple studies from various countries have reported a higher incidence of total injuries earlier in the playing season of rugby union (Orchard, 2002:419; Alsop, 2000:106; Upton, 1996:533; Clark *et al.,* 1990:560). Two of the many reasons for the tendency that rugby injury usually declines as the season progresses, are lack of preparation and match fitness at the beginning of the season (Roux *et al.*, 1987:308).

Many epidemiological studies have been performed to describe injury incidence as well as injury patterns in rugby union (Brooks *et al.,* 2005:757; Brooks *et al.,* 2005:767; Best, 2003:812; Bathgate, 2002:265; Holtzhausen, 2001:1; Garraway, 2000:348; Bottini *et al.,* 2000:94; Alsop *et al.,* 2000:97; Bird *et al.,* 1998:319; Jakoet & Noakes, 1998:45; Targett, 1998:280; Gerrard *et al.,* 1994:229; Clark *et al.,* 1990:559; Addely & Farren, 1988:22; Roux *et al.,* 1987:307). However, only a few studies focused on the aetiology and mechanism of injury to identify risk factors contributing to injuries and eventually the compilation of preventative programmes (Steward, 2004:457; Babic *et al.,* 2001:392; Lee *et al.,* 2001:412; Quarrie *et al.,* 2001:157). In their book "Rugby without risk" Noakes and Du Plessis (1996:97) summarized findings from various studies on risk factors in modern rugby union. The six major risk factors identified from these studies were an older age, participation at a higher level, match play, the fullbacks, wings as well as eighth men were identified as the most injured player positions, tackling, being tackled and the ruck and maul as the most dangerous phases of play and most injuries occurred during the early part of the season as well as the time after the mid-season break. These previously identified risk factors are mostly extrinsic factors of which the risk can only be reduced by means of more effective pre-season training as well as alterations to the laws of the game (Quarrie *et al.,* 2001:158). As early as 1954, O'Connell (as quoted by Noakes & Du Plessis, 1996:25) proposed that the risk of injury could be reduced by superior pre-season training, the use of protective devices for the head, ankles, shoulders and collar-bones, the use of flexible corner flags and padded goalposts and ensuring that injured players were fully fit before returning to the game. The question still remains whether the correction of intrinsic risk factors by means of exercise programmes and orthotic devices could lead to further reduction of rugby union injuries. There is, therefore, a tremendous need for research that identifies intrinsic risk factors in rugby union players.

Intrinsic risk factors for sport injuries are physical characteristics such as somatotype, joint mobility, muscle tightness/weaknesses, ligamentous instability, anatomical abnormalities (malalignments), motor abilities and psychological profile, which includes motivation, risk taking and stress coping (Parkkari *et al.,* 2001:989; Quarrie *et al.*, 2001:157). Theories to explain the increase in rugby union injuries as a result of intrinsic characteristics of players are firstly that the BMI, body mass and mesomorphy of rugby union players have increased over the last years because large body size is such a significant predictor of success in rugby union (Olds, 2001:258). This implicates that play is faster, players are bigger and fitter and tackling is harder. Secondly, at elite levels the ball is in play for longer periods, increasing the number of tackles a player is exposed to, which could result in injury (Bathgate *et al.,* 2002:268; Jakoet & Noakes, 1998:48). Other intrinsic risk factors that have been identified to contribute to injuries in rugby union players are hypermobility of joints (Steward, 2004:457); shortcomings in some biomechanical aspects of a rugby union player such as core stability and dynamic mobility (Hattingh, 2003:181); previous injuries, stress, aerobic and anaerobic performance and cigarette smoking (Quarrie *et al.*, 2001:157). Lee *et al.* (2001:412) stated that the personalities and characteristics of players, which affect the risk that players take in game situations, as well as their awareness on the field play a role in sustaining injuries.

Identifying intrinsic risk factors in any athlete enables the athlete to make use of professionals to compile rehabilitative and corrective exercise programmes and prescribe proper orthotic devices. Given the limited information available on intrinsic risk factors for rugby union injuries, the question to be answered in this study is: What is the injury incidence and nature of the U/21 rugby union squad of the Rugby Institute (RI) of the North-West University (NWU) and which of the measured biomechanical, postural and anthropometrical characteristics can be identified as possible intrinsic risk factors for injuries sustained?

The results obtained from this study will help to identify the possible intrinsic risk factors that contribute to rugby union injuries. This will assist Biokineticists in evaluating the rugby players during the pre-season in order to compile corrective and preventative programmes to reduce injuries in rugby union players.

1.3 OBJECTIVES

- To determine the incidence and nature of injuries among U/21 rugby union players at the RI of the NWU.

- To determine which of the biomechanical, postural and anthropometrical characteristics will contribute to musculoskeletal injuries of the U/21 rugby union players at the RI of the NWU.

1.4 HYPOTHESES

- The injury incidence of the U/21 rugby union squad of the RI of the NWU is similar to those of other amateur teams, but lower than elite professional teams observed in the literature and the nature of injuries are varied.

- Various biomechanical, postural and anthropometrical characteristics of U/21 rugby union players of the RI of the NWU will contribute to musculoskeletal injuries in different body regions.

1.5 STRUCTURE OF THE DISSERTATION

This dissertation is presented in article format and consists of four chapters. Chapter 1 includes the introduction, problem statement, objectives and hypotheses of this study. This will be followed by a review article (Chapter 2): "Selected intrinsic risk factors contributing to musculoskeletal injuries in sport: a review". The review article will be submitted to The British Journal of Sports Medicine and the focus of this article will be on intrinsic risk factors contributing to sport injuries in general, because of the lack of research available on intrinsic risk factors related to rugby union injuries. The research article (Chapter 3) investigates the injury incidence and patterns of rugby union players of the U/21 squad of the RI at the NWU. Selected biomechanical, postural and anthropometrical characteristics of players that may be identified as possible risk factors contributing to injuries sustained during the first five months of the 2005 season are also described in Chapter 3. The research article will be submitted to The British Journal of Sports Medicine. These articles were written according to the instructions to authors of the journal to which the article will be submitted. The results of the study are summarised in Chapter 4, together with the conclusion and recommendations for future research. A structure of the dissertation is shown in Figure 1.

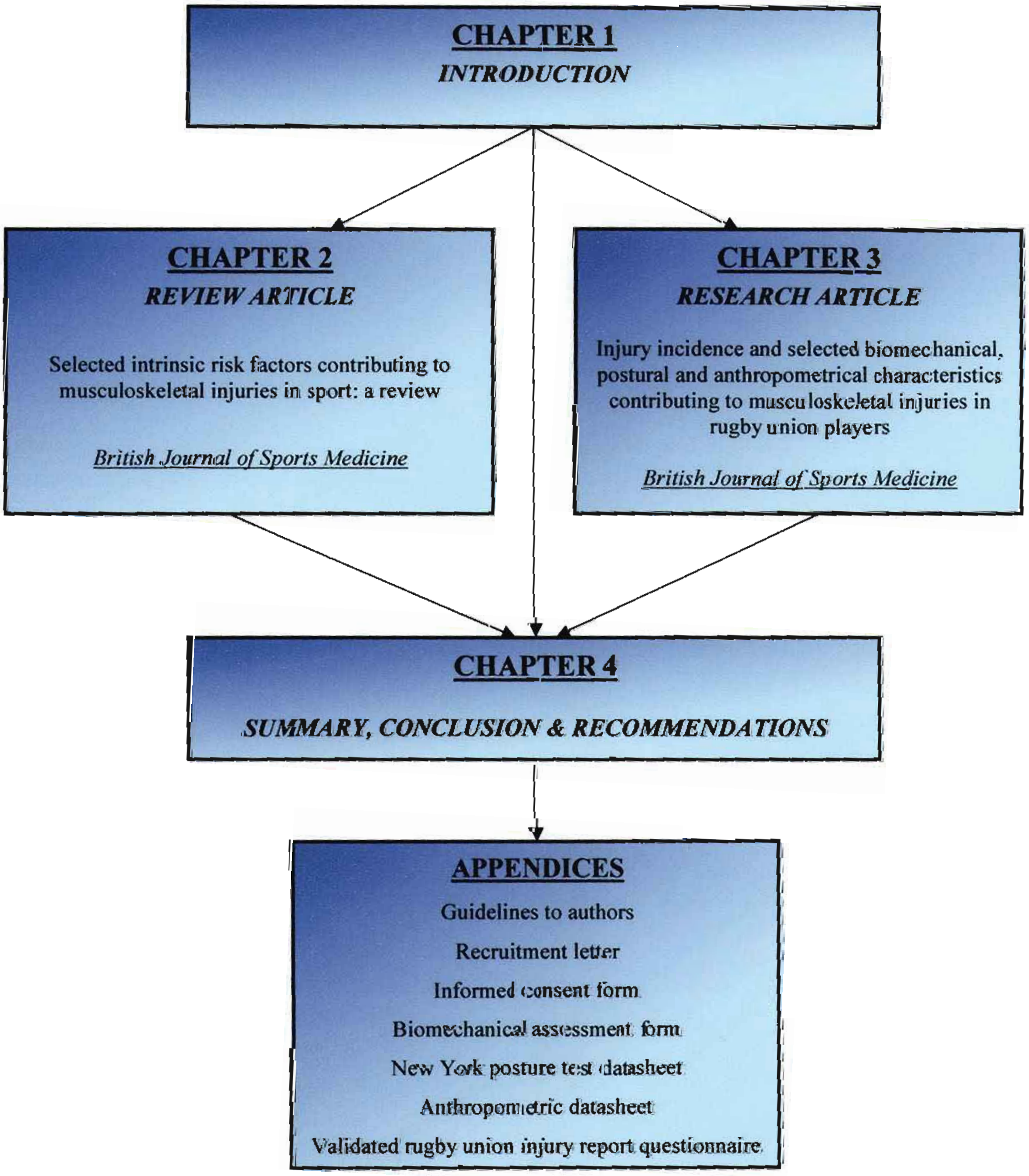

Figure 1: A schematic presentation of the structure of this dissertation

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CHAPTER 2

Selected intrinsic risk factors contributing to musculoskeletal injuries in sport: a review

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ABSTRACT

Considerable concern has been expressed in recent years over the increasing number of musculoskeletal injuries in the athletic population. This review highlights some already identified intrinsic risk factors for sport injuries to provide athletes, coaches, sport scientists and different specialists in sport medicine with knowledge to identify intrinsic risk factors for sport injuries and explains how biomechanical, postural and anthropometrical characteristics modify injury risk. Although controversial literature exists, leg length discrepancy, excessive pronation, knee genu valgum and larger Q-angles seem to be the malalignment parameters mostly connected to lower extremity injuries in the athletic population. Muscle strength imbalances and poor flexibility in the quadriceps, hamstring and gastrocnemius muscles are significant risk factors for lower extremity injuries. In the shoulder girdle, muscle strength imbalances result in altered neuromuscular control and abnormal movement patterns. Postural characteristics such as an increased lumbar lordosis have been related to hamstring strains and a forward head, forward shoulders and thoracic kyphosis increases the risk of obtaining shoulder injuries. An older age has been related to injuries in the athletic population, however, the physical demands of the sport play a major role in the risk for injury in different age groups. The findings of studies investigating the relation between player characteristics and sport injuries are, however, inconsistent because of the differences in the physical demands of the various sporting activities, different playing conditions, differences in player characteristics under investigation, different research methodologies used as well as differences in the way injury is defined. To compile successful strategies for the reduction and prevention of injuries, each sport participant needs to be screened as an individual with individual risk factors and preventative measures must be adapted for each sport's own specific demands.

Keywords: sport injuries; intrinsic risk factors; biomechanical abnormalities; postural faults; body composition

1. INTRODUCTION

In the last few decades athletes continue to set new standards within sport performance that resulted in an increase in the intensity of training and competition, increasing the risk for musculoskeletal injuries.[3, 22, 36] The annual cost of sport injuries worldwide has been an estimated $1 billion.[39]

Progress in the development of sport medicine has been made, improving diagnosis, treatment, rehabilitation of injuries, performance of athletes and identifying risk factors for injuries. A few researchers compiled strategies to reduce and prevent some sport injuries by means of the following principles:

- Sport injury incidence data alone are not useful in injury prevention. The **exact mechanisms of injury** need to be carefully examined by means of video analysis, athlete interviews, clinical studies where radiography, magnetic resonance imaging, arthroscopy or computed tomography are used, as well as by means of cadaver studies and mathematical modelling of an injury situation.[11, 26]
- Medical examiners must be aware of the **specific demands of a sport** to be able to identify potential high-risk individuals and for prescription of individual exercise programmes.[37]
- **Pre-season conditioning** programmes must include **sport-specific exercises**.[18]
- **Skill training** to decrease energy expenditure and mechanical load; **perception education and cognitive skills** to ensure that athletes are aware of the outcomes of risk taking as well as being aware of the environment they play in and the competitors they play against and **motivational support** to ensure that athletes are not only more competitive, but are also aware of the risks associated with higher competitiveness.[36]
- Sport participants should be educated about the risk factors associated with the sport they practice and modification of behaviour must focus on the **early detection of symptoms of injuries**.[57]

- Safe sport participation should focus on **full rehabilitation** after injury and information on the selection of **proper orthotic devices** (i.e. shock-absorbing insoles, medical braces, etc.) to avoid the recurrence of injury.[13, 58]

Many intrinsic and extrinsic risk factors have been identified in different sporting activities. There is, however, little agreement in the findings of the different studies and effective preventative interventions are yet to be designed for each specific injury type in a given sport. Athletic trainers must ensure that each athlete is screened for individual risk factors and screeners must evaluate the body as a whole. Therefore, the focus of this article is to provide an overview of the already identified biomechanical, postural and anthropometrical risk factors in order to highlight the most important factors contributing to injury. This information may assist athletes, coaches, trainers and physical therapists in identifying intrinsic risk factors and adopting preventative strategies for sport injuries.

2. SELECTED RISK FACTORS FOR INJURY PREDICTION

A new tendency in sport injury prevention is the multifactorial approach that identifies internal and external risk factors that increase the athlete's proneness to injury as well as a thorough description of the injury mechanism and events leading to injury.[3] According to Meeuwisse's multifactorial approach, the interaction between internal and external risk factors creates the mechanism, which results in injury.[38] Leadbetter identified seven basic mechanisms of injury from a sport medicine perspective: (1) contact or impact, (2) dynamic overload, (3) overuse, (4) structural vulnerability, (5) inflexibility, (6) muscle imbalance and (7) rapid growth.[as quoted by 62]

Information on injury mechanisms must be considered in a model that explains how internal and external risk factors can modify injury risk and a thorough description of events leading to the injury, as well as the whole body and joint biomechanics at the time of injury, are important. For the purpose of this review, intrinsic risk factors from previous studies and review articles were consulted in order to determine the role of biomechanical and postural risk factors as well as anthropometrical characteristics in injury prediction (Tables 1, 2, 3 & 4; Appendix I & II).

2.1 Biomechanical and postural risk factors

Biomechanics is a science concerned with the efficient or inefficient use of static and dynamic forces acting on and in the human body during rest and with movement.[6, 23, 43, 54] Optimal posture combines both minimal muscle work and minimal joint loading, distributing force over a larger area by optimising segmental alignment and, therefore, reduces joint surface compression and lessens the risk of degenerative changes to a joint.[45]

Any force exerted on the body may result in subluxations, dislocations, fractures, sprains and strains. The nature and magnitude of stress or load on the musculoskeletal system and the biomechanics involved during the time of injury determine the extent of the injury and the resistance of the body to these forces.[17, 43] Acute injuries occur when maximal forces of tension, load or torsion in a specific structure of the human body exceed the critical limits of that structure and lead to failure of the tissues involved, resulting in fractures, dislocations, sprains and strains. In the case of overuse injuries, repetitive submaximal forces or forces below the acute injury threshold result in a combined fatigue effect and then lead to injuries such as bursitis, tendonitis or stress fractures.[1, 6, 12, 43, 62]

Previous studies (Tables 1 & 2; Appendix I) clearly identified strength imbalances, flexibility, different malalignment characteristics and poor posture as intrinsic risk factors in different sporting activities. In order to obtain consensus from the literature, muscle strength imbalances, flexibility, malalignment and poor posture will be discussed as part of the biomechanical and postural risk factors.

2.1.1 Muscle strength imbalances

In a stationary body, static forces must balance one another for a system to be in equilibrium.[31, 62] Muscle strength imbalances distort alignment resulting in undue stress on joints, ligaments and muscles. Muscle imbalances are usually associated with handedness, habitually poor posture and a consequence of occupational or sporting activities in which there is persistent use of certain muscles without adequate exercise of opposing muscles.[23]

The effect of muscle imbalances for example in the shoulder girdle, may lead to altered neuromuscular control and abnormal movement patterns with elevation of the upper extremity. Winging of the medial scapular border, downward rotation of the inferior angle and scapular dysrhythmia are results of parascapular muscle imbalances.[14] Weakness of the posterior rotator cuff muscles (infraspinatus, teres minor) results in loss of force couples at the glenohumeral joint and inability of the rotator cuff muscles to control the upward shear of the humeral head produced by contraction of the deltoid muscle during humeral elevation, which eventually results in subacromial impingement of the humeral head.[14]

A decreased ratio of hamstring to quadriceps strength was a significant risk factor for traumatic leg injuries in a study done by Soderman *et al.*[as quoted by 39] Knapik *et al.*[25] found that imbalances of the lower extremity muscles resulted in an increase in lower extremity injuries in female athletes if they had a right knee flexor 15% stronger than the left knee flexor tested at 180 degrees/second, as well as a knee flexor/extensor ratio of less than 0.75 at 180 degrees/second. Strong forces are generated at high contractile velocities by the stronger side or stronger agonist muscle and result in injury if the muscles of the weaker leg or weak antagonist are unable to absorb or properly transfer these forces. Also, a decrease in explosive strength (tested by means of a vertical jump) leads to a reduced muscular capacity to absorb high patellofemoral forces during fast eccentric sporting activities and results in patellofemoral pain.[63] However, in a review on strength, flexibility and athletic injury, Knapik *et al.*[24] found that no relationships have been demonstrated between antagonistic/agonistic strength ratios within the knee joint and injuries and there is no direct evidence that correcting right/left imbalances with strength training will reduce injuries.

A reduced strength of the hip abductors relative to the adductors is associated with increased pronation at the foot and may, therefore, contribute to lower extremity injuries.[20] In athletes with smaller dorsiflexion-to-plantar flexion ratios it is not only the inability of the dorsiflexion muscles to absorb strong forces generated by the plantar flexors, but dorsiflexion is also more difficult when an inversion action occurs and weak dorsiflexion muscles then fail to keep the ankle in a stable position.[4, 61] No differences were found in inversion, eversion and plantar flexion peak torques among athletes who sustained ankle sprains and those who did not. Baumhauer *et al.*[4] found higher ratios of eversion to inversion strength in athletes who sustained ankle injuries.

It is clear from the above-mentioned studies that muscle strength imbalances play a role in sport injuries, however, standardization of norms for muscle strength ratios is impossible as dominant muscle groups differ among different sports. Forces generated during functional activities must be properly transferred, especially on the non-dominant antagonist, which seem to be prone to injuries. The athletic trainer must be aware of which muscle groups are dominant in the sporting activity in which the athlete competes to incorporate exercises for both the dominant muscle groups and its antagonists as well as dominant and non-dominant sides.

2.1.2 Flexibility

Flexible musculotendinous units are less likely to be overstretched and flexible joints can withstand a greater amount of stress compared to relatively stiff joints, therefore, increased flexibility may reduce the risk of musculoskeletal injury.[12]

A decreased dorsiflexion range of motion contributes to ankle inversion sprains and is not only a result of weak dorsiflexion muscles, but a shortened gastrocnemius muscle also creates a decrease in dorsiflexion and could be considered as a predictive factor of ankle inversion sprains in men.[61] Limitations of dorsiflexion range of motion appear to be a more convincing risk factor for lower limb injuries such as stress fractures, iliotibial band friction syndrome and medial tibial stress syndrome than that of plantar flexion. The compensatory effects because of dorsiflexion limitation, such as hypermobile dorsiflexion of the forefoot on the rearfoot and excessive and prolonged pronation, have more significance in producing injuries than the limited dorsiflexion in itself.[40] Tight quadriceps muscles create high patellofemoral stresses during sport activities and predispose athletes to patellofemoral pain syndrome.[40] A decreased flexibility of the quadriceps and hamstring muscle groups leads to an increase in tendon strain with joint movements and predisposes athletes to tendon overload and development of conditions such as patellar tendonitis.[41]

Although several studies have indicated that flexibility is not an important factor in the prediction of injury [19, 30, 59], a review on risk factors for lower extremity injuries [39], found that four studies have reported an association between muscle tightness and injury, whereas one did not find such an association. Possible reasons for the inconsistency in research findings could be the differences in research designs and sample sizes in the above-mentioned studies. The importance of an increased flexibility also differs across the various sporting activities under investigation.

2.1.3 Anatomical malalignment link to injury incidence

During malalignment, muscles are resting in a shortened or lengthened position that eventually leads to adaptive shortening or lengthening of the muscles.[21, 51] Malalignment in the lower extremities changes the biomechanical work pattern and increases load on the lower leg, knee as well as the hip. The following section explains the effects of different malalignment characteristics in the lower extremities.

Leg length discrepancy

Anatomical or true differences in leg length can cause potential problems in the weight-bearing joints while functional or apparent leg length discrepancies may be a result of rotation or lateral pelvis tilt, malalignments of the spine, muscle tightness or weaknesses across joints in the lower extremities.[2, 16] Common musculoskeletal disorders associated with differences in lower limb length is low back pain, hip pain, osteoarthritis of the hip and myofascial pain syndrome, as well as injuries such as lower extremity stress fractures, iliotibial tract friction syndrome, trochanteric bursitis, lower limb overuse injuries and inversion injuries of the ankle.[1, 10, 16, 29, 35, 49, 53] There is disagreement in the literature regarding the amount of discrepancy necessary to create complications. Arnheim and Prentice [2] suggest leg length differences up to 25 mm can occur before symptoms are produced in the non-athlete, while inequality as little as 3 mm may cause symptoms in highly active athletes. Gurney [16] mentioned in a review on leg length discrepancy that non-symptomatic limb differences in studies varies from 10 mm to 50 mm in the general population, while a difference of 10 mm causes problems in individuals undergoing intensive training.

The risk of lower extremity stress fractures increases in athletes with significant leg length discrepancies because of the greater forces usually emitted through the longer leg. The increase in force transmission through the longer leg is a result of a decrease in contact area between the femoral head and the acetabulum because of the pelvic tilt towards the shorter side.[16, 40] According to Kendall *et al.* [23] and Sahrmann [53], the hip on the side of the longer leg is adducted, accompanied by excessive lengthening or weakness of the hip abductors. The weak abductor muscles allow the hip to move more laterally over the foot during running or rapid change in direction, which leads to excessive hip adduction during the swing phase of gate. This, together with the supination of the foot can contribute to inversion injuries of the ankle.

There is, however, controversy as to whether leg length discrepancy leads to excessive pronation or supination of the foot on either the long or short side. In the case of compensatory pronation, prolonged sporting activities in shoes that do not provide sufficient support for the longitudinal arch of the foot, plantar fasciitis may be developed.[49] Excessive pronation of the foot causes an increased inward turn of the lower leg and may result in secondary knee valgus and trochanteric bursitis.[29, 49]

Excessive pronation

Kendall *et al.* [23] described two types of pronation namely, pronation without flatness of the longitudinal arch and pronation with flatness of the longitudinal arch. The first form of pronation causes strain medially at the knee during weight bearing activities, while pronation with flatness of the longitudinal arch places strain on the muscles and ligaments on the inner side of the foot. Pronation instead of supination of the foot during heel strike leaves the foot mobile and unprepared to absorb the ground reaction forces. Pronation during the push-off phase of gait decreases the stability of the foot, increasing the forces transmitted through a closed kinetic chain to the lower leg, knees and hip. For example: pronation increases the load on the medial border of the foot and the anterior and posterior tibialis muscles have increased stress imposed upon them, which can cause medial tibial stress syndrome.[40] An athlete with a flat foot arch generally experiences greater forces in the Achilles tendon than an athlete with a high foot arch.[6] Genetic risk factors for developing Achilles tendonitis in rugby players include tight inflexible calf muscles as well as excessively mobile feet that pronate excessively during walking and running.[44] Excessive pronation also increases inward rotation of the lower leg, changing the biomechanical work pattern of the thigh muscles and the insertion of the iliotibial tract is drawn anteromedially, tighter across the lateral femoral epycondyle [29, 49] and as a result the following injuries may occur: chondromalacia patellae; iliotibial band friction syndrome; tibialis posterior syndrome; plantar fasciitis and trochanteric bursitis.

Although controversy exists regarding the amount of discrepancy necessary to develop into injury, the use of proper orthotic devices would be advisable to avoid injury in athletes who present anatomical leg length discrepancy or excessive pronation. Athletes presenting functional leg length differences should consider advice from medical professionals to provide rehabilitative exercises showing which muscles should be strengthened and which should be stretched.

Knee genu valgum, genu varum and recurvatum

The knee of an adult individual is normally in approximately 6° of valgus. A distance of 9 to 10 cm between the ankles in stance is considered excessive.[33] Genu valgum places chronic tension on the ligamentous structures of the medial part of the knee, increased compression of the lateral aspect of the knee surface and abnormal tightness of the iliotibial band as well as the tensor fascia latae.[2, 23] An individual has genu varum if the knees are more than two finger widths apart when the ankles are together.[33] Motions and postures correlated with genu varum include excessive lateral angulation of the tibia in the frontal plane, medial tibial torsion and excessive hip abduction.[33]

Cowan *et al.* [10] found that the relative risk of overuse injury was significantly higher among male infantry trainees with a high prevalence of valgus knees. A review on biomechanical risk factors for exercise related lower limb injuries done by Neely [40] indicated that several studies have found genu valgum to be a risk factor for tibial stress fractures, but a few others, however, could find no association between genu valgum and stress fractures or knee pain. Excessive varus alignment causes high tensile stress in the lateral capsular ligamentous tissues as well as excessive medial tibiofemoral contact force and pressure and, therefore, contributes to injuries such as stress fractures and chronic knee pain.[34, 40]

Knee hyperextension produces undue anterior compression and increased tension on the posterior muscles and ligaments leading to stretching of the posterior joint capsule, the anterior cruciate ligament is slacked and compressive forces alter the anterior articular surface of the tibia.[53] Knee hyperextension in the resting position increases the tension on the ACL and produces a preloading effect on the ACL since injury to the ACL usually results from the leg being in a position of internal rotation and hyperextension [30] (Table I, Appendix A). Genu recurvatum commonly occurs as a compensation for lordosis or swayback and there is notable weakness of the hamstring muscles in these individuals.[2]

Large Q-angle

The normal Q-angle is 10° for males and 15° for females, with a Q-angle of more than 20 degrees being excessive, which may lead to pathological conditions associated with improper patellar tracking in the femoral groove.[2] Large Q-angles may be due to femoral anteversion, genu valgum or external tibial torsion.[30, 40] A large Q-angle together with a lack in geometric stability or muscle imbalance because of weakness of the vastus medialis obliquus causes patellar instability and may lead to patellofemoral pain, patella dislocation or recurrent patellar subluxations.

The mechanism of injury caused by an increased Q-angle is due to the composite angle of pull of the quadriceps muscle group leading to abnormal lateral tracking of the patella during quadriceps contraction, causing abnormal stresses on the surrounding soft tissues and articular cartilage.[40, 49] This was supported by Cowan *et al.* [10] who found male infantry trainees with a Q-angle of more than 15 degrees having a 5 times greater risk of developing a stress fracture.

Controversial results by Witvrouw *et al.* [64] show that malalignment parameters (limb-length discrepancy, Q-angle, medial intercondylar distance) are not discriminators for patellar tendonitis in an athletic population. A review by Neely [40] indicated that some studies found no relation between larger Q-angles and low back injuries, iliotibial band friction syndrome, shin splints or plantar fasciitis. Neely concludes that an excessively large Q-angle predisposes to overuse knee pain but its relation to other lower limb injuries is unconfirmed.

It remains highly controversial as to whether biomechanical characteristics such as muscle strength imbalances and flexibility as well as malalignment parameters such as leg length discrepancy, excessive pronation, knee recurvatum, knee valgus and varus and large Q-angles predispose athletes to injury. Much research has been done, but researchers fail to provide proper uniform populations and the variety of methods used for measurement contributes to poorly constructed studies. The normal ranges of biomechanical characteristics are usually standardized for non-athletic population whose intensity and frequency of training differ greatly from those of professional athletes. A large amount of research is still needed in this area to connect biomechanical parameters as potential risk factors to specific injuries in the high performance sporting population.

Wells and Luttgens [60] stated that the skeletal structure should be architecturally and mechanically sound so that there is minimum strain on the weight bearing joints. The upright posture is the normal standing posture for humans. If the upright posture is correct, it has been proposed since the early 1900's as a state of balance requiring minimal muscular effort to maintain.[15] These statements make it clear that the biomechanical structures in the human body are influenced by a person's posture. Therefore, postural defects cannot be excluded when identifying intrinsic risk factors in athletes.

2.1.4 Poor posture related to sport injuries

Good posture is the state of muscular and skeletal balance which protects the supporting structures of the body against injury and in which the muscles will function most efficiently. Poor posture is a faulty relationship of the various parts of the body resulting in less balance of the body over its base of support that produces increased strain on the supporting structures.[23] The proprioceptive system recognizes a faulty static posture as normal that places the body in a position that is not mechanically functional and economical, and joints are then stressed beyond normal if this individual is placed in a dynamic situation.[30] These statements are supported by a study on the effects of pronated and supinated foot postures on static and dynamic postural stability by Cote *et al.*[9] The study indicated that dynamic reach differed in some directions among individuals with pronated, supinated or neutral foot postures. Pronaters reached further in the anterior and anterior medial directions and supinators further in the posterior and posterio-lateral directions, which indicates that postural stability is affected by foot type under both static and dynamic conditions.

Postural defects must be seen from a total body perspective. For example, a subject standing in a tense position increases the pelvic tilt so that the pelvis rotates forward on the femur, carrying the lumbar spine forward and with it the body's centre of gravity. To compensate for this position, the legs adopt a hyperextended position while the upper body thrust backwards, increasing the lumbar and dorsal curvatures.[6] An increased lumbar lordosis has been related to hamstring strains in athletes participating in rugby, hurling and football.[19] Broomfield *et al.* [6] explain that with the pelvis tilting anteriorly the abdominal muscles as well as the thigh extensor muscles become stretched and weakened while the erector spinae and thigh flexor muscles should be stretched. On the other hand one could argue that the thigh and hip extensors need to be stretched, while the abdominal muscles as well as the upper leg flexor muscles should be strengthened to allow the pelvis to tilt posterior.

The forward head or slouched posture has been associated with an increased thoracic kyphosis, forward shoulder posture and a scapula that is protracted, elevated, anteriorly tilted and downwardly rotated.[28] Greenfield *et al.* [14] investigated the differences in scapular protraction and retraction, forward head position, midthoracic curvature and passive humeral elevation in the plane of the scapula between healthy subjects and those with shoulder overuse injuries. The forward head position and humeral elevation was significantly greater in the patient group than in the healthy group, as well as in the uninvolved shoulder. Scapula protraction and rotation were significantly related to injury in the patient group but were not significantly greater than those of the healthy group. In the flexed head position, levator scapula tightness opposes upward rotation of the scapula and increases the tendency to tip the scapula anteriorly, assuming an axis of rotation at the AC joint. Prolonged and repetitive shoulder elevation together with awkward cervical and head postures are believed to be contributing factors in the occurrence of shoulder pain and combined shoulder and neck complaints.[32] Exaggerated thoracic kyphosis adversely influences length-tension relationships of the shoulder girdle muscle, which in turn may cause mal-tracking of the humeral head within the glenoid fossa. Postural correction may restore normal movement patterns in the shoulder girdle and has a positive effect on shoulder range of movement and the point at which pain is experienced.[7, 28]

Hennessy and Watson [19] stated that anatomic variations are risk factors for only a few individuals while functional abnormalities such as muscle imbalances about a joint, poor strength and poor range of motion (sections 2.1.1 and 2.1.2) are more important risk factors. Watson [59] found defects of posture to be a significant indicator of injury in high-level players of body contact sport and suggested that posture evaluation must be quantitative, precise and based on high quality photographs of the subjects if they are to be of value in the prediction of sport injury.

2.2 Body composition and sport injuries

In this era professional participation in a wide variety of sports has erupted. The anthropometric dimensions are not only used for health purposes, but in the athletic population these variables play an important role in determining the potential for success in a chosen sport.[46] Medical professionals, sport scientists as well as coaches, therefore, need to enrich their knowledge, not only in morphological optimisation for optimal sports performance, but also on the effect different anthropometric dimensions has on the development of sport injuries.

Different body types are associated with different postural and biomechanical defects. The ectomorphs are associated with postural defects such as forward head, abducted scapulae, round shoulders, kyphosis and lordosis. The endomorphs suffer mainly from leg deformities such as genu valgum, flat feet and everted feet, due to the added burden of additional weight. The mesomorphs are generally free from major postural defects but may develop minor problems as they grow older, especially if they increase their body weight.[6] Some postural and biomechanical defects have previously been associated with injuries (as explained in the previous section of this article). Therefore, one could assume that an athlete's body type may indirectly influence his/her proneness to injury.

Age, gender and body size are among those intrinsic risk factors associated with the development of some specific injuries in sport, depending on the type and intensity of activity.[55] In a retrospective study on outpatient sport clinic material, Kujala *et al.* [27] found that taller height along with other factors had a statistically significant association with injuries of the knee. Witvrouw *et al.* [64], however, found no significant difference between subjects who developed patellar tendinitis and those who did not with respect to weight and height. Increased weight and body mass index were significantly associated with noncontact ACL injury among Australian footballers.[48] The most dangerous loading situation for the anterior cruciate ligament occurs when the knee is fully extended and weight bearing, and the anteriorly directed tibial force is combined with internal tibial torque.[17] It is obvious then that an increase in bodyweight will increase the load on the knee joint and, therefore, also increase the risk of injury. However, the misconception that the leaner the body, the better the performance in some sports has led to unrealistic weight loss goals set by coaches in various sports.[37] This author stated that obesity slows down reaction time and decreases cardiovascular efficiency, but extreme loss of weight may result in premature fatigue, loss of strength and eventually to injury.

In a review on risk factors for lower extremity injuries, Murphy *et al.* [39] indicated that increased injury incidence with increased age has been reported among soccer players, Australian football players, recreational athletes and military recruits. Age was not found to be an injury risk in studies performed on track and field athletes, dancers, female soccer players and female netball players. In their review these authors even found two studies showing an increased injury incidence at a younger age. Orchard [47] investigated intrinsic and extrinsic risk factors for muscle strains in 1607 Australian football players. An older age was found to be a risk factor for hamstring and calf muscle strains (even when adjusted for injury history), but was not a risk factor for quadriceps muscle strains. The above findings were explained with the theory that abnormalities of the lumbar spine are implicated in the development of muscle strains, since the lumbar nerve roots L5 and S1, which supply the hamstring and calf muscles, are more likely to be affected by age-related spinal degeneration than the nerve supply of the quadriceps muscles (L2, L3 & L4). The investigation also indicated that quadriceps muscle strains were more common in shorter players.

However, research exists that found no particular connection between athletes' anthropometrical characteristics and injuries obtained [61, 63], other studies clearly identified some anthropometrical risk factors for injury prediction [8, 47, 48, 50] (Table 3; Appendix II). Coaches and athletes must acknowledge these findings because of the major role body composition plays in the performance of athletes.

3. CONCLUSION

Musculoskeletal injury is an unfavourable reality in the athletic population. Current literature indicates that many studies have investigated the extent of the sport injury problem and in the last few decades researchers also focused on the aetiology and mechanism of injury to identify potential risk factors. In this article the researcher reviewed sport injury literature to explain how muscle imbalances, flexibility, poor posture, malalignments as well as anthropometrical characteristics may be related to injury.

Although controversial literature exists, leg length discrepancy, excessive pronation, knee genu valgum and larger Q-angles seem to be the malalignment parameters mostly connected to lower extremity injuries in the athletic population. Muscle strength imbalances as well as poor flexibility in the thigh, hamstring and gastrocnemius muscles have also been reported as significant risk factors for lower extremity injuries. Muscle strength imbalances about the shoulder girdle result into dysfunctions such as scapula winging, scapular dysrhythmia and altered neuromuscular control, which together with postural characteristics such as forward head, forward shoulders and thoracic kyphosis increases an athlete's risk to obtain shoulder injuries.

There is not only a strong relationship between the biomechanical and postural characteristics, but certain postural defects are related to the body type of an athlete as indicated in section 2.2. Controversial findings have been reported as to whether anthropometrical characteristics such as increased weight, height, BMI, body fat and somatotype predispose athletes to injury. An older age seems to be related to injuries in the athletic population, however, the physical demands of the sport plays a major role in the risk for injury in different age groups.

This review article once again highlights the inconsistency in literature findings. The differences in methodologies used and variations in sample sizes of groups under investigation as well as the differences in injury definition complicate comparison of research findings. Each sporting activity has unique physical demands with different risk factors contributing to injury proneness and the variables under investigation will also not be consistent among various sports. Therefore, to compile successful strategies for the reduction and prevention of injuries, each sport participant needs to be screened as an individual with individual risk factors and preventative measures must be adapted for each sport's own specific demands. It is of utmost importance that physical trainees, coaches and sport scientists are aware of already identified risk factors for sport injuries as well as how these risk factors eventually develop into injury to be able to identify high-risk athletes.

4. FUTURE RECOMMENDATIONS

Future injury epidemiological studies should make use of longitudinal prospective data collection where injured and non-injured athletes are observed. After identifying significant risk factors prevention trials must be incorporated to emphasize the intrinsic risk factors that can be corrected and the extrinsic risk factors that should be eliminated where possible.

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APPENDIX I

TABLE 1: A SUMMARY OF STUDIES IDENTIFYING BIOMECHANICAL & POSTURAL RISK FACTORS FOR SPORTS INJURIES

AUTHOR (S) & YEAR	STUDY DESIGN	SUBJECTS	SPORTING ACTIVITIES	MEASUREMENTS	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Knapik *et al.* (1991:79)	Longitudinal prospective study	➢ 138 female athletes ➢ Mean age = 18.9 years	Tennis, volleyball, soccer, field hockey, fencing, basketball, squash	➢ Flexibility measurements: hip flexors; hip extensors; hip adductors; hip external rotators; knee flexors; ankle dorsiflexors ➢ Strength measurement: Maximal isokinetic torque of the knee extensors and knee flexors at 30 degrees/second; knee extensors and knee flexors at 180 degrees/second	➢ A right knee flexor 15% stronger than the left knee flexor at 180 deg/sec ➢ A right hip extensor 15% more flexible than the left hip extensor (A stronger left knee as well as greater range of motion in the left hip extensor also showed a likelihood to injury – though not significant – 90% of the subjects was right leg dominant) ➢ A knee flexor/knee extensor ratio of less than 0.75 at 180 deg/sec
Hennessy & Watson (1993:245)	Cross-sectional study	➢ 34 athletes ➢ Mean age = 24.5 years	➢ Rugby, hurling, football	➢ Postural components: head erectness; shoulder symmetry; spinal curvature; hip symmetry; foot and ankle alignment; knee hyperextension; upperback roundness; trunk erectness; abdomen protrusion; lumbar lordosis ➢ Hamstring flexibility	➢ Lumbar lordosis (poor low back posture) correlated with hamstring injury
Greenfield *et al.* (1995:287)	Descriptive study	➢ 60 subjects (34 male & 26 female) ➢ Mean age = 39 years	-	➢ Scapular protraction (standing) ➢ Scapular rotation (standing) ➢ Forward head position (standing) ➢ Midthoracic curvative (standing) ➢ Passive humeral elevation in the plane of the scapula in standing	➢ Increased forward head ➢ Increased humeral elevation
Loudon *et al.* (1996:91)	Case-control study	➢ 40 female athletes ➢ Mean age = 28.5 years	Running, basketball, soccer, tennis, volleyball	➢ Standing pelvic position ➢ Hip position ➢ Standing sagittal knee position ➢ Standing frontal knee position ➢ Hamstring length ➢ Prone subtalar joint position ➢ Navicular drop	➢ Knee recurvatum ➢ Excessive navicular drop ➢ Excessive subtalar joint pronation
Witvrouw *et al.* (2000:480)	Prospective follow-up study	➢ 282 physical education students (151 male & 131 female & 24 developed patello-femoral pain) ➢ Mean age = 18.6 years	Swimming, track & field, gymnastics, soccer, basketball, volleyball, jazz dance, judo	Physical fitness & cardiorespiratory exercise capacity; joint laxity; lower leg alignment (leg length difference, foot alignment, muscle length of hamstring, quadriceps femoris and gastrocnemius); static patellofemoral alignment characteristics (Q-angle, genu varum , genu valgum); isokinetic strength of quadriceps and hamstring muscles	➢ Decreased explosive strength (poor vertical jump performance) ➢ Shortened quadriceps muscle ➢ Shortened reflex response time of hte vastus medialis obliquus muscle ➢ Hypermobile patella

TABLE 1: CONTINUED

AUTHOR (S) & YEAR	STUDY DESIGN	SUBJECTS	SPORTING ACTIVITIES	MEASUREMENTS	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Orchard *et al.* (2001:196)	Longitudinal prospective cohort study (period = 1992-1999).	➢ 1643 individual players ➢ 120 ACL-injuries ➢ Mean age = 24 years	Australian football	Mechanisms of ACL-injury (contact = force was directly to knee & non-contact = force was i.e. to upper body with a fixed foot); past ACL injury	➢ Previous injury to the ACL is a strong risk factor to both the injured and contralateral knee.
Orchard (2001:301)	Longitudinal prospective cohort study (period 1992-1999)	➢ 1607 individual players ➢ 672 hamstring strains ➢ 163 quadriceps strains ➢ 140 calf muscle strains ➢ Mean age = 23.53	Australian football	Recent history of injury to the hamstring, calf and quadriceps muscles (within the previous 8 weeks); past history of injury to the hamstring, calf and quadriceps muscles (more than 8 weeks ago)	Intrinsic factors for hamstring injury: ➢ Recent hamstring injury ➢ Past hamstring injury ➢ Past calf injury Intrinsic factors for calf injury: ➢ Recent calf injury ➢ Past calf injury ➢ Past quadriceps injury Intrinsic factors for quadriceps injury: ➢ Recent quadriceps injury ➢ Past quadriceps injury ➢ Recent hamstring injury
Quarrie *et al.* (2001:157)	Prospective cohort study	➢ 258 male players	Rugby union	Previous injury experience, age, ethnic origin, psychological well-being, competition anxiety, alcohol use, cigarette smoking status, height, body mass, BMI, sum of six skinfolds, aerobic endurance, anaerobic endurance	➢ Previous injury experience ➢ Cigarette smoking status ➢ Stress ➢ Aerobic and anaerobic performance
Watson (2001:222)	Two-year retrospective study	➢ 86 subjects ➢ Mean age = 24.3 years	Soccer, hurling, Gaelic football	➢ 6 Flexibility measurements (spinal flexion; hip abduction; hip flexion; ankle dorsi-flexion; hip hyperextension; shoulder hyperextension) ➢ Posture assessment from a grid for: forward head; kyphosis; shoulder symmetry; back symmetry; scapulae abduction; scoliosis; rib hump; chest mechanics; sway-back; lumbar lordosis; knee interspace; knee hyper extension; tibial torsion; ankle posture; foot arch ➢ Muscle-skeletal clinical examination (i.e. patella function; ankle proprioception; signs of previous injury) ➢ Measurement of running speed and acceleration from a standing start over distances 5, 10, 15, 20m	➢ Acceleration over 10 m from a standing start ➢ Number of musculo-skeletal deficiencies (muscle imbalances, weaknesses of muscle groups that protect and stabilize joints, joint function and signs of lack of full recovery from previous injury) ➢ Previous injury ➢ Poor posture

TABLE 1: CONTINUED

AUTHOR (S) & YEAR	STUDY DESIGN	SUBJECTS	SPORTING ACTIVITIES	MEASUREMENTS	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Witvrouw *et al.* (2001:193)	Two-year prospective study	➢ 138 subjects (99 male & 39 female) ➢ 19 developed patellar tenditinis ➢ Mean age = 18.8 years	Swimming, track & field, gymnastics, soccer, basketball, volleyball, jazz dance, judo	Leg alignment (leg-length discrepancy, Q-angle, medial tibial intercondylar distance); muscular tightness & muscle strength (hamstring & quadriceps)	➢ Tight hamstring and quadriceps femoris muscles
Brockett *et al.* (2004:379)	Cross-sectional study	➢ 27 athletes {9 with previous unilateral hamstring strains (8 males & 1 female & 18 uninjured athletes (males)} ➢ Mean age = 30.8 years	23 Australian Football players, 4 Track & Field athletes	➢ Isokinetic mean torque and optimum angles (hamstring/quadriceps) of the injured and uninjured leg of the previously injured subjects ➢ Isokinetic mean torque and optimum angles (hamstring/quadriceps) of the uninjured subjects	➢ The shorter optimum angle of previously injured muscles makes them more prone to injury from eccentric exercise
Burne *et al.* (2004:441)	Prospective cohort study	➢ 122 men ➢ 36 women ➢ Mean age = 18.3 years	Australian Defence Force Academy Trainees	➢ Intrinsic measurements: hip range of motion; leg length discrepancy; maximum ankle dorsiflexion; foot type; rear foot alignment & tibial alignment	➢ ↑ internal & external hip range of motion
Willems *et al.* (2005:415)	Prospective cohort study	➢ 241 male physical education students ➢ 44 sustained inversion sprains ➢ Mean age = 22.5 years	Soccer, handball, basketball, volleyball, track & field, gymnastics, karate, swimming, dance	Functional motor performance (general balance; explosive jump ability; running speed; cardiovascular endurance); joint position sense; muscle strength (isokinetic peak torque & peak torque compared to body mass for concentric and eccentric eversion-inversion as well as plantarflexion-dorsiflexion movements of the ankle); lower leg alignment; postural control and muscle reaction time.	➢ Slower running speed ➢ Less cardiorespiratory endurance ➢ Less general balance ➢ Less movement coordination ➢ ↓ dorsiflexion range of movement ➢ ↓ dorsiflexion muscle strength ➢ ↓ reaction time of tibialis anterior and gastrocnemius muscles

TABLE 2: A SUMMARY OF REVIEW ARTICLES REPORTING ON BIOMECHANICAL & POSTURAL RISK FACTORS IN SPORT INJURIES

TITLE OF STUDY	AUTHOR(S) & YEAR	STUDY OBJECTIVE	INTRINSIC RISK FACTORS REVIEWED IN THIS STUDY	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Preseason physical examination for the prevention of sports injuries	McKeag (1985:430)	Reviewed literature for injury risk factors to enable the reader to adjust physical examination forms according to the candidate's age, type of sport and level of participation.	Injury predictors reviewed: ➢ Maturity staging ➢ Flexibility ➢ Cardiovascular fitness	➢ Unilateral weakness in a muscle or muscle group
Overuse injuries in sport: a review	Renström & Johnson (1985:317)	Reviewed previous studies to ensure a proper understanding of overuse injuries and future prevention.	Reviewed extrinsic and intrinsic risk factors, as well as diagnosis and treatment of injuries to the musculotendinous unit; muscle injuries; compartement syndrome; muscle soreness; tendon injuries; injuries to the insertion or origin of muscle and tendon; overuse syndromes and joint injuries.	➢ Malalignment (excessive pronation; femoral neck anteversion; orthopaedic disorders) ➢ Leg length discrepancy ➢ Muscular imbalance ➢ Quadriceps and hamstring insufficiency
Knee injuries in athletes: review of exertion injuries and retrospective study of outpatient sports clinic material	Kujala *et al.* (1988:447)	-	-	➢ Increased patellar passive medial-lateral range of motion ➢ Increased knee laxity ➢ Inequality of limb length ➢ Patella alta
Intrinsic risk factors and athletic injuries	Taimela *et al.* (1990:213)	Reviewed individual characteristics predisposing to musculoskeletal injuries and injury prevention in athletes.	Injury history; body size; local anatomy and biomechanics; aerobic fitness; muscle strength, imbalances, tightness; ligamentous laxity; central motor control; psychological factors; psychosocial factors; general mental ability	➢ Anatomy, biomechanics, psychological factors: Controversy in literature – injury proneness depends on type and intensity of activity. ➢ Aerobic fitness: Lack of fitness increases injury risk. ➢ Muscle strength, imbalance and tightness: ↑ muscle imbalances and tightness ↑ injury risk - ↓ muscle strength ↑ injuries ➢ Central motor control: ↓ cmc ↑ injury proneness ➢ Psychosocial factors: ↑ life stress ↑ injury proneness ➢ General mental ability: ↓ intelligence ↑ injury proneness (needs further research)

TABLE 2: CONTINUED

TITLE OF STUDY	AUTHOR(S) & YEAR	STUDY OBJECTIVE	INTRINSIC RISK FACTORS REVIEWED IN THIS STUDY	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Strength, flexibility and athletic injuries	Knapik *et al.* (1992:287)	Critically evaluated studies researching the association between strength, flexibility and athletic injuries by considering the study design, different types of sports, injury definitions used; statistical analysis used and the sample size.	Reviewed studies on the following subjects: ➢ Strength and injuries ➢ Right and left side strength imbalances and injuries ➢ Antagonist/agonist imbalances ➢ Flexibility and injuries ➢ Flexibility imbalances and injuries ➢ Hypermobility and injuries ➢ Past injuries and strength imbalances ➢ Prior injuries and flexibility imbalances ➢ Strength training to correct muscular imbalances	➢ Right/Left strength imbalances may increase the risk of lower body sprains and muscle strains ➢ Either high or low flexibility in the hip or low back region is associated with a higher incidence of lower extremity injuries ➢ Flexibility imbalances in the hip region may be associated with sprains and muscle strains in the lower body
Intrinsic risk factors for exercise-related lower limb injuries	Neely (1998:253)	Reviewed literature concerning intrinsic risk factors that have been considered risks for lower limb injuries.	Physical fitness and previous injury	Military as well as civilian population: ➢ Past history of injury (particularly knee injuries) ➢ Low level of physical fitness
Biomechanical risk factors for exercise-related lower limb injuries	Neely (1998:411)	Reviewed studies to identify abnormal biomechanics statistical significantly associated with lower limb injuries.	Ankle dorsi-flexion; ankle plantar flexion; limited hip eversion; excessive joint laxity; leg length discrepancy; excessive pronated foot; excessive supinated foot; excessive high and low foot arches; large Q-angle; genu varum; genu valgum; muscle tightness.	➢ Limited ankle dorsi-flexion ➢ Limited hip eversion ➢ Excessive joint laxity ➢ Leg length discrepancy ➢ Excessive supinated foot ➢ Excessive pronated foot ➢ Excessive high foot arch ➢ Excessive low foot arch ➢ Large Q-angle
The impact of stretching on sports injury risk: a systematic review of the literature	Thacker *et al.* (2004:371)	Searched MEDLINE (1966– 2002); Current Contents (1997–2002); Biomedical Collection (1993–1999); Cochrane Library; SPORTDiscus to review the evidence for the effectiveness of stretching to prevent injuries in sports.	Investigated the following: ➢ Stretching to improve flexibility ➢ Adverse effects of stretching or flexibility ➢ Warm to prevent injury	➢ Stretching was NOT significantly associated with a reduction in total injuries.
Sports Injuries	Anderson (2005:116)	A clinical approach to diagnosis and treatment of common injuries	-	**Intrinsic risk factors for overuse injuries of the knee:** ➢ Flat feet ➢ Tight hamstrings ➢ Femoral anteversion

APPENDIX II

TABLE 3: A SUMMARY OF STUDIES INVESTIGATING ANTHROPOMETRY AS RISK FACTORS FOR SPORT INJURIES

AUTHOR (S) & YEAR	STUDY DESIGN	SUBJECTS	SPORTING ACTIVITIES	MEASUREMENTS	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Witvrouw *et al.* (2000:480)	Prospective follow-up study	➢ 282 physical education students (151 male & 131 female & 24 developed patello-femoral pain) ➢ Mean age = 18.6 years	Swimming, track & field, gymnastics, soccer, basketball, volleyball, jazz dance, judo	Anthropometric variables (height, weight, body fat, body composition)	➢ None of the anthropometric variables tested were statistically significant
Orchard (2001:301)	Longitudinal prospective cohort study (period 1992-1999)	➢ 1607 individual players ➢ 672 hamstring strains ➢ 163 quadriceps strains ➢ 140 calf muscle strains ➢ Mean age = 23.53	Australian football	Age; height; weight; body mass index and race.	Factors associated with hamstring injury: ➢ Older age Factors associated with calf injury: ➢ Older age Factors associated with quadriceps injury: ➢ Shorter players
Orchard *et al.* (2001:196)	Longitudinal prospective cohort study (period = 1992-1999).	➢ 1643 individual players ➢ 120 ACL-injuries Mean age = 24 years	Australian football	Weight; height; age	➢ Increased age; increased weight and increased body mass index with noncontact injury. (Regression equations were not used)
Quarrie *et al.* (2001:157)	Prospective cohort study	➢ 258 male players	Rugby union	Age, ethnic origin, height, body mass, BMI, sum of six skinfolds	➢ BMI
Witvrouw *et al.* (2001:193)	Two-year prospective study	➢ 138 subjects (99 male & 39 female) ➢ 19 developed patellar tenditinis ➢ Mean age = 18.8 years	Swimming, track & field, gymnastics, soccer, basketball, volleyball, jazz dance, judo	Anthropometric variables (height and weight)	➢ None of the anthropometric variables tested were statistically significant
Burne *et al.* (2004:441)	Prospective cohort study	➢ 122 men ➢ 36 women ➢ Mean age = 18.3 years	Australian Defence Force Academy Trainees	Lean calf girth	➢ ↓ lean calf girth
Willems *et al.* (2005:415)	Prospective cohort study	➢ 241 male physical education students ➢ 44 sustained inversion sprains ➢ Mean age = 22.5 years	Soccer, handball, basketball, volleyball, track & field, gymnastics, karate, swimming, dance	Anthropometrical characteristics (body mass index; ponderal indices; somatotype; fat mass; fat percentage, fat-free mass; density)	➢ None of the anthropometric variables tested were statistically significant

TABLE 4: A SUMMARY OF REVIEW ARTICLES REPORTING ON ANTHROPOMETRY AS RISK FACTORS FOR SPORT INJURIES

TITLE OF STUDY	AUTHOR (S) & YEAR	STUDY OBJECTIVE	ANTHROPOMETRICAL RISK FACTORS REVIEWED IN THIS STUDY	STATISTICAL SIGNIFICANT INTRINSIC RISK FACTORS IDENTIFIED FROM STUDY
Knee injuries in athletes: review of exertion injuries and retrospective study of outpatient sports clinic material	Kujala *et al.* (1988:447)	-	-	➢ Taller height
Intrinsic risk factors and athletic injuries	Taimela *et al.* (1990:213)	Reviewed individual characteristics predisposing to musculoskeletal injuries and injury prevention in athletes.	Age; gender; body size	➢ Age & gender: Controversy in literature – injury proneness depends on type and intensity of activity. ➢ Body size: Excessive height and weight increase injury risk.
Intrinsic risk factors for exercise-related lower limb injuries	Neely (1998:253)	Reviewed literature concerning intrinsic risk factors that have been considered risks for lower limb injuries.	Age; gender; physical build; body fat	Military population: ➢ High body mass index ➢ High percentage body fat ➢ Age over 24
Risk factors for lower extremity injury: a review of the literature	Murphy *et al.* (2003:16)	Reviewed prospective studies on risk factors for lower extremity injuries through Medline and the Cochrane register.	Age, gender, body size	➢ Age: Controversy in literature – (difficult to compare studies because of different sports, age ranges & injury types investigated) ➢ Gender: Female athletes have an increased risk of ACL injuries. ➢ Body size: Controversy in literature – (different techniques to represent body size make it difficult to compare findings)

CHAPTER 3

Injury incidence and selected biomechanical, postural and anthropometrical characteristics contributing to musculoskeletal injuries in rugby union players

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ABSTRACT

Objectives: The objectives of this research are firstly to determine the nature and incidence of injuries among U/21 rugby union players at the Rugby Institute of the North-West University (South Africa) and secondly, to determine which of the selected intrinsic characteristics contributed to musculoskeletal injuries obtained during the first five months of the 2005 season. ***Methods:*** A prospective once-off subject availability study was performed. Only players of the U/21 squad were eligible for the study (N=49). Biomechanical, postural and anthropometrical assessments were performed on all subjects before the start of the 2005 season. All injuries obtained were recorded by means of a validated rugby union injury report questionnaire. A stepwise discriminant analysis was performed to determine the independent characteristics with the greatest contribution to injuries after which the effect size index ("*better than chance*") (I>0.3) was calculated to determine the practical significant validity of selected variables. ***Results:*** A total of 66 injuries with an injury rate of 8.6/1000 training hours and 61.8/1000 game hours were reported. Severe injuries accounted for 53% of all injuries to forward players with the ankle being the most injured anatomical region. In the back line severe injuries accounted for 11% with the shoulder being the most injured region. The statistical analysis identified practical significant contributing characteristics in players who presented with lower extremity injuries. The strongest predictors for lower extremity injuries (I>0.3) were uneven hips, pronated feet, tight hamstrings, anatomical leg length differences, gait pronation and a tall stature. ***Conclusion:*** The conclusion that can be drawn from this study is that certain postural and biomechanical imbalances in the lower extremities contribute to injury in this area.

Keywords: rugby union injuries; intrinsic risk factors; biomechanical abnormalities; postural faults; body composition

INTRODUCTION

Since the introduction of professionalism in 1995 the injury rate in rugby union has increased on professional as well as amateur level.[6, 19] The overall injury rate during the 1995 Rugby World Cup was 32 injuries per 1000 player hours [27], while during the 2003 Rugby World Cup the overall injury rate increased to 97.9 injuries per 1000 player hours.[7] The highest injury rate reported in rugby union to date was that of one Super 12 squad during the 1997 Super 12 competition, which was 150 injuries per 1000 player hours.[24]

The contact phases of rugby implicate extrinsic forces, which are commonly associated with soft-tissue contusions, joint strains, fractures, dislocations, lacerations, grazes as well as head or spinal injuries.[20] Many epidemiological studies have described injury incidence and patterns in rugby union [1, 3, 6-8, 9, 10, 14, 19, 20, 24, 27, 44, 49], but only a few studies focused on the aetiology and mechanism of injury to identify risk factors related to injuries and eventually compile preventative programmes.[5, 30, 43, 47] In their book "Rugby without risk" Noakes and Du Plessis [39] summarized findings from various studies on risk factors in modern rugby union. The major risk factors identified from these studies were an older age, participation at a higher level, match play, the fullbacks, wings as well as the eighth men were identified as the most injured player positions, tackling, being tackled, and the ruck and maul as the most dangerous phases of play. The most injuries occurred during the early part of the season as well as the time after the mid-season break. These previously identified risk factors are mostly extrinsic factors of which the risk to contribute to injuries can only be reduced by means of more effective pre-season training as well as alterations to the laws of the game.[43]

The increase in rugby union injuries by means of intrinsic characteristics of players has been explained by the increase in BMI, body mass and mesomorphy of rugby union players over the last years, because large body size is a significant predictor of success in rugby union.[40] Play is faster, players are bigger and fitter, resulting in tackling that is harder. At elite level the ball is also in play for longer periods, increasing the number of tackles that could result in injury.[6, 27] Biomechanical aspects of a rugby union player that have been identified to contribute to injuries are hypermobility of joints [47] and shortcomings such as core stability and dynamic mobility.[22] Other previously identified intrinsic risk factors are previous injuries, stress, aerobic and anaerobic performance and cigarette smoking [43],as well as the personalities and characteristics of players which affect the risk that players take in game situations and their on-field awareness.[30]

Identifying intrinsic risk factors in any athlete enables the athlete to make use of professionals to compile rehabilitative and corrective exercise programmes and prescribe proper orthotic devices. Given the limited information available on intrinsic risk factors for rugby union injuries, the purpose of this study was firstly to determine the injury incidence and patterns of rugby union players of the U/21 team of the RI of the NWU and secondly, to determine which of the measured biomechanical, postural and anthropometrical characteristics are possible risk factors for injury among these rugby union players. This study may contribute to the current knowledge base of intrinsic risk factors in rugby union players and the advancement of prevention and rehabilitation of rugby injuries.

METHODS

Study design and subjects

Forty-nine players (twenty-eight forwards and twenty-one backline players) of the U/21-squad of the RI of the NWU (South Africa) were recruited at the end of the 2004 season to participate in this study. Ethical approval for the study was obtained from the Ethics Committee of the North-West University. This prospective once-off subject availability study comprised of an initial baseline examination to ascertain the biomechanical, postural and anthropometrical characteristics of players, as well as injury recording of the first five months of the 2005 season by means of a validated rugby union injury report questionnaire.[36]

Measurements and Equipment

Biomechanical assessment

In this study biomechanics refers to the static forces acting in the body and the pro-forma was compiled from various sources.[28, 34] Goniometric measurements were used to determine the range of motions of joints as well as the flexibility of selected muscle groups.

Biomechanical tests included flexibility/range of motion, stability and special tests for the lower extremities (flexibility of the hamstring and quadriceps muscle groups, achilles tightness, knee genu valgum, knee genu varum, knee genu recurvatum, tibial torsion, Q-angle, range of motion in plantarflexion and dorsiflexion, functional and anatomical leg length differences), pelvic girdle (flexibility of the gluteus maximus muscle, hip adductor muscles, iliopsoas and iliotibial tract, symmetry of the sacroiliac joint), upper extremities (range of motion of shoulder internal and external rotators, upper extremity stability, scapula humeral rhythm and scapula stability). An upper limb and lower limb tension test, as well as a lower abdominal muscle strength test were included. Pronation and supination of the ankle joint was evaluated by means of a computer assisted gait analysis.[51]

Postural analyses

The New York Posture Test that is designed for identifying thirteen categories of deformities was used for evaluation and identification of possible postural deformities in players.[6, 17, 28, 34, 46] Postural assessment was based on high quality photographs from a lateral and posterior (side-and back) view. The following aspects of posture were assigned a score of 5 (normal posture), 3 (slightly abnormal posture/moderate deviation) or 1 (abnormal posture/major deviation): forward head, flat chest, winged scapulae/round shoulders, kyphosis, inclined trunk, protruding abdomen, lordosis, twisted head, uneven shoulders, scoliosis, uneven hips and pronated feet. The subjects stepped down into powdered white chalk and then onto a black board to check for foot abnormalities (flat feet).

Anthropometrical assessment

Anthropometric variables (21) {body mass (kg), stature (cm), 9 skinfolds (mm), 6 girths (cm) and 4 breadths (cm)} were measured. All measurements were taken according to the methods of ISAK.[26] These anthropometric measurements were used to determine the body fatness, muscle mass, skeletal mass and somatotype (endomorphy, mesomorphy and ectomorphy) of all players. Body fatness were calculated by means of the following skinfolds: triceps, subscapular, abdominal, supraspinale, front thigh and calf skinfolds according to the formula of Whithers *et al.*[54] Muscle and skeletal mass were calculated according to the formulas of Lee *et al.* [31] and Martin [as quoted by 18], respectively. The somatotype was determined according to the Heath-Carter anthropometric somatotype method.[13]

Five-month injury surveillance

A validated rugby union injury report questionnaire was used to determine the previous injury history and new injury data of all players.[36] A Biokineticist explained the questionnaire to each player. Only the injuries sustained during the first five months of the 2005 season were recorded because of the tendency of high injury rates at the beginning of the season, as described in the literature. All injuries diagnosed by the medical team of the Rugby Institute as well as injuries not reported to the medical team were reported. 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 was missed, "moderate" if two weeks were missed and "severe" if more than two weeks were missed. The questionnaire included the site of injury, phases of play and period in the season in which a player became injured, the position played at the time of injury, the mechanism of injury as well as the amount of games or training sessions missed. The research also differentiated between match and practice injuries. Incidence of injuries was expressed as the number of injuries per 1000 game hours and the number of injuries per 1000 training hours for comparison with other studies.

Statistical analyses

The SAS System for Windows [50] was used for statistical analysis. The effect size index [15], d was calculated to determine the practical significant differences for means of all measurements presented as values between injured and uninjured players for biomechanical, postural and anthropometrical characteristics. Also, the effect size index [15], phi-coefficient was calculated to determine practical significant differences (phi > 0.5) for variables that were categorized. A stepwise discriminant analysis identified the independent characteristics that discriminated mostly between the players with and without injuries within specific body regions. Back-classification by means of the "Jack-knife method" determined whether the independent characteristics that were selected to contribute to injuries were valid.[25] The effect size, I ("better than chance") was then determined, with I > 0.3 been taken to be practically significant.

RESULTS

All the basic anthropometric characteristics of the average U/21 forward player significantly differed (d > 0.8) from those of the average U/21 backline player (Table 1). The forwards were on average heavier with especially more pronounced endomorphic and mesomorphic components, while the backs showed a greater ectomorphic component. If graded, the forwards had a low ectomorphy, average endomorphy and very high mesomorphic component, while the backline presented low endomorphic as well as ectomorphic components and a high mesomorphy. Both the average U/21 forward player and the average U/21 backline player of the RI of the NWU could be categorized as an endomorphic mesomorph.

Table 1: The mean (± SD) of the basic anthropometric variables of the average U/21 forward & backline player

Variable	Forward (N=28) Mean ± SD	Back (N=21) Mean ± SD	Effect size (d)
Stature (cm)	184.9 ± 5.7	177.9 ± 6.4	1.1
Body mass (kg)	103.9 ± 12.7	82.6 ± 9.3	1.7
Muscle mass (kg)	43.4 ± 3.2	37.8 ± 3.0	1.8
Body fat (%)	17.7 ± 5.7	12.1 ± 4.4	1.0
Endomorphy	4.1 ± 1.5	2.9 ± 1.0	0.9
Mesomorphy	7.7 ± 1.0	6.9 ± 0.9	0.8
Ectomorphy	0.8 ± 0.7	1.5 ± 0.6	1.0

Significant difference (d > 0.8)

Incidence and nature of injuries

There was a total of 66 injuries within the 49 participants during the first five months of the 2005 season. The mean incidence of injuries within forward players during game time was 60.4 per 1000 game hours and 9.3 injuries were sustained per 1000 training hours, while in backline players, injuries equilibrates to a mean of 63.2 injuries per 1000 game hours and 7.8 per 1000 training hours. The combined average injury rate for forwards and backs was 61.8 per 1000 game hours and 8.6 injuries per 1000 training hours. Injuries expressed as a percentage of the total (Figure 1.1) gives the false impression that the training methods might be incorrect and dangerous, however, if injuries are expressed per 1000 game hours and per 1000 training hours it becomes clear that the risk of being injured in game time is much higher than sustaining injuries during training. The incidence of new injuries was significantly higher than recurrent injuries and accounted for 76% of all injuries in forwards and 96% in backline players, with the majority of these injuries being acute (Figure 1.2). Figure 1.2 represents both the chronic type of injuries appearing for the first time during the first five months of the 2005 season as well as the chronic injuries re-appearing from the previous season, while Figure 1.1

only shows the percentages of forward and backline players complaining of first-time chronic type of injuries during the first five months of the 2005 season.

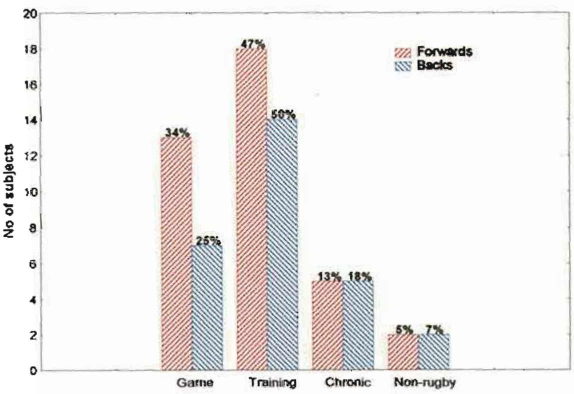

Figure 1.1: Time and place of injury

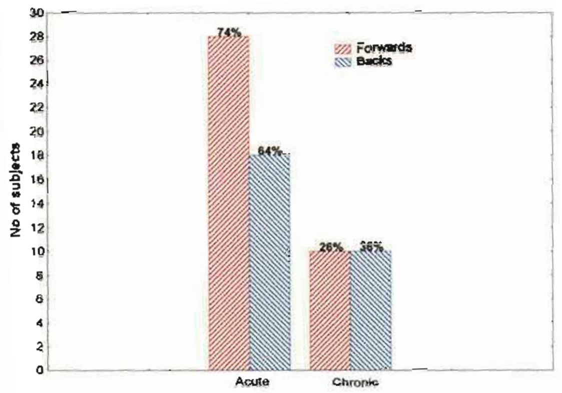

Figure 1.2: Type of injury

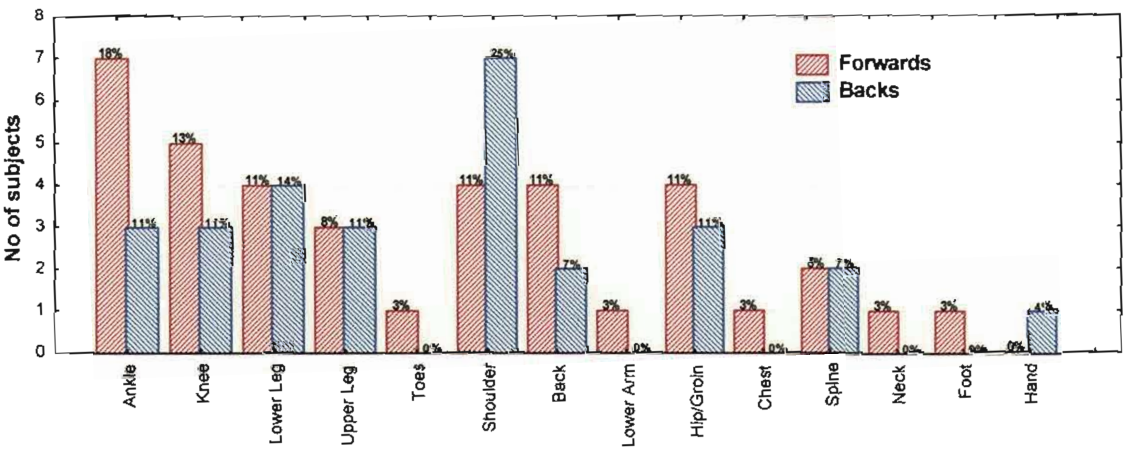

Figure 1.3: The various anatomical regions injured during the five-month injury surveillance of the forwards and backs

The most injured body region (Figure 1.3) for forward players was the ankle (18%), followed by the knee (13%). Tackling being by far the most dangerous phase of play in the backline (Figure 1.5) explains why the shoulder was the most injured body region (25%) in backline players. All injuries sustained in the upper extremity regions were to the shoulder, except for one forearm and one hand injury. It, therefore, seemed logical to divide the body into three major parts for determining the risk factors that contribute to injuries: injuries to the shoulder region, injuries to the back as well as spine (which included the one neck injury) and injuries to the lower extremities.

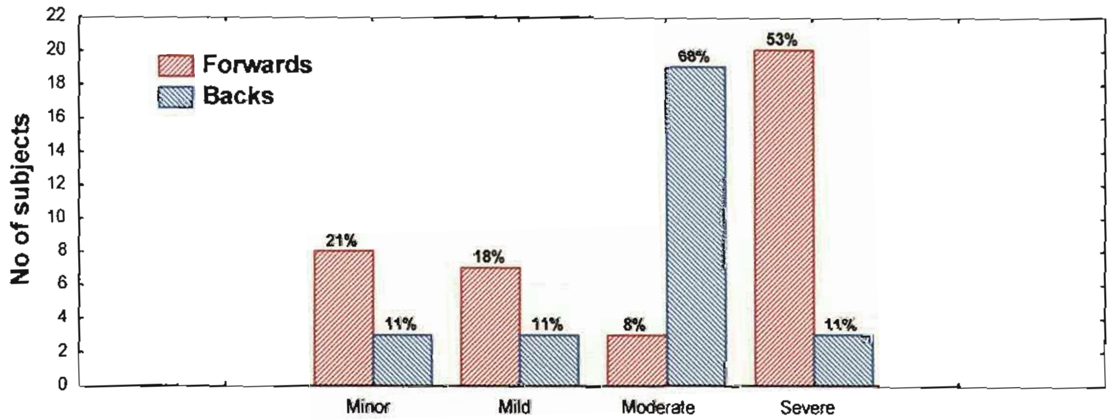

Figure 1.4: The distribution of the injury severity in the forwards and backs

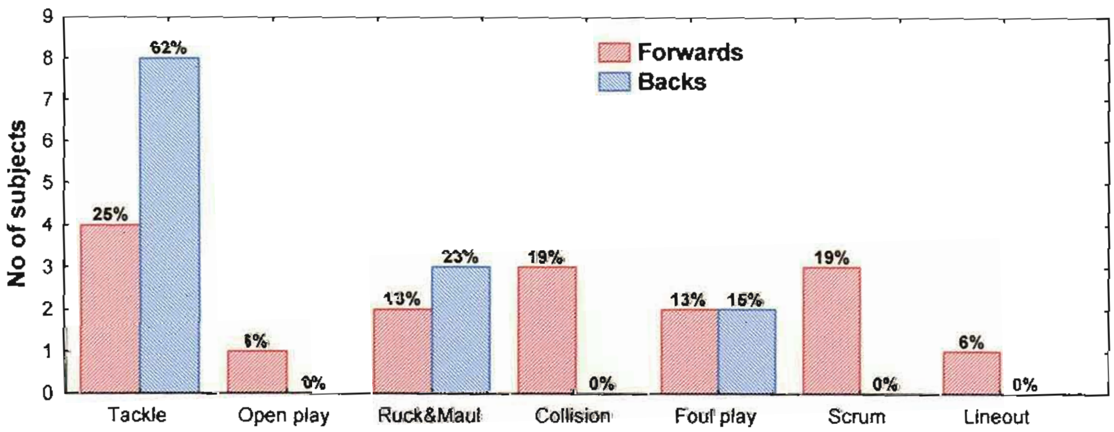

Figure 1.5: The different phases of play in which injuries were obtained in the forwards and backs

Figure 1.4 shows incidence of injury as a function of severity. Minor injuries allowed the player to return to the game or training session in which injured. Excluding minor injuries, a total of 30 injuries to the forwards and 25 injuries sustained by backline players caused a player to miss at least one week of training sessions as well as games played during the recovery time. Most injuries to the forwards were severe (53%) (more than two weeks missed), while in backline players, moderate injuries (>1 to 2 weeks absence) accounted for 68% of all injuries. The tackle was the main cause of injury

(Figure 1.5) to both forwards (25%) and backs (62%). In the forwards the tackle was closely followed by the collision and scrum, each contributing to 19% of all injuries.

Biomechanical, postural and anthropometric characteristics contributing to injuries

The stepwise discriminant analysis identified valid contributing characteristics in players who presented with lower extremity injuries. Table 2 shows the mean values for measurements presented as values in injured and uninjured players as well as the proportion of injuries for measurements presented as categories. The strongest practically significant predictors ("better than chance") (I>0.3) for lower extremity injuries were uneven hips, pronated feet, tight hamstring muscles, anatomical leg length differences, gait pronation and a taller stature. These variables have a cumulative effect on the risk for sustaining injury to the ankle, lower leg, knee, upper leg and hip joint. Nine of the ten players who presented with uneven hips and twelve of the twenty-eight players who presented with pronated feet sustained one or more lower extremity injury. This indicated that a player who presented with uneven hips (partial $R^2 = 0.15$) as well as pronated feet (partial $R^2 = 0.15$) had a 30% chance of sustaining lower extremity injuries during the rugby season.

Table 2: Characteristics selected to contribute to lower extremity injuries in forward and backline players combined

Variables (Categories)	N	% Injured players	N	% Uninjured players	Partial R^2
Uneven hips (N=10)	9	90.0	1	10.0	0.15
Pronated feet (N=28)	12	42.9	16	57.1	0.15
Weak hip abductors (N=11)	4	36.4	7	63.6	0.04
Variables (Values)	**Injured Players N**	**Injured Players Mean ±SD**	**Uninjured Players N**	**Uninjured Players Mean ±SD**	**Partial R^2**
Hamstring tightness	26	60.7 ±7.2	23	58.5 ±9.9	0.08
Anatomical leg length difference	26	0.5 ±0.6	23	0.7 ±0.7	0.08
Running gait pronation	25	9.2 ±4.6	22	7.7 ±3.6	0.06
Taller stature	26	182.68 ±7.0	23	181.4 ±7.4	0.05

I=0.5 (all variables combined)

Biomechanical, postural and anthropometrical characteristics selected by means of the stepwise discriminant analysis that contributed to shoulder injuries were tight shoulder internal rotator and adductor muscles (partial $R^2 = 0.11$), a high body mass (partial $R^2 = 0.06$) as well as kyphosis (partial $R^2 = 0.08$). In the back and spine region uneven hips (partial $R^2 = 0.04$), tight gluteus maximus (partial $R^2 = 0.02$) as well as tight hamstring muscles (partial $R^2 = 0.03$), a large muscle mass (partial $R^2 = 0.03$) and high body mass (partial $R^2 = 0.03$) were selected. The effect size index ($I > 0.3$), however, indicated that none of the selected parameters were practically significant to increase the risk of sustaining injuries to the shoulder joint ($I = -1.3$) as well as to the back region ($I = -2.1$).

DISCUSSION

In the current study a total body profile (biomechanical, postural and anthropometrical characteristics) of the participating rugby union players was taken to analyse the contribution of these player characteristics to injuries sustained during the first five months of the 2005 season.

A total of 66 injuries was reported, of which 55 enabled a player to participate in training sessions as well as games played for at least one week during the five-month injury surveillance. The combined injury rate for forwards and backs equilibrates to 61.8 injuries per 1000 game hours, which seems to be high in comparison with other club level injury rates previously reported.[5, 19] This rate is, however, lower than those of elite teams such as Super 12 and World Cup Squads reported after the start of the professional era in 1995.[6, 10, 19, 24, 49] The combined injury incidence during training of 8.6 per 1000 training hours was much higher than the 2.0 injuries per 1000 training hours observed in English professional rugby union.[11] as well as the 1.24 injuries reported during the Croatian rugby project.[5]

Comparison of injury rates among different studies are supposed to be possible because of the expression of injury rates per 1000 hours of participation, however, the differences in injury definition makes such comparisons extremely difficult. In the current study injuries where the player was able to return to the game or training session in which injured, were included as minor injuries.[36] These injuries were brought into calculation for the overall number of injuries per 1000 hours of participation because a player sustaining a minor injury might be more cautious of taking risks for the remainder of the game or training session, therefore, not playing to his full potential. In most previous studies the researchers only included injuries where players were not able to continue with play after the injury.[3, 5, 6, 8, 10, 14, 49] None of these references used the same definition for injury.

There seems to be consensus in literature regarding the fact that injuries are more prevalent during the early parts of a season.[3, 14, 19, 29, 49] In the current study, February and March were the months during which most injuries were reported. It should be highlighted, however, that in this study the researcher did not differentiate between pre-season matches and in-season matches and that injuries sustained during all matches played from January 2005 until the end of May 2005 were recorded. Therefore, comparison with a recent study that reported a significantly lower injury incidence during preseason matches compared with the average in-season matches [10], is not possible.

A possible explanation for the higher rate of injuries in the beginning of a season could be that at club level, rugby union players are less dedicated to following off-season conditioning programmes. Studies performed on other sporting activities [48, 53] as well as one rugby union study [44] indicated that a lack of aerobic fitness increased the risk of injury, which could also explain the high number of training injuries in the current study. Alsop *et al.* [3], however, found that pre-season fitness had no effect upon how quickly the injury rate declined in rugby union players as the season progresses. In the current study re-injuries accounted for only 24% of all injuries in forwards and a surprisingly low 4% in backline players. These low percentages, especially in the backs, exclude explanations for high early-season injury rates such as injuries sustained during the previous season not being fully rehabilitated and the correct orthotic devices not being prescribed to protect the region of previous injury.

The tackle was the phase of play in which most injuries occurred, being especially dangerous in backline players. This is in agreement with almost all the previous studies investigating rugby injuries.[3, 6, 10, 14, 27] The high speed of tackles in the backline as well as the tendency of modern rugby union players to have a more pronounced mesomorphic component [5, 40], increases the forces imposed on both the tackler as well as the player being tackled. It is, therefore, not surprising that in the current study the most injured body region in backline players was the shoulder. The most injured body region for forward players was the ankle (18%) followed by the knee (13%). Forwards are more exposed to phases of play such as the scrum, loose scrum, rucks and mauls where forces are applied from different angles, exposing the knee and ankle joints to great forces during unstable positions.

The second objective to identify biomechanical, postural and anthropometrical characteristics that contributed to injuries sustained during the five-month injury recording, indicate that tight shoulder internal rotators and adductors, a high body mass and kyphosis might be considered as intrinsic risk factors for shoulder injuries and uneven hips, tight hamstring as well as gluteus maximus muscle groups, large muscle mass and high body mass as risk factors for back and spine injuries. However, none of these characteristics were found to be practically significant. The small subject group as well as the few injuries sustained to the back and spine might be reasons for this finding.

Practical significant contributing characteristics were only in players who presented with lower extremity injuries. The strongest predictors for lower extremity injuries ($I>0.3$) were uneven hips, pronated feet, tight hamstring muscles, anatomical leg length differences, gait pronation and a tall stature. This research, however, did not investigate the relation of these different parameters to a specific kind of injury, but to specific body regions. Therefore, the more of the selected characteristics a player presented with, the higher the chance of sustaining an injury to the lower extremity region.

Although not many studies have investigated intrinsic risk factors in rugby union injuries, especially biomechanical and postural characteristics, many studies attempted to identify mechanisms and risk factors for injuries in other activities. Neely [38] found that the risk for lower extremity stress fractures increases in athletes with significant leg length discrepancies because of the greater forces emitted usually through the longer leg. Other common musculoskeletal disorders that can be associated with differences in lower limb length are low back pain, hip pain, osteoarthritis of the hip and myofascial pain syndrome as well as injuries such as lower extremity stress fractures, iliotibial tract friction syndrome, trochanteric bursitis, lower limb overuse injuries and inversion injuries of the ankle.[2, 16, 21, 32, 35, 41, 45]

Many controversial studies have been published on the association between flexibility of different muscle groups and injuries sustained in the lower extremities.[23, 33, 37, 38, 52-53, 55-56] In this study hamstring tightness contributes significantly to lower leg injuries. Tight gluteus maximus muscles, although not practically significant, was selected to increase the risk of injuries to the back and spine region. Rugby union is characterised by kicking, running, quick changes in direction and phases of play such as the scrum, loose scrums as well as forming of rucks or mauls where driving forces are needed. Any biomechanical and postural malalignments as well as poor flexibility increases the forces emposed on joints, ligaments and musculotendous units even more, which are already high because of the dangerous nature of the game of rugby.

The finding in the current study that gait pronation increases the risk of lower limb injuries is in agreement with research by Noakes & Du Plessis [39] that indicated genetic risk factors for developing Achilles tendonitis in rugby players include tight inflexible calf muscles as well as excessively mobile feet that pronate excessively during walking and running. Excessive pronation increases inward rotation of the lower leg, changing the biomechanical work pattern of the thigh muscles and the insertion of the iliotibial tract is drawn anteromedially, tighter across the lateral femoral epycondyle.[32, 41] These biomechanical changes increase load on the lower leg, knee as well as the hip and as a result the following injuries may occur: chondromalacia patellae, iliotibial band friction syndrome, tibialis posterior syndrome, plantar fasciitis and trochanteric bursitis. A taller stature being indicated as a significant predictor of lower extremity injuries is in contrast with the finding of a recent study on hamstring injuries in rugby union that indicated no significant differences in the incidence of hamstring muscle injuries as a function of age, height, body mass or body mass index.[9]

CONCLUSION

Body contact sport, such as rugby union, has a great risk of injuries because of the dangerous extrinsic forces emposed on the body. The purpose of this study was to investigate the nature and incidence of injuries to rugby union players as well determining which intrinsic characteristics contributed to musculoskeletal injuries.

A total of 66 injuries with an injury rate of 8.6/1000 training hours and 61.8/1000 game hours was reported. The tackle was the phase of play in which most injuries occurred. The most injured body region for forward players was the ankle followed by the knee, and backline players sustained most injuries to the shoulder region. None of the selected biomechanical, postural and anthropometrical characteristics were practically significant to contribute to shoulder as well as back and spine injuries. The strongest predictors for lower extremity injuries were uneven hips, pronated feet, tight hamstring muscles, anatomical leg length differences, gait pronation and a tall stature.

The conclusions that can be drawn from this study are firstly, that the injuries to rugby union players of the U/21 squad of the Rugby Institute of the North-West University are high in comparison with those of other club level players and that postural and biomechanical imbalances of the lower extremities may increase the risk for injury in this area. This study highlights the need for preseason biomechanical and postural evaluations to prescribe rehabilitative exercise programmes and the correct orthotic devices for players presenting with abnormalities to protect these players from sustaining injuries.

Future studies should attempt to assess the influence of biomechanical and postural parameters on specific rugby union injuries over a complete season with a larger player sample. There is also an urgent need for standardization in defining injury in rugby union.

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CHAPTER 4

Summary, conclusions and recommendations

- SUMMARY
- CONCLUSIONS
- RECOMMENDATIONS
- STUDY LIMITATIONS

4.1 SUMMARY

The objectives of this study (Chapter 1) were firstly to determine the injury incidence and patterns of rugby union players of the U/21 squad of the Rugby Institute of the North-West University and compare it with those of other rugby union teams observed in the literature. The second aim was to identify the biomechanical, postural and anthropometrical characteristics that could contribute to injuries sustained within the U/21 squad during the first five months of the 2005 season.

The review article (Chapter 2) focused on intrinsic risk factors for sport injuries in general because of the lack of research available on intrinsic risk factors related to rugby union injuries. The relative risk of injury for different types of sporting activities indicated that the risk of injury varies between various sporting activities. Endurance sports generally seem to have high rates of overuse injuries, while contact sport carries a greater risk of acute injuries and permanent disability. Individual screening of athletes is important because of the inconsistent research findings presented in the literature. Muscle imbalances, abnormal flexibility, poor posture, malalignments as well as anthropometrical characteristics might be related to injury. Although controversial literature exists, leg length discrepancy, excessive pronation, knee genu valgum and larger Q-angles seem to be the malalignment parameters mostly connected to lower extremity injuries in the athletic population. Muscle strength imbalances as well as poor flexibility in the quadriceps, hamstring and gastrocnemius muscles have been reported as significant intrinsic risk factors for lower extremity injuries. Muscle strength imbalances of the shoulder girdle result in dysfunctions such as scapula winging, scapular dysrhythmia and altered neuromuscular control, which together with postural characteristics such as forward head, forward shoulders and thoracic kyphosis increases an athlete's risk to sustain shoulder injuries.

The research article, "Injury incidence and selected biomechanical, postural and anthropometrical characteristics contributing to musculoskeletal injuries in rugby union players" is presented in Chapter 3. The findings indicated a total injury incidence of 66 injuries with an injury rate of 8.6/1000 training hours and 61.8/1000 game hours for forward and backline players combined. None of the selected biomechanical, postural and anthropometrical characteristics contributed significantly to the shoulder girdle as well as back and spine injuries. The practically significant predictors for lower extremity injuries were uneven hips, pronated feet, tight hamstring muscles, anatomical leg length differences, gait pronation and a tall stature.

4.2 CONCLUSIONS

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

4.2.1 Hypothesis 1:

The injury incidence of the U/21 rugby union squad of the Rugby Institute of the North-West University are similar to those of other amateur teams, but lower than elite professional teams observed in the literature and the nature of injuries are varied.

The first part of hypothesis 1, "the injury incidence of the U/21 rugby union squad of the RI of the NWU are similar to those of other amateur teams, but lower than elite professional teams observed in literature" is rejected based on the high amount of injuries sustained during the five months of injury recording. An injury rate of 8.6/1000 training hours and 61.8/1000 game hours was reported, which is rather high in comparison with other club level or amateur teams observed in the literature. The injury rate during training hours in this study is even higher than those of elite professional teams. Injuries sustained per 1000 game hours was, however, lower than the latest reported rates for elite professional teams. The second part, "the nature of injuries are varied", is accepted. The nature of injuries in this study were varied. Similarities of findings in this study compared to those of both amateur and elite teams reported in the literature were that the tackle was the most dangerous phase of play and that the most injured body region in forwards was the ankle followed by the knee. Previous studies also indicated that the shoulder was the most injured body region, which was true in this study for backline players.

4.2.2 Hypothesis 2:

Various biomechanical, postural and anthropometrical characteristics of U/21 rugby union players of the Rugby Institute of the North-West University will contribute to musculoskeletal injuries in different body regions.

Hypothesis 2 is accepted based on the research findings that practically significant contributing biomechanical, postural and anthropometrical characteristics were identified in players who presented with lower extremity injuries. The practically significant predictors for lower extremity injuries were uneven hips, pronated feet, tight hamstring muscles, anatomical leg length differences, gait pronation and a taller stature. None of the selected biomechanical, postural and anthropometrical characteristics measured in this study contributed practically significantly to shoulder girdle as well as back and spine injuries.

4.3 RECOMMENDATIONS

The limited research available on the contribution of intrinsic risk factors to rugby union injuries emphasises the importance of further research regarding this matter. Future studies should attempt to assess the influence of biomechanical and postural parameters on specific rugby union injuries over the complete season or more than one season. Various clubs with the same age groups should be included to ensure larger player sample sizes. There is also an urgent need for standardization of the way injury is defined in rugby union.

The inconsistency in the literature regarding potential risk factors for sport injuries in general (Chapter 2) highlights the need for uniformity in the research methodologies used, the definition of injury and ways data are being presented. Follow-up studies should also be implemented to investigate the effectiveness of preventative strategies. Only once consensus regarding potential intrinsic and extrinsic risk factors and preventative strategies in a specific sporting activity has been reached across various studies can universal preventative programmes be implemented during the off-season period.

4.4 STUDY LIMITATIONS

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

- The small sample size with a large distribution in injury type resulted in a loss of statistical power. A longitudinal study design, where more clubs with players the same age are included, would have increased the number of subjects and random inclusion would have been possible.
- Players recruited to participate in this study were all from the same institution, the U/21 squad of the Rugby Institute to the North-West University. The results, therefore, cannot be generalized to all U/21 rugby union players.
- The comprehensive test battery may have deferred the subjects to participate in this study due to the time needed to complete the test protocol.
- Lastly, only the injuries sustained during the first five months of the 2005-season were reported. Different results might have been obtained for injury surveillance over a complete season.

APPENDIX A

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 dequately described and their conditions defined?
5. **Methods** - are they adequately described? For randomised 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.]

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 (go to Online Submission and 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 randomisation, 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 (eg, 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 overgeneralisation) 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

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.

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

Colour images

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

Colour images should be saved and supplied as TIFF, GIF, EPS, PowerPoint or high quality JPEG files to a minimum of 600 dpi. Colour 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 colour images on all unsolicited articles. This charge is heavily subsidised 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 that A4 (210 mm x 297 mm). The charge for colour processing will be £100 +VAT for the figure. Parts of colour 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 colours can lead to contamination or loss of colour 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.

REFERENCES

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.)

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/adc.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/adc.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.bmjjournals.com/cgi/eletters/86/5/e11#EL1

APPENDIX B

INLIGTINGSBRIEF RAKENDE RUGBY-PROJEK

Geagte Speler

'n Studie (waarby die O/21-span van die PUK Rugby Instituut betrek word), word deur die Skool vir Biokinetika, Rekreasie en Sportwetenskap geloots.

Die doel van hierdie studie is om te bepaal of intrinsieke faktore [soos byvoorbeeld spierwanbalanse; swak postuur; biomeganiese afwykings (bv. swak soepelheid, afwykings in hardlooppatrone) en antropometriese veranderlikes (vetpersentasie, spiermassa, BMI, ens.) bydrae tot beserings in rugby. Deur hierdie bepaalde faktore te identifiseer kan rugbybeserings in die toekoms moontlik verminder of sodoende voorkom word.

Die volgende toetse gaan op betrokke spelers uitgevoer word:

- Kin Com (Isokinetiese toetse) van die enkel, knie, heup en skouer. Hiermee word die agonis-antagonis verhouding (bv. Quadriceps : hamstring), sowel as die verhouding van die piekkrag teenoor die liggaamsmassa bepaal.
- Antropometriese profiel waarmee persentasie liggaamsvet, spiermassa asook somatotipe bepaal word.
- Biomeganiese analise wat insluit 'n postuurevaluering, soepelheids- en stabiliseringstoetse en 'n hardloopanalise.
- Geskiedenis van beserings in die afgelope seisoen word geneem en beseringsinsidensie van al die betrokke spelers sal in die 2005 rugby-seisoen gemonitor word.

Watter voordeel trek jy uit die studie?

- Die geldwaarde van al die toetse beloop om en by R1 000,00 per speler. Jy kry dit alles verniet.

- Na verloop van die eerste toetsgeleentheid sal elke speler 'n verslag ontvang wat die uitslae van al die toetse saamvat. Jy weet dus wat jou spierverhoudings, vetpersentasie, spiermassa en somatotipe is. (Die verslag sal dus jou eie waarde & die normale waarde aan jou toon.)
- Indien daar enige postuur of biomeganiese abnormaliteite is sal daar in jou verslag riglyne verskaf word oor hoe om dit te verbeter.

LET ASB. DAAROP DAT GEEN SPELER SE DATA INDIVIDUEEL AAN DIE RUGBY INSTITUUT BEKEND GEMAAK WORD NIE.

Watter voordeel trek die Rugby Instituut uit die studie?

- Die antropometriese profiel van die O/21-groep as geheel kan duidelik uitgebeeld word.
- Probleemareas wat uit die biomeganiese profiel van die spelers na vore kom kan aangespreek word.
- Die isokinetiese toetse sal aandui of die spelers se piekkrag in verhouding tot liggaamsmassa is.
- Die sportwetenskaplikes van die betrokke groepe sal dus aanpassings in die gimnasiumprogramme kan maak ten opsigte van die verskeie probleemareas wat uitgewys word.

Jou deelname aan hierdie studie dra by tot belangrike navorsing in die veld van rugby en sportbeserings as geheel. Indien jy enige navrae het rakende die studie kontak my gerus by 082 410 2027 OF (018) 299-1824!!

Vriendelike groete
Erna Bruwer

APPENDIX C

YUNIBESITI YA BOKONE-BOPHIRIMA
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT

CONFIDENTIAL

INFORMED CONCENT

PART 1

1. **School/Institute**

- School for BRS and Institute

2. **Title of the project**

- The contribution of selected intrinsic factors on the nature and incidence of injuries in rugby union players at the Rugby Institute of the North-West University

3. **Aim of this project**

- To determine the incidence and nature of injuries among U/21 rugby union players at the Rugby Institute of the North-West University.
- To determine which of the biomechanical, postural and anthropometrical characteristics will contribute to musculoskeletal injuries of the U/21 rugby union players at the Rugby Institute of the North-West University.

4. **Explanation of the nature of all procedures:**

- ***Demographic information***

The subject's demographic and personal information (gender, race, age, etc.) will be collected by means of a demographic information questionnaire.

- ***Biomechanical assessment***

Goniometric measurements will be used to determine the range of motions of joints as well as the flexibility of selected muscle groups.

Biomechanical tests included flexibility/range of motion, stability and special tests for the lower extremities (flexibility of the hamstring and quadriceps muscle groups; achilles tightness; knee genu valgum, knee genu varum, knee genu recurvatum; tibial torsion; Q-angle; range of motion in plantarflexion and dorsiflexion; functional and anatomical leg length differences), pelvic girdle (flexibility of the gluteus maximus muscle, hip adductor muscles, iliopsoas and iliotibial tract; symmetry of the sacroiliac joint), upper extremities (range of motion of shoulder internal and external rotators; upper extremity stability; scapula humeral rhythm and scapula stability). An upper limb and lower limb tension test, as well as a lower abdominal muscle strength test were included. Pronation and supination of the ankle joint was evaluated by means of a computer assisted gait analysis (Video Trak gait analysis, 2001).

➢ ***Postural analyses***

Postural assessment will be based on high quality photographs from a lateral, and posterior (side-and back) view. The following aspects of posture were assigned a score of 5 (normal posture), 3 (slightly abnormal posture / moderate deviation) or 1 (abnormal posture / major deviation): forward head, flat chest, winged scapulae / round shoulders, kyphosis, inclined trunk, protruding abdomen, lordosis, twisted head, uneven shoulders, scoliosis, uneven hips, pronated feet. The subjects stepped down into powdered white chalk and then onto a black board to check for foot abnormalities (flat feet).

➢ ***Anthropometrical assessment***

Anthropometric variables (21) {body mass (kg), stature (cm), 9 skinfolds (mm), 6 girths (cm) and 4 breadths (cm)} were measured. All measurements were taken according to the methods of ISAK (2001).

➢ ***Five-month injury surveillance***

A validated rugby union injury report questionnaire will be used to determine the previous injury history and new injury data of all players (McManus, 2000:344.). Players will self-report all injuries diagnosed by the medical team of the Rugby Institute as well as injuries not reported to the medical team.

5. Description of benefits which may be expected from this project:

The results obtained from this study will help coaches, sport scientists and Biokineticists to identify the possible intrinsic risk factors that contribute to rugby union injuries. This will assist in evaluating the rugby players during the pre-season in order to compile corrective and preventative programmes to reduce injuries in rugby union players.

PART 2

To the subject signing the consent as in part 3 of this document:

You are invited to participate in the research project as described in Part 1 of this document. It is important that you read the following general principles, which apply to all participants in our research project:

- Participation in this project is voluntary.
- You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of the project.
- We encourage you to ask questions at any stage about the project and procedures.
- We require that you indemnify the University from any liability due to detrimental effects of treatment by University staff or students or other subjects to yourself or anybody else. We also require indemnity from liability of the University regarding any treatment to yourself or another person due to participation in this project, as explained in Part 1. Lastly it is required to abandon any claim against the University regarding treatment of yourself or another person due to participation in this project as described in Part 1.

PART 3
Consent

Title of the project:

The contribution of selected intrinsic factors on the nature and incidence of injuries in rugby union players at the Rugby Institute of the North-West University

I, the undersigned...(full names) read the information on the project in PART1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project.

I indemnify the University, also any employee or student of the University, of any liability against myself, which may arise during the course of the project.

I will not submit any claims against the University regarding personal detrimental effects due to the project, due to negligence by the University, its employees or students, or any other subjects.

(Signature of the subject)

Signed at .... on ....

Witnesses

1. ....

2. ....

Signed at................................. on...

APPENDIX D

BIOMEGANIESE EVALUASIE

	LêEND (Op rug)	
	R	**L**
Leg Length (Functional)		
Leg Length (Anatomical)		
Hamstring straight leg raise		
Hamstring 90° – 90° test (Degrees & Neurological)		
Gluts muscles (Flexes hip to ASIS)		
Lower abdominal muscles	Fair 90° Fair+ 75° Good- 60° Good 45° Good+ 30° Normal 15° - 0°	Fair 90° Fair+ 75° Good- 60° Good 45° Good+ 30° Normal 15° - 0°
VMO Comparison	No apparent difference Apparent diff.	No apparent difference Apparent Diff.
Thomas Test (Been reguit op bed)	Negative Positive	Negative Positive
UPPER LIMB TENSION TEST	**1 2 3 4**	**1 2 3 4**
Shoulder Internal Rotation		
Shoulder External Rotation		
Ankle	Neutral Plantarflexion Dorsiflexion	Neutral Plantarflexion Dorsiflexion
	LêEND (Op maag)	
Functional Extension Mobility test (ASIS to bed)		
Knee Tibial Torsion		
Ely's Rectus Femorus test	Negative Positive	Negative Positive
	LêEND (Op Sy)	
Ober Toets	Negative Positive	Negative Positive

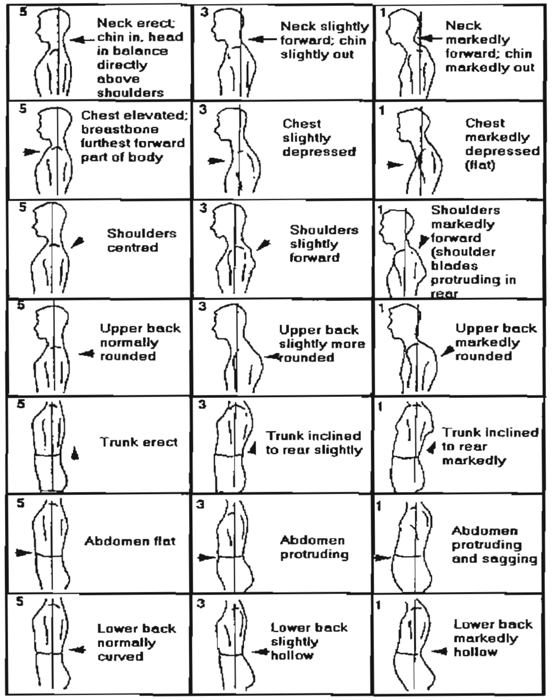
	STAANDE	
	R	**L**
Kendall	Knee extension Abduction Psoas: Verkort Normaal Verleng Voet: Lateraal Neutraal Mediaal	Knee extension Abduction Psoas: Verkort Normaal Verleng Voet: Lateraal Neutraal Mediaal
Trendelenburg	Negative Positive	Negative Positive
Babinski	Negative Positive	Negative Positive
Knee Valgus (Meet tussen Maleoli)		
Knee Varus (Meet med. Aspek knie)		
Knee recurvatum (Observeer patella hoog/laag)	Negative Positive	Negative Positive
Achilles Rom (Hurksit)	Negative Positive	Negative Positive
Knee (Q-Angle)		
Trog. – Tib. Laterale		
Tib. – Laterale Floor		
Tib. Lat. – Med. maleoli		
Sacroiliac Cleft Test	Symmetrical Asymmetrical	Symmetrical Asymmetrical
Hipabduction agains wall		
Hand Behind Back ROM		
Hand Behind Neck ROM		
Scapula Humeral Rhythm		
Push Against Wall (Scapula unilateral Winging)	Negative Positive	Negative Positive
Floor Push-ups (Bilateral scapula winging	Negative Positive	Negative Positive
UPPER EXTREMITY STABILITY TEST Markers 91cm – push-up stand – one hand to other – 15seconds x 3	Value 1 Value 2 Value 3	Value 1 Value 2 Value 3

APPENDIX E

POSTURE RATING CHART

SIDE VIEW POINTS

SCORE



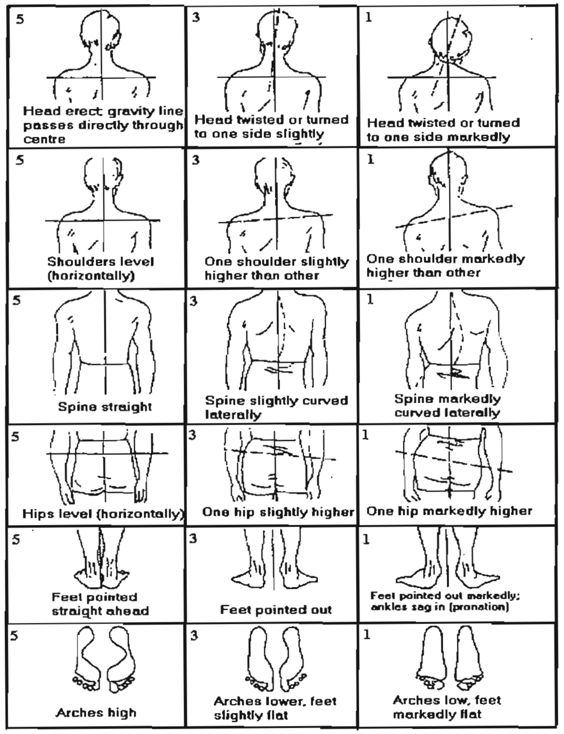
Forward Bending Test (Y/N) ☐

L/R ☐

POSTURE RATING CHART

BACK VIEW POINTS

SCORE



Total: ☐

New York Posture Test

APPENDIX F

ANTROPOMETRIESE PROFORMA

Naam: .... **Datum:** ....

VERANDERLIKE	METING 1	METING 2	METING 3
Velvoue (mm)			
Triseps			
Supskapulêr			
Pektoraal			
Midaksilla			
Iliokristale			
Supra-spinale			
Abdominale			
Frontale dy			
Mediale kuit			
Omtrekke (cm)			
Boarm (ontspanne)			
Boarm (gespanne)			
Pols			
Abdomen (minimum)			
Gluteale/Heup (maksimum)			
Dy (mid)			
Kuit (maksimum)			
Enkel (minimum)			
Deusneë (cm)			
Gewrig (bi-stiloïed)			
Humerus			
Femur			
Enkel			
Liggaamslengte (cm)			
Liggaamsmassa (kg)			

APPENDIX G

VALIDATED RUGBY UNION INJURY REPORT QUESTIONNAIRE

ID:______

Name ______________________ **Team** ______________

Date _____/_____/________ **Position** ______________

Site of injury [Head, Face, Neck, Shoulder, UArm, LArm, Wrist, Hand, Fingers, Thumb, Chest, Abdomen, Spine, Back, ULeg, LLeg, Knee, Ankle, Foot, Toes, Other____]

Acute _________________ **OR Chronic** _________________

Diagnosed by: (Docter, Fisio) ______________________________________

Treatment: ____

Severity of injury

Minor *(if able to return to game/training in which injured)*
Mild *(if missed one week)*
Moderate *(if missed two weeks)*
Severe *(if missed more than two weeks)*

Mechanism of injury

Extrinsic / Intrinsic
Explain: ___________________________________
____

Where

Game / Training

Phases of play or aspect of training

Scrum, Lineout, Ruck, Maul, Tackle, Kicking, Pileup, Collision, Other____________________________
(Fixed play or open play)

Time of game	1st half / 2nd half / time on
Position played	____________________
(number)	_____
Back or forward	B / F
Relationship of ball and injured player	near ball / behind ball
Play	legal / illegal
Protective gear	________________________________
Period in season	________________________________
If terrain a factor of injury	hard / soft / muddy / other ____________________
If weather a factor of injury	hot / cold / wet / other____________________

(McManus, 2000)