

**Thoracic posture, electromyography and isokinetic strength of the shoulder  
in relation to shoulder injuries in semi-professional rugby players**

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## AUTHOR'S CONTRIBUTION

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The principle author of this thesis is Mr. G. Bolton. The contribution of each of the co-authors involved in this study is summarized in the following table:

Author	Contribution
Mr. Garth Bolton	Author. Design and planning of manuscripts, compilation and execution of relevant testing procedures, literature review, data extraction, writing of manuscripts, interpretation of results.
Co-authors	Contribution
Prof. S.J. Moss	Promoter. Co-reviewer, assistance in writing in manuscripts, selection of studies, data extraction, design and planning of manuscripts, interpretation of results. Critical review of the contents, including the Thesis and Articles 1, 2 and 3.
Dr. P.C. Venter	Co-promoter. Assistance in writing of manuscripts and general recommendations with regards to Articles 1, 2 and 3.
Martinique Sparks	Co-author on Article 1: Critical reviewer on the manuscript submitted for publication.

The following is a statement from the co-authors confirming their individual role in each study and giving their permission that the manuscripts may form part of this thesis.

*I declare that I have approved the above mentioned manuscripts, that my role in the study, as indicated above, is representative of my actual contribution and that I hereby give my consent that they may be published as part of the Ph.D. thesis of Garth Bolton.*

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Prof. S. J. Moss

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# ABSTRACT

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## **Thoracic posture, electromyography and isokinetic strength of the shoulder in relation to shoulder injuries in semi-professional rugby players**

The game of rugby union has evolved over the years into a professional sport in which an increased incidence of injury is evident. This also applies to the shoulder joint. It appears that certain risk factors are associated with shoulder pathology among rugby players as well as among the general population. In a competitive sporting environment where high stress loads are placed upon the body and joints, this association may be even more pronounced. Despite the fact that numerous studies have investigated the various factors that potentially play a role in the occurrence of shoulder injuries among sports participants generally, similar studies involving rugby union players in particular are limited. Previous studies have investigated and profiled rugby players with regards to posture, shoulder isokinetic muscle strength and electromyographic patterns, but no study has yet investigated the relationship between these factors and the role they may play in the risk of being injured. It would be beneficial to have a better understanding of the interplay between these factors and to identify the most likely factors to predict and/or prevent shoulder injuries in rugby players. With this information at hand, it might be possible to identify players who are at risk of shoulder injuries in order that they may potentially benefit from effective “pre-habilitation” protocols.

The aim of this study was to determine what the relationship between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns in injured and uninjured rugby players was, and to determine which of these variables might predict shoulder injuries.

### **Methods**

Ninety-one (91) uninjured semi-professional rugby union players’ shoulder joint range of motion differences (ROM) were manually tested with the hand-behind-the-neck and hand-behind-the-back method. The profiling and classification of the thoracic posture was performed using the New York Posture Test. Scapular muscle activation patterns were determined by means of electromyography (EMG) measuring the activation of the upper and lower trapezius, serratus anterior and infrapinatus muscles. The isokinetic muscle strength of

the rotator cuff muscles was determined at 60°/sec (Kin-Com 500H) measuring concentric and eccentric forces during internal and external rotation.

## **Results**

Some participants presented with non-ideal or unsatisfactory shoulder internal rotators (59%) and external rotators (85%) bilateral ROM differences. Of all the participants, 68% presented with an abnormal shoulder position in the lateral view, and the sequence of muscle activation of the scapula stabiliser muscles was found to be: serratus anterior; lower trapezius; infraspinatus and then upper trapezius. The isokinetic antagonist/agonist strength ratio for shoulder rotation during concentric muscle contraction was 64% for the non-dominant and 54% for the dominant shoulder. The corresponding ratios for the eccentric muscle contraction of the non-dominant and dominant shoulders were 67% and 61% respectively.

The median muscle onset times of the backline players' non-dominant infraspinatus muscles were 35.90 ms for ideal, 95.20 ms for non-ideal, and 93.90 ms for the unsatisfactory external rotators' range of motion (ROM) differences. The median firing orders of the forwards' dominant lower trapezius muscle was 3 for ideal, 1 for non-ideal, and 2 for unsatisfactory external rotators' ROM differences. Among the forward shoulder group and the normal shoulder position group of the forwards respectively, the median muscle onset time of their non-dominant infraspinatus muscle was 113 milliseconds (ms) and 42 ms. Their non-dominant serratus anterior muscles' median onset time was 78.85 ms among the players with a rounded back, and 31.90 ms among the players with a normal thoracic curvature. The backline players displayed a median non-dominant serratus anterior onset time of 47.45 ms (in the uneven shoulder group) versus 32.75 ms (in the even shoulder group). The median firing order of the backline players' non-dominant infraspinatus muscle was third in the normally curved back group. Among the players with an abnormally rounded back, however, the median firing order changed to second. The median external rotation/internal rotation isokinetic strength ratio of the forward players was 63% (forward shoulders), versus 56.50% (normal shoulder position). This was for their non-dominant shoulders. Certain isokinetic shoulder strength ratios displayed statistically significant correlations with scapular muscle activation patterns but they were not clinically significant.

Players who had sustained shoulder injuries during the season differed significantly from those who had not sustained injuries with regards to the following baseline measurements: age (the injured were older), height (the injured were taller) and non-dominant/dominant concentric external rotation ratio (the injured had a higher ratio). Among the backline players

baseline differences occurred within age (the injured were older), weight (the injured were heavier), height (the injured were taller) and the body mass index (BMI) (the injured had a higher BMI). The variables that displayed statistically significant predictive values towards future injury were age (1.34 times increase for each year older), insufficient shoulder external rotator ROM differences (16.15 times increase if an unsatisfactory ROM difference occurs), uneven shoulders (4.43 times increase if shoulders were abnormally uneven) and the non-dominant/dominant concentric external rotation strength ratio (a 1.42 times increase for every 10% that the ratio increases).

## **Conclusion**

Profiling of the group of players revealed that their non-ideal or unsatisfactory flexibility of shoulder external rotators, their forward shoulders in the lateral view, and their weakness of the shoulder external rotators did not result in abnormal scapular muscle activation patterns.

Positive relationships were found between certain postural abnormalities (forward shoulders, a rounded back and uneven shoulders) and the delay of muscle onset times of infraspinatus and serratus anterior, as well as the firing order of infraspinatus. Forward shoulders increased antagonist/agonist isokinetic shoulder rotation strength ratios. Non-ideal or unsatisfactory flexibility of shoulder external rotators displayed positive relationships with altered infraspinatus muscle onset times and an altered lower trapezius muscle firing order. No clinically significant correlations were found between isokinetic shoulder strength ratios and scapulae muscle activation patterns.

It appears that posture (uneven shoulders), has a higher predictive ability than shoulder strength imbalance (non-dominant/dominant concentric external rotation ratio) regarding future shoulder injury. However, age and especially external rotator ROM deficiency proved to be strong predictors of future shoulder injury in semi-professional rugby players.

Key words: EMG, isokinetic, posture, shoulder, injury

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# OPSOMMING

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## **Torakale postuur, elektromiografie en isokinetiese krag van die skouer en die verband met skouerbeseerings onder semi-professionele rugbyspelers**

### **Agtergrond**

Rugby het gedurende die laaste twee dekades verander van 'n amateurstatus-sportsoort in 'n professionele sportsoort met 'n toenemende voorkoms van beseerings. Hierdie toename is ook opmerklik ten opsigte van skouerbeseerings. Verskeie studies het bewys dat daar sekere risikofaktore is wat rugbyspelers asook individue in die breë bevolking meer vatbaar maak vir skouerbeseerings. In 'n mededingende sportiewe omgewing waar fisieke vereistes hoër is as dié van normale daaglikse aktiwiteite, kan hierdie korrelasies nog verder versterk word. Ten spyte van die feit dat verskeie studies die moontlike bydraende faktore van skouerbeseerings onder sportlui bestudeer het, is die voorkoms van soortgelyke studies met die oog op rugbyspelers beperk. In die verlede het sekere studies rugbyspelers se torakale postuur, skapulêre spier-aktiveringspatrone en isokinetiese krag van die skouers bestudeer, maar tot op hede het geen studie die onderlinge verband tussen hierdie faktore asook hulle vermoë om potensiële skouerbeseerings te voorspel, ondersoek nie. Inligting van hierdie aard behoort van waarde te wees, aangesien dit moontlik sal kan help om spelers te identifiseer wat meer vatbaar is vir skouerbeseerings. Sodoende kan hierdie spelers teoreties baat vind by meer oefenintervensies wat beseerings sal voorkom.

Die doel van hierdie studie was om te bepaal wat die verhouding tussen torakale postuur, isokinetiese skouerkrage en skapulêre spier-aktiveringspatrone onder beseerde en nie-beseerde rugbyspelers was asook om te bepaal watter van hierdie veranderlikes die beste voorspeller van skouerbeseerings blyk te wees.

### **Metodes**

Een-en-negentig (91) onbeseerde semi-professionele rugbyspelers se bilaterale skouerbeweging-omvangsverskille is getoets met behulp van die “hand-agter-die-rug”- en “hand-agter-die-nek”-metode. Die profiel en klassifisering van hulle torakale postuur is gedoen met behulp van die “New York Posture Test”. Skapulêre spier-aktiveringspatrone is

bepaal deur middel van elektromiografietoetsing (EMG-toetsing) wat die aktiveringspatrone en aanvangstye van die boonste trapezius-, laer trapezius-, serratus anterior- asook infraspinaatusspiere bepaal het. Die konsentriese en esentriese spierkrag van die rotatorkraagspiere is bepaal deur isokinetiese toetings met interne en eksterne rotasie teen 60 grade per sekonde (Kin-Com 500H).

## **Resultate**

Van die deelnemers in die studie het nie-ideale of onbevredigende bewegingsomvangverskille in hulle bilaterale skouer- interne rotators (59%) en eksterne rotators (85%) getoon. Van al die deelnemers het 68% abnormale skouerposisie (vanuit 'n laterale aansig) ten toon gestel en die aktiveringsvolgorde van die skapulêre spiere was soos volg: serratus anterior; laer trapezius; infraspinaatus en dan boonste trapezius. Die isokinetiese antagonis-/agoniskragverhouding vir skouerrotasie gedurende konsentriese spierkontraksie was 64% vir die nie-dominante skouer en 54% vir die dominante skouer. Die ooreenstemmende verhouding vir die esentriese spierkontraksie van die nie-dominante en dominante skouer was 67% en 61% onderskeidelik.

Die mediaan vir spieraanvangstye van die agterspelers se nie-dominante infraspinaatusspiere was 35.90 millisekondes (ms) vir ideale, 95.20 ms vir nie-ideale en 93.90 ms vir onbevredigende eksterne rotator-bewegingsomvangverskille. Die mediaan-aktiveringsvolgorde vir die voorspelers se dominante laer trapezius was derde vir ideale, eerste vir nie-ideale en tweede vir onbevredigende eksterne rotator-bewegingsomvangverskille. Onder die voorspelers wat in die vorentoe-skouer-groep en normale-skouerposisie-groep geval het, was die mediaan-spieraktiveringsaanvangstyd vir die nie-dominante infraspinaatus 113 ms en 42 ms onderskeidelik. Hulle nie-dominante serratus anterior-mediaanaanvangstyd was 78.85 ms onder die spelers met 'n "ronde" rug en 31.90 ms onder die spelers met 'n normale torakale kurwe. Die agterspelers het 'n mediaan- nie-dominante serratus anterior-aanvangstyd van 47.45 ms (in die ongelyke skouergroep) teenoor 32.75 ms (in die gelyke skouergroep) getoon. Die mediaan-aktiveringsvolgorde vir die agterspelers se nie-dominante infraspinaatusspier was derde in die groep wat 'n normale torakale kurwe ten toon gestel het. Onder die spelers met 'n abnormale geronde rug het die mediaanvolgorde egter na tweede verander. Die mediaan- eksterne rotasie-/interne rotasie-isokinetiese kragverhouding vir die voorspelers was 63% (vorentoe skouers) versus 56.50% (normale skouerposisie). Dit was vir hulle nie-dominante skouers. Sekere isokinetiese skouerkragsverhoudings het statisties beduidende korrelasies met skapulêre

spieraktiveringspatrone ten toon gestel, maar hierdie korrelasies was nie klinies beduidend nie.

Deelnemers wat beserings gedurende die seisoen opgedoen het, het beduidend verskil van die onbeseerde deelnemers ten opsigte van die volgende metings: ouderdom (die beseerde spelers was ouer), lengte (die beseerde spelers was langer) en nie-dominante/dominante konsentriese eksterne rotasiekragverhouding (die beseerdes het 'n hoër verhouding gehad). Onder die agterspelers het basislynverskille voorgekom met betrekking tot ouderdom (die beseerde deelnemers was ouer), gewig (die beseerde deelnemers was swaarder) en die liggaamsmassa-indeks (LMI) (die beseerde spelers het 'n hoër LMI getoon). Die veranderlikes wat statisties beduidende voorspellende waarde tot toekomstige skouerbeserings ten toon gestel het, was ouderdom ('n toename van 1.34 keer vir elke jaar ouer), onvoldoende skouer- eksterne rotator-bewegingsomvangsverskille ('n toename van 16.15 keer as 'n onbevredigende bewegingsomvangsverskil voorkom), ongelyke skouers ('n toename van 4.43 keer as die skouer ongelyk was) en die nie-dominante/dominante konsentriese eksterne rotasiekragverhouding ('n toename van 1.42 keer vir elke 10% wat die verhouding toeneem).

### **Gevolgtrekking**

Die deelnemerprofile het aangedui dat hulle nie-ideale of onbevredigende soepelheid van skouer- eksterne rotators, hulle vorentoe skouers (vanuit 'n laterale aansig) en hulle relatiewe swakheid van skouer- eksterne rotatorkrag nie abnormale skapulêre spieraktiveringspatrone tot gevolg gehad het nie.

Positiewe verhoudings is gevind tussen sekere postuurafwykings (vorentoe skouers, 'n ronde rug en ongelyke skouers) en die vertraging van spieraktiveringsaanvangstye van infraspinatus en serratus anterior asook die aktiveringsvolgorde van infraspinatus. Vorentoe skouers het die antagonis-/agonis- isokinetiese skouerrotasiekragverhoudings verhoog. Nie-ideale of onbevredigende soepelheid van skouer- eksterne rotators het positiewe verhoudings getoon met veranderde aanvangstye vir infraspinatus-spieraktivering en veranderde laer trapeziusaktiveringsvolgorde. Geen klinies beduidende korrelasies is tussen isokinetiese skouerkragverhoudings en skapulêre spieraktiveringspatrone gevind nie.

Die gevolgtrekking van die studie is dat dit wil voorkom asof postuur (ongelyke skouers) 'n hoër voorspellende waarde as spierwanbalans (nie-dominante/dominante konsentriese eksterne rotasieverhouding) het ten opsigte van toekomstige skouerbeserings. Tekortkominge

in ouderdom en veral skouer- eksterne rotatorbewegingsomvang het ook geblyk sterk voorspellers van toekomstige skouerbeserings onder semi-professionele rugbyspelers te wees.

Sleutelwoorde: EMG, isokineties, postuur, skouer, besering

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## LIST OF ABBREVIATIONS

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<b>% :</b>	Percentage
<b>60°/sec:</b>	Sixty degrees per second
<b>Abn. RBack:</b>	Abnormally rounded back
<b>AC:</b>	Acromioclavicular
<b>ACC:</b>	Compensation Insurance Corporation
<b>B:</b>	Beta coefficient
<b>BMI:</b>	Body mass index
<b>C.I.:</b>	Confidence interval
<b>C:</b>	Concentric
<b>cm:</b>	Centimeters
<b>CRCP:</b>	Chronic rotator cuff pathology
<b>D:</b>	Dominant
<b>DCR:</b>	Dynamic control ratio
<b>E:</b>	Eccentric
<b>EMG:</b>	Electromyography
<b>ER/IR CD:</b>	External rotation/internal rotation concentric dominant
<b>ER/IR CND:</b>	External rotation/internal rotation concentric non-dominant
<b>ER/IR ED:</b>	External rotation/internal rotation eccentric dominant
<b>ER/IR END:</b>	External rotation/internal rotation eccentric non-dominant

<b>ER:</b>	External rotation
<b>ER:</b>	External rotation
<b>GH:</b>	Glenohumeral
<b>IF:</b>	Infraspinates
<b>IR/ER:</b>	External/internal rotation
<b>IR:</b>	Internal rotation
<b>IR:</b>	Internal rotation
<b>IRB:</b>	International Rugby Board
<b>JPS:</b>	Joint position sense
<b>Kg:</b>	Kilogram
<b>LT:</b>	Lower Trapezius
<b>m<sup>2</sup>:</b>	Square meter
<b>Microvolt:</b>	mV
<b>Milliseconds:</b>	ms
<b>Millisekondes:</b>	ms
<b>N:</b>	Sample size
<b>ND/DcER:</b>	Non-dominant/dominant concentric external rotation
<b>ND/DcIR:</b>	Non-dominant/dominant concentric internal rotation
<b>ND/DeER:</b>	Non-dominant/dominant eccentric external rotation
<b>ND/DeIR:</b>	Non-dominant/dominant eccentric internal rotation
<b>ND:</b>	Non-dominant
<b>Nm:</b>	Newton meter
<b>NWU PUK RI:</b>	North-West University PUK Rugby Institute
<b>NWU:</b>	North-West University

<b>° :</b>	Degrees
<b>OR:</b>	Odds ratio
<b>p:</b>	Probability
<b>RIPP:</b>	Rugby Injury and Performance Project
<b>ROM:</b>	Range of motion
<b>S.E.:</b>	Standard error
<b>SA:</b>	Serratus Anterior
<b>SARU:</b>	South African Rugby Union
<b>SD:</b>	Standard deviation
<b>SLAP:</b>	Superior labral anterior-posterior
<b>UT:</b>	Upper Trapezius

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# CHAPTER 1

## INTRODUCTION

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### **1.1 Introduction**

The game of rugby union has gained in popularity globally and in South Africa (International Rugby Board, 2011). In conjunction with the increased intensity and competitiveness of the game, this has led to the fact that rugby has one of the highest incidences of injury per player hour when compared to other sports (Brooks *et al.*, 2005:757; Headey *et al.*, 2007:1537; Gabbett 2008:325; Fuller *et al.*, 2010:159). The occurrence of shoulder injuries among rugby players is also on the increase (Brooks *et al.*, 2005:757). Although certain external factors contribute to the occurrence of injuries among rugby players, there are also factors intrinsic to an individual that may play a role (Taimela *et al.*, 1990:205; Brooks *et al.* 2005:757; Fuller *et al.*, 2010:165). Identifying these possible risk factors at an early stage may have a significant influence on the pro-active prevention of especially shoulder injuries among rugby players.

### **1.2 Problem statement**

Rugby union is a vigorous contact sport which enjoys particular popularity in Australia, Britain, France, New Zealand and South Africa (Quarrie 2001:158). According to Brooks *et al.* (2005:757), rugby union is one of the most popular professional team sports in the world, but various authors have reported that rugby has one of the highest incidences of injury (Brooks *et al.*, 2005:757; Headey *et al.*, 2007:1537; Gabbett 2008:325; Fuller *et al.*, 2010:159). Holtzhausen (2001:6) reported an incidence rate for rugby of 86.4 injuries per

1000 player game hours. This is a higher rate than the injury rates for Australian rugby league (44.9 injuries per 1000 player game hours), Australian rules' football (33.5 injuries per 1000 player game hours) and football (16.9 injuries per 1000 player game hours) as reported by Gibbs (1993:700).

Quarrie (2001:158) states that the nature and incidence of rugby injuries have been well documented. In New Zealand a large player base (about 120000 in a population of 3.8 million people) and a high incidence of injury (Hume and Marshall, 1994:18), makes rugby the largest contributor to sports injury cost (quoted by Quarrie, 2001:158). Rugby enjoys great popularity in South Africa, where 651146 players (including women rugby players) are currently participating in the sport (International Rugby Board, 2012). The South African Rugby Union (SARU) could not indicate rugby's annual contribution towards medical cost, but with such a large player base, it is safe to assume that rugby's contribution to sports injury costs would be substantial.

According to the literature, certain intrinsic and extrinsic factors may predispose rugby players to injury (Quarrie *et al.*, 2001:157). The extrinsic risk factors include the nature of the sport and environmental conditions (Quarrie *et al.*, 2001:157), the phase of play (Bathgate *et al.*, 2002:268), the playing position (Targett, 1998:280), and the level of play (Bathgate *et al.*, 2002:268). Intrinsic risk factors are specific to the individual and include age, anthropometric characteristics, fitness, psychological characteristics, health status, and injury history (Quarrie *et al.*, 2001:157).

In a prospective study done on elite Australian rugby union players, Bathgate *et al.* (2002:268) found that the tackling phase of play accounted for most injuries, which is in accordance with most other studies (Jakoet and Noakes, 1997:47; Bird *et al.*, 1998:323; Brooks *et al.*, 2005:765; Fuller *et al.*, 2007:865). Garraway *et al.* (2000:350) found in a study on professional and amateur rugby players that the highest proportion (48%) of injury episodes occurred in the tackle situation.

Brooks *et al.* (2005:761) observed no significant differences in the incidence of injury between forwards and backs. However, other studies at club level have reported higher incidences of injury for forwards than backs in rugby union (Targett, 1998:280). Quarrie (2001:158) is of the opinion that the type of injury a player is likely to sustain is related to the playing position. According to Brooks *et al.* (2005:761), greater demands are placed on

forwards than backs in terms of contact and collision situations in rugby union. The significantly greater body mass of forwards allows them to develop greater momentum than back line players during play (Brooks *et al.*, 2005:761). These factors have been suggested as possible explanations for the higher incidence of injury among forwards (Brooks *et al.*, 2005:761).

Lower limb injuries seem to be the most common injuries to occur among rugby players (Bird *et al.*, 1998:322; Brooks *et al.*, 2005:761). Bathgate *et al.* (2002:268) found that in Australian players of rugby union lower limb injuries accounted for just over half of the injuries. Most of these were knee and thigh injuries. These authors also found a low rate of injuries to the upper limb (15.4%), compared to the studies of Jakoet and Noakes (1997:47) and Bird *et al.* (1998:323). However, Bathgate *et al.* (2002:268) also found that upper limb injuries accounted for 34.4% of the severe injuries. When involved, the upper limb was more likely to be severely injured. For example, 55.6% of the reported shoulder injuries were severe (Bathgate *et al.*, 2002:268). Bird *et al.* (1998:322) also found that shoulder dislocation/instability was responsible for the second highest number of days of absence from play. Acromioclavicular and rotator cuff injuries were especially noticeable in forwards (Bird *et al.*, 1998:322). In a study done by Bruwer (2006:53) on under-21 rugby players from the North-West University, it came to the fore that the most common region of injury among backline players was the shoulder region (25%). These injuries result in muscle strength imbalances (Chandler *et al.*, 1992:455), faulty scapular muscle activation (Cools *et al.*, 2002:222) and poor posture (Watson, 2001:224).

A number of studies have quantified the importance of the rotator cuff muscles in shoulder rotation strength to prevent injury (Itoi, 1997:77; David *et al.*, 2000:99; MacDermid *et al.*, 2004:593). It has been determined that the rotator cuff muscles are prime movers in shoulder rotation and that they also play a role in stabilizing the shoulder joint (David *et al.*, 2000:99). Previous studies have demonstrated that reliable measures of rotator cuff strength can be obtained with certain isokinetic dynamometers (Leggin *et al.*, 1996:19). Isokinetic muscle evaluations are commonly used in the assessment of muscle performance in healthy and injured athletes (Leroux, 1994:113). David *et al.* (2000:96) state that the strength of shoulder muscles is often measured with isokinetic dynamometers, even though most studies involved healthy subjects and only a very limited number used incapacitated patients. According to Mikesky *et al.* (1995:6420), concentric strength has been used frequently to determine whether or not an athlete is functionally ready to return to the field of play after injury.

Mikesky *et al.* (1995:6420) state that the assessment of concentric strength reveals only a part of the muscle's function, and that eccentric contractions are an integral part of sports performance. Consequently, the testing of eccentric strength seems to be of the utmost importance among athletes (Mikesky *et al.*, 1995:6420). Isokinetic muscle strength measurements have been well studied and reported in muscle imbalance studies in various sports, but few have focused on rugby (Mikesky, 1995:638; Wang *et al.*, 2000:39). Coetzee *et al.* (2002:25) and Edouard *et al.* (2009:863) have however aimed to establish profiles of the internal rotation (IR) and external rotation (ER) shoulder strength of rugby players by isokinetic muscle strength assessment, and also investigated whether or not rotator cuff muscle imbalances occurred among rugby players. Coetzee *et al.* (2002:25) found a concentric external/internal rotator muscle ratio of 61% for rugby backline players, and 57% for the rugby forwards. Edouard *et al.* (2009:865) found that the mean ER/IR ratio among the rugby players was 67% and that no imbalances were found among the rotator muscles of the rugby players.

Cools *et al.* (2004:64) is of the opinion that isokinetic investigations alone do not reflect the quality of scapulothoracic muscle performance. In addition to a sufficient isokinetic test protocol, the use of electromyography (EMG) is considered valuable for investigating neuromuscular performance in healthy and injured shoulders (Hancock & Hawkins, 1996:84). Bagg and Forest (1986:111) describes electromyography as "an extremely useful investigative procedure in determining muscle activity in living human subjects". A combination of EMG testing with isokinetic dynamometry could provide relevant information regarding the function of shoulder musculature. Clinical inferences based on isokinetic strength-related parameters are limited due to the inability to isolate a specific muscle (David *et al.*, 2000:100). Consequently, David *et al.* (2000:100) stress the need for a combined test protocol.

The complexity of the shoulder joint and girdle should be considered in order to correctly evaluate muscle strength and activation respectively. The mobility of the shoulder complex involves combined motions of the sternoclavicular, acromioclavicular, scapulothoracic and glenohumeral joints (Fayad, 2006:932). Ebaugh *et al.* (2006:224) describe shoulder girdle motion as a complex and synchronous movement of the scapula, clavicle, and humerus. During an arm raise the scapula rotates upwardly, tilts posteriorly, and rotates externally (McClure *et al.*, 2001:276), while the clavicle elevates and retracts (Ludewig *et al.*, 2004:141; McClure *et al.*, 2001:276) and the humerus elevates and rotates externally (Stokdijk *et al.*,

2003:296). The generally accepted scapula-humeral ratio is 1:2 (Inman *et al.*, 1996:12). This coordinated motion is important for normal functioning of the shoulder girdle and is dependent upon capsulo-ligamentous structures and neuromuscular control (Kibler and McMullen, 2003:142).

Of the many muscles attached to the scapula, some act as scapular rotators and others are concerned with glenohumeral movement (Cools *et al.*, 2004:64). According to Cools *et al.* (2003:547), the optimal functioning of the scapulae stabilising muscles depends on the correct timing of the muscle activation of the scapula muscles. When considering the important role that shoulder musculature plays in producing and controlling shoulder motion, it makes sense that impairments of these muscles could alter the motion of the scapula, clavicle, and/or humerus (Ebaugh *et al.*, 2006:224). Kibler (1998:327) states that weakness in one or more scapular rotators may cause muscular imbalance in the force couples around the scapula, leading to abnormal kinematics. Altered scapular kinematics has been identified in individuals with impingement syndrome (Warner *et al.*, 1992:191), rotator cuff tears (Paletta *et al.*, 1997:516), and glenohumeral instability (Paletta *et al.*, 1997:516; Warner *et al.*, 1992:191; Horsley *et al.*, 2010:8). Bagg and Forest (1986:111) state that a good understanding of the muscular coordination of scapular rotators is fundamental to a more complete understanding of movement in the shoulder region. Hence the need for electromyography.

Currently the literature available on the electromyography of rugby players linking shoulder injuries with abnormal scapular muscles recruitment is limited. However, the relationship that exists between shoulder pathology and altered muscle recruitment patterns among overhead athletes may be similar to that among rugby players. Cools *et al.* (2004:67) found that overhead athletes with impingement symptoms showed abnormally timed muscle recruitment in the trapezius muscle. The study indicated that in response to a sudden arm movement the experimental group demonstrated significantly slower muscle activation in the middle and lower trapezius compared to the control group. This was true for both the injured and the uninjured extremity. More specific to rugby, Horsley *et al.* (2010:1) did a study where the objective was to assess the influence of a superior labral anterior-posterior (SLAP) lesion on the onset of EMG activity in shoulder muscles during a front-on rugby tackle. Horsley *et al.* (2010:8) also found that a delay of onset time occurred among the muscles pertaining to the injured shoulder with the exception of an associated earlier onset of activation of the serratus anterior muscles.

According to Goldberg *et al.* (2003:179), macro-traumatic failure and tearing of the rotator cuff in the younger patient is more likely when associated with a high-energy contact sport (i.e. rugby). It is rare that a single extraneous force from an injury is greater than the tensile strength of the normal tendon (Goldberg *et al.*, 2003:179). When rotator cuff tears occur in such athletes, the cuff may already be weakened from an accumulation of micro-trauma caused by rugby-related activities. These activities include tackling, being tackled, scrumming, mauling and engaging in line-outs. During a single rugby match players can make up to 30 tackles, forwards can scrum 25 times per match, maul 30 times per match, and participate in 31 line-outs per match (International Rugby Board, quoted by Goldberg *et al.* (2003:179)).

Loss of the stabilising muscles' activity, together with inadequate muscle strengthening, may result in a posture with a more pronounced kyphosis, as is often observed in rugby players (Bruwer, 2006:56). Finley and Lee (2003:566) concluded that increased thoracic kyphosis significantly alters the kinematics of the scapula during humeral elevation. According to Watson (2001:224), defects of posture are important predictors of specific types of sports injuries. In normal shoulder function, the inferior muscles of the rotator cuff play a key role in containing the humeral head within the glenoid fossa through the synchronous action of the infraspinatus, teres minor (external rotators) and subscapularis (internal rotator) (Arcuni, 2000:60; Reddy *et al.*, 2000:520). Subacromial impingement is associated with inadequate humeral head depression during the critical first portion of elevation, resulting in superior migration of the humerus into the subacromial space (Reddy *et al.*, 2000:520). Impingement of the rotator cuff tendons between the humeral head and the coraco-acromial arch is a common sign in chronic rotator cuff pathology (CRCPP), often resulting in shoulder pain associated with overhead activities (Arcuni, 2000:60). Evidence that links poor thoracic (specifically kyphosis) and upper limb posture to injuries in rugby players, however, seems to be unavailable.

The research question that needs to be answered, considering the above information as well as the nature of rugby (especially the mechanics of the tackle situation) is: What is the relationship between thoracic posture, isokinetic strength and scapulae muscle activation in injured and uninjured semi-professional rugby players, and which of these variables may predict shoulder injuries?

The contribution this study aims to make is to identify relevant information regarding the predictors of shoulder injuries. The literature clearly supports the use of isokinetic equipment to evaluate the strength and functionality of the shoulder joint (David *et al.*, 2000:95; Cools *et al.*, 2003:542). Falla *et al.* (2003:431) propose that future research should rather concentrate on investigating the presence of dysfunction in the deep rotator cuff of the shoulder and on assessing the nature of the dysfunction.

Results from the study will shed light on the most relevant tests to perform in order to predict and/or prevent shoulder injuries in rugby players. With this information at hand, it might be possible to identify players who are at risk of shoulder injuries to potentially benefit from more effective “pre-habilitation” protocols.

### **1.3 Objectives**

The main objectives of this study are to determine:

1. The thoracic posture, isokinetic shoulder strength ratios and scapulae muscle activation patterns among semi-professional rugby union players.
2. The relationship between thoracic posture, isokinetic shoulder muscle strength and scapulae muscle activation patterns among semi-professional rugby players.
3. Which of the thoracic posture, isokinetic shoulder strength or scapulae muscle activation patterns in semi-professional rugby players predicts shoulder girdle injuries.

### **1.4 Hypothesis**

This study is based on the following hypotheses:

1. That an abnormally kyphotic thoracic posture is observed, isokinetic shoulder strength ratios are within the normal range and abnormal scapulae muscle activation patterns exist among semi-professional rugby players.
2. That a significant positive relationship is found between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns among semi-professional rugby players.
3. Thoracic posture will be the most significant predictor of shoulder girdle injuries among semi-professional rugby players, compared to isokinetic shoulder strength and scapulae muscle activation.

## 1.5 Structure of the thesis

The results of this thesis will be presented in the format of three individual research articles. Each article will consist of a unique aim, discussions and conclusions. All of the articles will be presented for publication in accredited scientific journals. Chapter 1 is the introductory chapter, in which the problem statement, objectives and hypotheses of the study are given. The list of references is proposed at the end of the chapter according to the Harvard guidelines adapted by the North-West University (NWU). Chapter 2 is a review of the current literature and aims to discuss the increased incidence of injuries, particularly shoulder injuries, after the introduction of professionalism into the game of rugby union. The chapter reports on the correlations the literature indicates between poor posture, isokinetic weaknesses and imbalance, altered scapular activation patterns, and potential shoulder injury. The list of references is proposed at the end of the chapter according to the regulations of the NWU Harvard style.

In Chapter 3 the profiles of semi-professional rugby union players with regards to thoracic posture, isokinetic shoulder strength ratios, and scapulae muscle activation patterns are presented. This article was published in the *South African Journal of Sports Medicine*. The regulations of this journal will be attached as an Appendix (Guidelines for Authors) at the end of the thesis.

Chapter 4 is an article that determines the relationship between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns among injured and uninjured semi-professional rugby players respectively. This article will be presented for publication in the *Journal of Biomechanics*. The list of references at the end of the chapter will be proposed according to the regulation of this journal, which will be attached as an Appendix (Guidelines for authors) at the end of the thesis.

Chapter 5 aims to determine which of thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns in professional and semi-professional rugby players predict shoulder girdle injuries. This article will be presented for publication in the *International Journal of Rehabilitation Research*. The list of references at the end of the chapter will be proposed according to the regulation of this journal, which will be attached as an Appendix (Guidelines for authors) at the end of the thesis.

Chapter 6 consists of a general discussion, conclusion, limitations and general recommendations for the overall findings of the stated objectives.

The method and results of this study will be incorporated in Chapters 3, 4 and 5. Therefore, no separate method and results chapter will be presented in this thesis.

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# CHAPTER 2

## LITERATURE REVIEW: INTRINSIC RISK FACTORS RELATED TO SHOULDER INJURIES IN RUGBY UNION

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### **2.1 Introduction**

Rugby union is a popular sport, and ranks second in terms of global participation as a football code (Hughes & Fricker, 1994:249). The consequences for accepting the financial, and various other rewards accompanying the emergence of professionalism in rugby union in 1995 appear to include a major increase in player morbidity (Garraway *et al.*, 2000:348). This has happened to such an extent that Medved (quoted by Babić *et al.* 2001:392) considered the number of injuries in rugby “greater

than among all other sports". It has been reported by various authors that rugby has one of the highest incidences of injury (Brooks, 2005:757; Gabbett, 2008:324; Fuller, 2010:159). Epidemiological studies have shown that the incidence of shoulder injuries is increasing (Herrington and Horsley, 2009:1). According to Funk and Snow (2007:1), the shoulder is the second most common site of injury in the rugby union player, making up almost 20% of all rugby injuries. Upper limb injuries accounted for 34% of the severe injuries in a study done by Bathgate *et al.* (2002:268). Bathgate *et al.* (2002:268) also reported that the upper limb, when involved, was more likely to be severely injured and that 55% of the shoulder injuries that were seen were of a severe nature.

When the nature of rugby union is investigated and the introduction of professionalism into the game is considered, it is hardly surprising that the literature describes rugby as one of the most dangerous sports in terms of the incidence and severity of injuries. A fair percentage of all severe injuries that are suffered during rugby matches and training are in fact shoulder injuries. By minimising the extent, occurrence and recurrence of shoulder injuries in rugby, rugby could theoretically be made a safer and even more popular game. The financial implications for players (arising from decreased injury costs) may also prove to be significant.

This literature review will introduce the origins of rugby union (abroad and in South Africa) investigate how the popularity of the game has increased over the years, and whether or not professionalism has played a role in the increased numbers of injuries sustained in the game. Regardless of the role of professionalism in terms of the popularity of rugby, it consistently comes to the fore that professionalism has had a significant impact on the morbidity of rugby players. This chapter will also discuss the role of certain extrinsic factors which seem to play a role in the occurrence of injuries, for instance a player's position and level of play, according to the literature. This literature review will, however, focus on the intrinsic risk factors such as posture (shoulder, upper back, forward head) and shoulder biomechanics that include the relevant muscle activation patterns and isokinetic muscle strength of the shoulder girdle and joint. The purpose of this literature review is to reveal the influence of these intrinsic risk factors on shoulder injuries.

## **2.2 The origins of rugby**

“In the year 1923, throughout the whole world where Rugby football is played, and especially in South Africa, thousands of Rugby men, old and young, turned their thoughts towards a famous school, in the pretty little town of Rugby in the county of Warwickshire, right in the centre of England, for it was there, exactly a hundred years ago, that a schoolboy named William Webb Ellis first took the ball in his arms and ran with it towards his opponents’ goal-posts, and so originated the football game which is called ‘Rugby’, in honour of the place where it occurred”. This is how Ivor D. Difford, in his 1933 publication of “The History of South African Rugby Football”, briefly described how the game of Rugby originated in 1823 (Difford, 1933:8).

Some historians, however, dispute this account of the origins of the game of rugby. According to Bath *et al.* (1997:8) there are so many conflicting reports of how the game of rugby came in to being that the only thing that is certain is that Rugby School's Webb Ellis did not spontaneously invent the game when he picked up the ball and ran with it, showing "a fine disregard for the rules of football (soccer) as played at his time" (Bath *et al.*, 1997:8).

According to Bath *et al.* (1997:224) some Irish historians of the game claim that William Webb Ellis was actually giving a demonstration of “Caid”. “This ancient Irish free-for-all is very similar to rugby, and Webb Ellis could have witnessed it as a young boy when his soldier father was stationed in Ireland with the Dragoons.” (Bath *et al.*, 1997:8). It is likely that the origins of the game go back even further than Caid, to the Roman Empire and a popular game of the time called “Harpastum”. “And even then it is said that the Romans actually imported that game from China and Japan where it had been played for many centuries, while some claim that the game was an Ancient Greek pastime called "Episkyros". Whatever the case might be, Harpastum was very much like rugby in that it involved two teams whose sole objective was to carry a leather ball stuffed with cloth or feathers over their opponents' goal line”. (Bath *et al.*, 1997:8)

## **2.3 Rugby in South Africa, and globally**

According to the South African Rugby Union (2011), the first match in South Africa took place between the "Officers of the Army" and the "Gentlemen of the Civil Service" at Green Point in Cape Town in 1862 and ended as a 0-0 draw. According to them the game spread with British colonisers through the Eastern Cape, Natal and along the gold and diamond routes to Kimberley and

Johannesburg. Over the years the popularity of the game has increased and it is a popular sport played worldwide by men, and increasingly by women (South African Rugby Union, 2011). According to Hughes and Fricker (1994:249) this international sport ranks second in participation only to soccer as a football code. People of every race and creed, from ages five to ninety-years, participate in rugby in more than 100 countries worldwide. In a few of those countries, New Zealand, Western Samoa, Tonga, and Wales for instance, it is the national sport, some say a religion (South African Rugby Union, 2011). Rugby also enjoys great popularity in South Africa, where 651146 players (including women rugby players) currently participate in the sport (IRB, 2012). The sport's governing body is the International Rugby Board (IRB) (Bathgate *et al.*, 2002:265) and currently 96 unions appear on the IRB's world rankings (IRB, 2011).

According to the Australian Rugby Union (quoted by Bathgate *et al.*, 2002:265) participation and interest in the sport of rugby has shown a considerable increase in Australia in the last 15 years. Increased participation in rugby may be linked to the onset of full professionalism of the sport in October 1995, owing to the fact that considerable financial rewards are to be gained from involvement and success at an elite level (Bathgate *et al.*, 2002:265).

#### **2.4 The incidence of rugby injuries**

Stokes *et al.* (1994:290) did a prospective study to compare the nature and frequency of injuries in football and rugby union. The study showed that rugby and soccer players had the same number of injuries, and while there were some differences in the nature of the injuries, there was no difference in overall severity (Stokes *et al.*, 1994:293). In contrast, Medved (quoted by Babić *et al.* 2001:392) considered the number of injuries in rugby "greater than among all other sports". It has been reported by various authors that rugby has one of the highest incidences of injury (Brooks *et al.*, 2005:757; Fuller *et al.*, 2010:159; Gabbett 2008:325; Headey *et al.*, 2007:1537). Bird *et al.* (1998:319) quote the Accident Rehabilitation and Compensation Insurance Corporation (1995) and Hume and Marshall (1994) and comment that rugby union has the highest incidence of injury of all the major sports. Bottini *et al.* (2000:94) are of the opinion that rugby potentially exposes players to a large number of injuries. Bottini *et al.* (2000:94) furthermore interpret the results of Gibbs (1993:696) and state that American football, professional ice hockey and Australian rules' football carry a higher incidence of injury. The age of professionalism has, however, changed the occurrence of injuries in rugby union and according to Holtzhausen (2001:1), the mean incidence of

recorded injuries among studies done by Targett, (1998:281); Garraway *et al.*, (2000:350) and Holtzhausen (2001:6) is 86.4 injuries per 1000 player game hours. This is higher than the injury rates for Australian rugby league (44.9 injuries per 1000 player game hours), Australian rules football (33.5 injuries per 1000 player game hours) and football (16.9 injuries per 1000 player game hours) as reported by Gibbs (1993:700).

#### **2.4.1 The influence of professionalism on rugby injuries**

Professionalism was adopted by the IRB after the third Rugby World Cup held in 1995 (Garraway *et al.*, 2000:348). The onset of full professionalism in the game of rugby has not only impacted on the popularity of the game in most parts of the world, but also on the intensity and pace the game is being played at and consequently on the occurrence of injuries.

Holtzhausen *et al.* (2001:12) points out that no clear indication of a difference in the incidence of injuries between professional and amateur rugby players exists. However, prospective cohort studies done by Garraway *et al.* (2000:349) and Bathgate *et al.* (2002:265) have indicated the contrary. The consequences for accepting the financial and various other rewards accompanying professionalism in rugby union appear to include a major increase in player morbidity (Garraway *et al.*, 2000:348). Brooks *et al.*(2005:757) indicate that even though rugby union enjoys increasing worldwide popularity, it has one of the highest reported incidences of injury at club level (120 injuries per 1000 player game hours), when compared to club soccer players (26 injuries per 1000 player game hours) and ice hockey players (78 injuries per 1000 player game hours). Holtzhausen (2001:12) confirms that a high incidence of injury exists in rugby union at a rate of 86.4 injuries per 1000 player game hours.

According to Nicholas (1997:375) increased physiological demands have been placed on elite rugby players since the introduction of professionalism. Bathgate *et al.* (2002:265) is of the opinion that professional players have had to adapt to the demands of increased physical and mental robustness, as well as to show the strength and pace expected of full-time athletes. It seems that the expectations of increased standards have also filtered down to the continuing majority of semi-professional and amateur players (Bathgate *et al.*, 2002:265). Meyer (2005:63) indicates that the body mass of Springbok rugby players increased by approximately 1.11 kilograms per decade between 1896 and 1975, and 4.28 kilograms per decade between 1975 and 2004. Meyer (2005:63) therefore states that

between 1975 and 2004, the body mass increase among elite South African rugby union players has accelerated more than during the time frame 1896-1975.

In a prospective study of injuries to elite Australian rugby union players, Bathgate *et al.* (2002:268) confirm the suspicion that injury rates have increased considerably in the professional era in rugby union. Prospective data were recorded from 1994 to 2000 on all injured Australian rugby union players. The injury rates in the periods before 1994-1995 and after 1996-2000, the start of the professional era, were 47 injuries per 1000 player hours and 74 injuries per 1000 player hours respectively (Bathgate *et al.*, 2002:265). Garraway *et al.* (2000:349) shows that injury rates in senior Scottish players almost doubled in the four years after the onset of professionalism. On average, an injury episode involving a professional player occurred for every 59 minutes of competitive play in which his team was involved (Garraway *et al.*, 2000:348).

According to Bathgate *et al.* (2002:268) various theories have been postulated as to why there is a higher rate of injuries at high/professional levels of play. Firstly, the seemingly more obvious reasons could be that play is faster, players are fitter and stronger, and that tackling and collisions are harder. Secondly, it was shown by the IRB in 1999 that at the elite level, and especially since 1995, the ball is in play for longer periods of the game. Thirdly, with the introduction of professionalism players are able to devote more time to increase their speed and power and to improve and hone their skills (Bathgate *et al.*, 2002:268).

With the advent of professionalism, more time is being spent training (Bathgate *et al.*, 2002:265). It has been suggested by Bathgate *et al.* (2002:265) that a greater proportion of injuries might be seen during training due to the fact that greater incentives to play motivate players to train with either chronic or recurring injuries. Garraway *et al.* (2000:348) did indeed observe a higher level of recurrent injuries during the early part of the season in professional rugby union players. They suggest that this may be due to a lack of an appropriate preseason break from the sport because of match commitments fulfilled in the traditional off season, in combination with overtraining or carrying existing injuries into the start of the next season. Financial or other considerations could also explain why the average duration of absence from playing/training for professionals was lower than the time spent away from the game by amateurs (Garraway *et al.*, 2000:348). The increase in time spent in training and playing could mean an increase in the length of time exposed to the risk factors involved with injury. The increase in the use of banned substances such as anabolic steroids

is also contributing to the increased risk in injury. It has been documented that anabolic steroids can cause localized rhabdomyolysis, or breakdown of skeletal muscle, in an area of anabolic steroid injection (Farkash *et al.*, 2009:98).

## **2.5 Risk factors associated with rugby injuries**

Apart from the consequences of the sport's adopting a fully professional approach, other potential risk factors have been classified by Taimela *et al.* (1990:205) as intrinsic and extrinsic risk factors to the sportsperson. Intrinsic factors are specific to the individual, and include age, sex, anthropometric characteristics, fitness, psychological characteristics, health status, biomechanical characteristics, and a history of previous injury. Extrinsic factors are those external to the individual and include the nature of the sport, environmental conditions, and equipment (Taimela *et al.*, 1990:205).

### **2.5.1 Extrinsic risk factors**

According to Brooks *et al.* (2005:757) and Fuller *et al.* (2010:165) there are well-known risk factors for injury in rugby players. These risk factors include going into the tackle at high speed, high impact force, collisions and contact with a player's head or neck (Fuller *et al.*, 2010:159). Bird *et al.* (1998:319) state that rugby is a full body contact game with many injuries resulting from extrinsic forces. Some of these extrinsic forces include impact, collision at speed, and body contact. These forces are inherent to the game of rugby and can result in significant musculoskeletal trauma (Bird *et al.*, 1998:319). Concussion, fractures and joint dislocations represent the more serious injuries, while muscle contusions, ligament sprains, and similar soft tissue injuries are the less severe yet more commonly seen injuries resulting from participation in rugby (Bird *et al.*, 1998:319).

Quarrie *et al.* (2001:157) state that certain intrinsic and extrinsic factors may predispose rugby players to injury. Extrinsic factors that predominantly appear to predispose players to injury include the grade or level of play, the phase of play i.e. the tackle situation, and the period of the game, and some evidence also suggests that the playing position may be a factor.

Numerous studies have confirmed a number of trends in injury patterns (Bathgate *et al.*, 2002:268). One of these trends is that an increased rate of injury appears to accompany a higher level of play (Bathgate *et al.*, 2002:268; Bird *et al.*, 1998:324; Brooks *et al.*, 2005:761; Garraway & MacLeod, 1995:1487; Waller *et al.*, 1994:227). The Rugby Injury and Performance Project (RIPP), a

prospective cohort study conducted in Dunedin, New Zealand, was undertaken to investigate risk and protective factors for rugby injury in order to develop potential injury prevention measures (Waller *et al.*, 1994:223). The authors found that the RIPP injury rates are the highest for the most senior grades or highest levels of the game, where skill, fitness, experience, and the intensity of the game are also expected to be highest. Bird *et al.* (1998:324) also examined the injury rates within player groups and found that injury rates were higher for “higher” grades of play. The notion is also supported by Brooks *et al.* (2005:761), who found that the incidence of injury was higher during major club competitions than during friendly/second team matches.

Williams and Blake (quoted in Bird *et al.*, 1998:324) have offered several explanations for this pattern. These include the increased size and strength of players, the higher levels of competitiveness, increased vigour, increased aggression, more foul play, and more matches during the season. Targett (1998:285) suggests that the higher incidence of injuries at higher standards of play is due to more efficient injury reporting regimes being available at elite clubs or provinces, due to the superior standard of their medical support. Bird *et al.* (1998:324) and Quarrie *et al.* (2001:165) postulate that the greater body mass of players at a higher level of play may be one of the contributory factors for the difference. Other factors that may explain the differences include body composition, levels of player fitness and strength, the time the ball is in play, and the more competitive nature of matches at higher standards (Bird *et al.*, 1998:324; Targett, 1998:285 & Quarrie *et al.*, 2001:165).

Holtzhausen (2001:1) reports that a higher incidence of re-injury was found in professional rugby players than in amateur players. According to Brooks *et al.* (2005:762), “the significantly greater severity of recurrent injuries compared with new injuries highlights the importance of ensuring the complete and effective rehabilitation of injured players”. The average duration of absence from playing/training for professionals (due to injury) was lower than the time spent away from the game by amateurs (Garraway *et al.*, 2000:348). Financial or other considerations could explain this occurrence, and may even serve as an explanation for the higher incidence of re-injury among professional rugby players as reported by Holtzhausen (2001:1). In part this may contribute to the overall higher incidence of injuries in higher levels or grades of play.

According to Bird *et al.* (1998:319), physiological fatigue has been suggested as a factor contributing to rugby injury and may be reflected by the period within the game when the most

injuries occur. Wekesa *et al.* (1996:63) argue that more injuries should occur during the second half of a match when players are fatigued than during the first half. Brooks *et al.* (2005:762) support this school of thought, because they found that the lowest incidence of injury was observed in the first quarter, and the highest in the final quarter of matches. According to Brooks *et al.* (2005:762) these results implicate fatigue as an injury risk factor, although it is difficult to identify specific causes.

However, the findings of Wekesa *et al.* (1996:63) and Brooks *et al.* (2005:762) are not in accordance with the findings of Bird *et al.* (1998:324). According to Bird *et al.* (1998:324) one would expect more injuries to occur in the later stages of the game, but in that particular study, injury events occurred evenly throughout the game. Therefore, Bird *et al.* (1998:324) found no evidence to suggest that fatigue contributed to the rugby injuries reported by their cohort. Bathgate *et al.* (2002:268) found in concordance with Bottini *et al.* (2000:95) that approximately two thirds of injuries occurred in the second half of the game. Interestingly, when dividing the game into quarters, the third quarter was seen to be overwhelmingly the time when most injuries occurred (40%). According to Bathgate *et al.* (2002:268), this may reflect the new laws introduced at the end of the 1996 season that allow the substitution of uninjured players. The authors suggest that the players may have been playing the third quarter as if it were their last, knowing that they may be substituted in the fourth quarter. Other factors, such as reduced concentration or inadequate warming up after the half-time break, could possibly, according to Bathgate *et al.* (2002:268), be significant factors in terms of the increase in injury during the third quarter of a rugby game.

According to Bird *et al.* (1998:324), “the literature is somewhat equivocal about which playing positions have the greatest risk of injury”. Brooks *et al.*, (2005:762) states that the significantly greater body mass of forwards, which according to Quarrie *et al.* (1995:263) allows them to develop greater momentum, in combination with the greater demands placed on forward players in terms of contact and collisions, have been suggested as possible explanations for the apparent higher incidence of injury in forward players.

Bathgate *et al.* (2002:268) found in their study that forward players were “disproportionately” injured compared with backline players. However, this occurrence may simply reflect the fact that the forward players are involved in more phases of the game than the backline players (Bathgate *et al.*, 2002:268). In the Croatian Rugby Project, Babić *et al.* (2001:398) found that the forwards sustained more injuries than the backs, but this difference was not statistically significant. Bird *et al.*

(1998:324) found no significant differences between the injury rates for positional groups. There was, however, variation between positions, with locks having the highest injury rate, followed by front row forwards and outside backs. Contrary to previous studies, Brooks *et al.* (2005:762) reported no significant difference in the incidence of injury for forwards and backs in their study of English professional rugby union players. Holtzhausen (2001:11) states that no significant trends in the proportion of injury episodes, based on player position, could be found in the literature for professional and amateur rugby union. To examine the factors associated with tackles in rugby union and to assess their impact on the risk of injury, Fuller *et al.* (2010:159) investigated thirteen English Premiership rugby clubs over a period of two seasons. In their study the authors found that midfield backs are more prone to injury when tackling than other players (Fuller *et al.*, 2010:162).

Whether forwards or backline players have the highest incidence of overall injury, and in spite of the conflicting literature concerning this matter, Nové-Josserand *et al.* (2005:87) found that shoulder injuries occurred more in forward players than backline players. This finding is supported by Webb and Bannister (1992:248) and Lee and Garraway (1996:215).

In studies investigating the nature and mechanisms of rugby union injury, a consistent finding has been the high proportion of injuries which occur in the tackle situation (Fuller *et al.*, 2007:865; Garraway & Macleod, 1995:1487; Lee and Garraway 1996:215). In fact, numerous studies have shown that the tackle was the phase of play in which most game injury events occurred (Bathgate *et al.*, 2002:268; Bird *et al.*, 1998:323; Brooks *et al.*, 2005:765; Fuller *et al.*, 2007:865; Garraway and Macleod, 1995:1487; Holtzhausen, 2001:9). The tackle was responsible for 56% of injuries during the 1995 Rugby World Cup, of which 29% were caused by being tackled and 27% by tackling the opponent (Jakoet and Noakes, 1998:46). Bird *et al.* (1998:323) found that the tackle situation was responsible for 40% of game injury events that occurred among 356 male and female rugby players during 1993 in a competitive club season in New Zealand. According to Holtzhausen *et al.* (2001:9), studies on Super-12 rugby players (Targett, 1998:285, Holtzhausen, 2001:30) found that the tackle was the most frequent cause of injury as well as the most frequent cause of severe injuries in professional rugby. In these studies it is somewhat disconcerting to notice that a total of 41 injuries per 1000 playing hours were sustained in the tackle, of which 22 injuries per 1000 player hours were moderate or serious injuries (Holtzhausen *et al.*, 2001:9). Gerrard *et al.* (1994:230) found in the New Zealand Rugby Injury and Performance Project (RIPP) that 33% of all rugby union injuries occurred in tackles. Rugby injury cost the Accident Rehabilitation and Compensation Insurance Corporation

(ACC) in excess of 19.6 million New Zealand dollars per annum back in the year 1997 (Wilson *et al.*, 1999:153).

Garraway *et al.* (1999:37) and Wilson *et al.* (1999:153) studied the factors involved in the tackle. Both studies found that the tackling player as well as the tackled player experienced a similar incidence of injury. Garraway *et al.* (1999:37) found that most injuries were sustained when an opponent defended from where the tackled player had only peripheral vision; the so-called “blind” tackles. Brooks *et al.* (2005:765) describe tackling as an “open” skill whereas actions such as scrumming and mauling are “closed” skills. The authors come to the conclusion that this “open” skill of tackling in open play is less predictable than scrumming and mauling. Brooks *et al.* (2005:765) report that the incidence of injury from being tackled is significantly higher for backs than forwards and that the higher kinetic energy generated by running backs in open play and the displacement of this energy into the tackle may be a contributing factor. Brooks *et al.* (2005:765) conclude that head-on tackles cause most injuries to players when tackling, and that the most common injuries are cervical nerve root injuries and concussion. A significant finding by Brooks *et al.* (2005:765) is that dislocation or instability of the shoulder cause the greatest number of days absent among tackling players.

Garraway and Macleod (1995:1486) found that tackling in rugby games was associated with 22% of all injury episodes and also accounted for 18% of all absence from employment or school, while being tackled was associated with a further 27% of injury episodes and resulted in 43% of all time lost from employment or education. Various authors (Bathgate *et al.*, 2002:268; Lee and Garraway, 1996:217; Garraway and Macleod, 1995:1487; Webb and Bannister, 1992:248) found that the phase of play most responsible for shoulder (more specifically acromioclavicular (AC) joint and glenohumeral (GH) joint) injuries was the tackle. From the literature, it therefore seems clear why the tackle has been identified as an aspect of rugby union carrying a substantial risk of injury and high medical and personal cost.

When looking at the distribution of injuries to the body in professional rugby players, certain trends have come to the fore. Numerous studies have indicated that the highest injury rates are recorded in the lower limb (Brooks *et al.*, 2005:762; Bathgate *et al.*, 2002:268; Babić *et al.*, 2001:396; Holtzhausen *et al.*, 2001:8; Garraway, 2000:350; Bird *et al.*, 1998:324; Targett, 1998:284). Targett (1998:284) found that among Super-12 rugby players, musculotendinous sprains and strains were

reported as the most common type of injury (28,6% of injuries, 43 injuries per 1000 player hours) and contusions as the second most common (22,4%, 34 injuries per 1000 player hours). Bird *et al.* (1998:324) also found that sprains and strains of a musculotendinous nature were the most common type of injury in that particular study. Although their low severity meant that these injuries did not generally cause players to miss a match, Brooks *et al.* (2005:762) found that thigh haematomas were the most common injury for forward players and backline players. In a prospective study performed on the England 2003 Rugby World Cup rugby players, Brooks *et al.* (2005:289) found that hamstring muscle injuries were the most common injuries to occur during the campaign. Calf injuries and hematomas were the second and third most common injuries (Brooks *et al.*, 2005:289). In another study, Brooks *et al.* (2005:762) listed hamstring injuries as the second most common injury, and found that their incidence was significantly higher in the backline players than in the forward players. According to Deutsch *et al.* (1998:562), this may be due to the greater acceleration, deceleration, and high speed demands placed on backline players as compared to forward players.

Babić *et al.* (2001:396) observed that the most frequently injured body parts were (in order of frequency) the lower limbs, the head, shoulders, upper limbs and lastly, the trunk. Bird *et al.* (1998:322) also found that shoulders were the third most commonly injured body part (6% of all game injuries) after sprained/strained knees (8%) and ankles (7%). Funk and Snow (2007:1) comment that the shoulder is the second most common site of injury in rugby players, making up almost 20% of all rugby injuries. Gabbett (2008:325) monitored the incidence of injuries among junior rugby league players over four seasons and found that the majority of injuries were sustained to the shoulder (15.6 per 1000 playing hours) and that injuries were most commonly sustained while being tackled (19.2 per 1000 playing hours) and while tackling (10.1 per 1000 playing hours).

Bathgate *et al.* (2002:268) found a low rate of injuries to the upper limb (15.4%) when compared with the studies of Jakoet and Noakes (1997:46) and Bird *et al.* (1998:322). However, upper limb injuries accounted for 34.4% of the severe injuries in the study (Bathgate *et al.*, 2002:268). The authors also reported that the upper limb, when involved, was more likely to be severely injured and that 55.6% of the shoulder injuries that were seen were of a severe nature. Eighty percent of the shoulder injuries were dislocations. Bathgate *et al.* (2002:268) also quote Best *et al.* (2000) when they state that at an elite level, an increase in shoulder girdle injuries, specifically rotator cuff tears that are associated with glenohumeral instability, has been observed. Brooks *et al.* (2005:758) found a significantly higher severity for upper limb injuries than head/neck and trunk injuries. Headey *et al.*

(2007:1540) found in their study among English professional rugby league players that shoulder injuries caused 15% more days of absence due to injury than did injuries to any other body part except the knee.

Nové-Josserand *et al.* (2005:88) did a retrospective study on 154 rugby players to report the proportion, the nature and the consequences of shoulder injuries in the French national rugby competition in 2003. It was the first epidemiological study of rugby injury in France. Of the one hundred and sixty-five injuries that were recorded, ninety-eight players (64%) had at least one shoulder injury, and thirty players (19%) had at least two shoulder injuries (Nové-Josserand *et al.*, 2005:85). AC joint injuries represented 62% of all shoulder injuries. This is similar to findings reported in studies by Gibbs (1993:700) and Van Heerden (1976:1379). Grade 1 AC disruption was observed in 39% of cases and grade 2 or 3 in 61% of cases. AC disruptions involved both shoulders in 34% of cases. Gleno-humeral instability was reported to be the second most frequent shoulder injury. It represented 15% of all shoulder injuries, and occurred in 23% of players who sustained shoulder injuries. Simonet and Cofield (quoted by Nové-Josserand *et al.*, 2005:87) reported that involvement in sport increases the rate of recurrence of shoulder dislocations from 30% to 80%. Other injuries that were reported included fractures (13% of all shoulder injuries), six sternoclavicular injuries, five rotator cuff tendon injuries, and four muscular contusions (Nové-Josserand *et al.*, 2005:85).

According to Nové-Josserand *et al.* (2005:87), exposure of the shoulder joint to injury is demonstrated by the high incidence of radiological abnormalities, even without any trauma being reported by the players. Funk and Snow (2007:3) state that diagnoses can be more difficult in contact athletes. These athletes can present with sub-clinical instability, due to the fact that the musculature in rugby players compensates for any ineffectiveness of the inferior glenohumeral ligament caused by trauma to the joint (Funk & Snow, 2007:3). The fact remains that shoulder injuries in rugby are inevitable due to the inherent nature of the game (Nové-Josserand *et al.*, 2005:87).

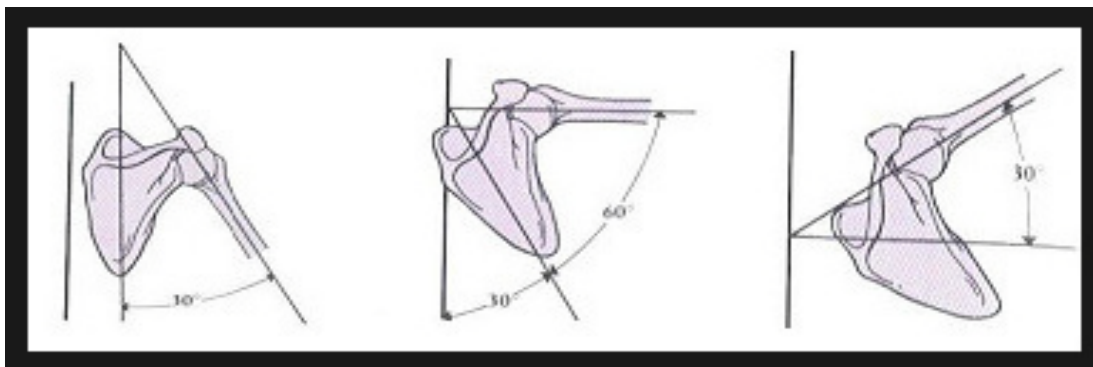
Prevention would normally consist of wearing protection, prohibiting deliberately dangerous play, and updating rugby rules (Burry & Calcinai, 1988:150). According to Burry and Calcinai (1988:150) such changes, along with further epidemiological investigation, are necessary to make rugby a safer game. Further research is, however, needed to investigate various other factors that

may predispose players to possible shoulder injuries, such as certain intrinsic factors (Taimela *et al.*, 1990:205). With this information at hand it seems feasible that preventative measures (apart from the above) may be encouraged not only to help prevent or minimise shoulder injuries, but also to make rugby a safer game. Although there are a number of intrinsic factors that may influence the occurrence of injuries, posture, muscle activation patterns and isokinetic muscle strength will be focused on.

### **2.5.2. Intrinsic risk factors**

The human shoulder can be seen as a perfect compromise between mobility and stability (Veeger and Van der Helm, 2007:2119). Veeger and Van der Helm (2007:2119) state that the joint complex allows for a large range of motion, well beyond that of the hip. According to the classic work of Inman *et al.* (1996:4), “Observations of the function of the shoulder joint”, the shoulder joint complex is composed of four independent articulations; the sterno-clavicular, acromio-clavicular, scapulo-thoracic, and gleno-humeral joints. Even though each of these articulations is an independent entity, capable of independent motion, they all contribute to the normal functional mechanism of the extremity. Importantly, the participation of each of these joints in the entire movement is simultaneous, and not successive (Inman *et al.*, 1996:4).

Elevation of the arm, both in flexion and in abduction, at the glenohumeral articulation is simultaneously accompanied by scapulothoracic movement (Inman *et al.*, 1996:4). As a matter of fact, the key to efficient shoulder function lies within a normal scapulohumeral rhythm (Kibler & Sciascia, 2010:300). This structure critically enhances the power of the associated muscles. In the first thirty to sixty degrees of elevation, the scapula “searches” for (in relationship to the humerus) a precise position of stability which may be obtained in one of several ways. Firstly, either the scapula remains fixed, with motion occurring at the glenohumeral joint until the stable position is reached, or secondly, the scapula moves laterally or medially on the chest wall. Thirdly, and in rare instances, the scapula oscillates until stabilisation is attained. Subsequently, the early phase of motion is highly irregular, and is characteristic for each individual. According to Inman *et al.* (1996:5) these characteristics seem to depend upon the habitual position which the scapula occupies in the subject when at rest. This phase of motion is related to the setting action of the muscles, therefore Inman *et al.* (1996:5) term it the “setting phase”.



**Figure 2.1: Scapulohumeral rhythm. After 30 degrees of humeral abduction, the scapula moves 1 degree for 2 degrees of humeral motion.**

(From <http://blog.naver.com/PostView.nhn?blogId=jsmoo93&logNo=50107386069>)

The authors remark that once thirty degrees of abduction or sixty degrees of forward flexion has been reached, the relationship of scapular to humeral motion remains remarkably constant. Beyond this point, a ratio of two of humeral to one of scapular motion exists - in other words, between thirty and one hundred and seventy degrees of elevation. For every ten degrees of motion that occur at the glenohumeral joint, five degrees of motion takes place in the form of rotation of the scapula on the thorax (Inman *et al.*, 1996:5).

Pertaining to this ratio, Inman *et al.* (1996:5) state that it is evident that the total range of scapular motion is not more than sixty degrees, neither is that of the glenohumeral joint greater than one hundred and twenty degrees. Under abnormal conditions, the motions of either one of the two joints can occur independently. To give an example, when the scapula is fixed, it is possible to raise the arm actively to the right angle, and passively to one hundred and twenty degrees. However, Inman *et al.* (1996:5) demonstrate that the loss of the effective bone leverage, due to a lack of scapular participation, consequently diminishes power by a third.

When reviewing the classic work of Inman *et al.* (1996:5), it seems evident that there is a scapulohumeral rhythm present. This rhythm or ratio also seems to be a necessity for normal shoulder function. It therefore appears that altered muscle recruitment patterns of scapular muscles, or weakening of these stabilisers, may result in the deterioration of normal shoulder function. The authors also state that the early phase of shoulder motion seems to depend upon the habitual position which the scapula occupies in the subject when at rest. This also implies that the resting posture may be of great importance when looking at normal shoulder function and possibly the restoration of

normal shoulder function. Kibler and Sciascia (2010:300) also state that control of the scapula's static position enables this structure to contribute towards normal shoulder function. It has also been postulated that muscle strength imbalance or weakness may well relate to shoulder injuries (Wang *et al.*, 2000:41). Therefore, this literature review will discuss the possible relationship between posture, isokinetic shoulder strength, and scapulae muscle activation patterns with future shoulder injuries, starting with the effect of posture on shoulder function, and as a possible predictor of future shoulder injuries.

## **2.6 Postural malalignments and the risk of shoulder injury**

Postural deviations that include forward head, winging scapulae, forward shoulder posture (defined as sagittal-plane or transverse-plane scapular resting position change), increased thoracic kyphosis, and humeral internal rotation have been implicated in the development of shoulder pain (Finley & Lee, 2003:566; Kebaetse *et al.*, 1999:945; Greenfield *et al.*, 1995:287; Griegel-Morris *et al.*, 1992:425). According to Greenfield *et al.* (1995:288), Kendall (1983) describes a forward head posture with rounded shoulders as a common postural malalignment. Postural deviations associated with this posture include extension at the atlanto-occipital articulations, a "flattening" or reversal of the mid-cervical spine lordosis, increased mid-thoracic spine kyphosis, protraction (abduction) of the scapulae with downward rotation (the inferior angle of the scapula moves medially while the glenoid fossa moves anteriorly and inferiorly), and internal rotation of the humerus (Greenfield *et al.*, 1995:288). Greenfield *et al.* (1995:288) quotes Doody *et al.* (1970) and Poppen and Walker (1976), and states that a forward head position in combination with round shoulders changes the normal orientation of the scapular plane, which is orientated between thirty to forty five degrees anterior to the frontal plane.

Solem-Bertoft *et al.* (1993:102) agree that an increased thoracic curvature accompanying a slouched posture may influence scapular kinematics and cause a reduction in the sub-acromial space. According to Grimsby and Gray (1997:140), it has been suggested that an exaggerated thoracic kyphosis may adversely influence length-tension relationships of the shoulder girdle muscles, which according to Wilk and Arrigo (1993:367) may in turn cause mal tracking of the humeral head within the glenoid fossa.

Bullock *et al.* (2005:29) did a study to compare the effect of slouched versus erect sitting posture on shoulder flexion range of motion (ROM) and pain in a population of subjects with impingement

syndrome. They hypothesised that shoulder flexion ROM would be greater and pain intensity associated with shoulder movement would be less in an erect sitting posture than in a slouched posture. According to Bullock *et al.* (2005:34), a 17 degree increase in shoulder flexion (which may arise from postural correction) may cause functional improvements with respect to everyday activities such as hair combing, putting on a coat, back-washing, washing the contra-lateral axilla, sleeping on the affected shoulder, reaching to a high shelf, pulling, and performing work-related activities. They also suggest that ROM loss may be directly attributed to changes in thoracic posture.

Bullock *et al.* (2005:34) state that limitations in shoulder flexion in a slouched posture may be caused by several factors. Ludewig and Cook (1996:57) studied the effect of cervical position on scapula orientation on twenty-five healthy subjects. Results of the study suggested that increased cervical flexion prevented upward rotation and posterior tilt of the scapula. The authors propose that cervical flexion generates tension in the levator scapulae muscles, which in turn impedes optimal scapular kinematics. According to Kebaetse *et al.* (1999:950), an increased thoracic kyphosis may lead to anteriorly tilted scapulae. The extent of thoracic kyphosis and anteriorly tilted scapulae may be exaggerated, when in combination with an excessive cervical flexion (due to tension in the levator scapulae), thus resulting in the limitation of shoulder flexion (Bullock *et al.*, 2005:34). As stated earlier, Solem-Bertoft *et al.* (1993:102) suggest that an increased thoracic curvature accompanying a slouched posture may influence scapular kinematics and cause a reduction in the sub-acromial space. This may cause impingement of supra-humeral soft tissue and subsequently reduce the overall ROM (Solem-Bertoft *et al.*, 1993:102). According to Lukasiewicz *et al.* (1999:575) it has been shown that impingement subjects display excessive anterior tilt during shoulder motion.

Griegel-Morris *et al.* (1992:430) studied the incidence of postural abnormalities of the thoracic and cervical spines and the shoulder regions in two age groups of healthy subjects, and the association of these abnormalities with pain. The study established a relationship between the severity of the postural abnormality and the incidence of pain in the cervical, thoracic, and shoulder regions. Eighty-eight healthy subjects answered a pain questionnaire and underwent postural assessments to determine forward head, rounded shoulders, and thoracic spine kyphosis. Frequency counts revealed postural abnormalities were common (forward head = 66%; thoracic spine kyphosis = 38%; rounded shoulders = 60%). Subjects with a severe forward head had an increased incidence of cervical spine-interscapular pain, and headaches, while those with severe rounded shoulders and thoracic spine

kyphosis had an increased incidence of inter-scapular pain (Griegel-Morris *et al.*, 1992:430). Griegel-Morris (1992:425) thus came to the conclusion that rounded shoulders, severe kyphosis and forward head posture correlated with inter-scapula pain, but not shoulder or upper arm pain as expected of an impingement syndrome.

Greenfield *et al.* (1995:287) recruited thirty patient subjects and thirty healthy subjects for their particular study. Scapular protraction and rotation, forward head position, mid thoracic curvature, and passive humeral elevation in the plane of the scapula were measured randomly in standing. Greenfield *et al.* (1995:293) found that forward head position was significantly greater in the patient group than in the matched control group. Also, humeral elevation was significantly greater in the healthy than in the patient group and in the uninvolved shoulders than the involved shoulders within the patient group. Other studies have also suggested that postural deviations found in the servical and thoracic spine, could adversely affect normal function of the glenohumeral joint (Lewis *et al.*, 2005:72; Sahrman, 2002b:377). However, in contrast to the findings of Kibler (1991:529), where the authors found a one centimeter greater difference in scapula protraction between the involved to uninvolved side in patients with shoulder injuries, Greenfield *et al.* (1995:29) found no significant difference in scapular protraction, rotation, and scapular symmetry between patient and healthy groups and between the involved and uninvolved sides among the patient group. However, scapula protraction and rotation were significantly related in the patient group. Greenfield *et al.* (1995:293) also found no significant difference in the amount of thoracic spine curvature between groups.

As stated earlier, cervical spine dysfunction due to postural changes can influence normal shoulder function (Lewis *et al.*, 2005:72; Sahrman, 2002b:377; Greenfield *et al.*, 1995:294). However, the proposal that postural change in the cervical spine is a consistent, isolated finding in patients with shoulder overuse injury remains debatable (Greenfield *et al.*, 1995:294). The authors put forward several explanations as to why their study produced the number of insignificant findings it did. One of these is the fact that almost all of the subjects obtained in the study were undergoing treatment at that stage or had previously been treated for an overuse injury. They propose that any postural changes in the thoracic spine or scapulothoracic junction may have been corrected with physical therapy treatment. However, Greenfield *et al.* (1995:294) put forward an interesting alternate explanation for the lack of significant postural differences in their study. They make the following statement: “the lack of mobility which may be observed in flexibility or mobility tests, rather than static postural measurements, may be the significant dysfunction”. Greenfield *et al.* (1995:294)

therefore come to the conclusion that perhaps the important question to answer is the following: what is the relationship between posture and overuse injuries?

From within the literature it comes to the fore that rounded shoulders and forward head posture change the normal orientation of the scapular plane (according to Greenfield, 1995:288), that an increased thoracic curvature accompanying a slouched posture may influence scapular kinematics and cause a reduction in the sub-acromial space (Solem-Bertoft *et al.*, 1993:102), that an exaggerated thoracic kyphosis may cause mal tracking of the humeral head within the glenoid fossa (Wilk and Arrigo, 1993:367), and that a slouched posture may cause limitations in shoulder flexion (Bullock *et al.*, 2005:34). There seems to be a clear indication of the relationship between postural deviations and flawed shoulder kinematics. Greenfield *et al.* (1995:294) question the validity of this school of thought by asking if mobility does not play a bigger role in defective shoulder function than static posture. Be that as it may, even though a relationship seems to exist between postural deviations and incorrect shoulder kinematics, according to Borstad (2006:549) a relationship between posture and impairment at the shoulder is theorised but not supported by evidence.

A possible explanation for the failure to find a relationship between postural deviations and shoulder pain is that these two entities apparently lie at the beginning and end, respectively, of a continuum as described by Sahrman (2002b:376). In the middle of the continuum, between these entities, lies movement alterations or altered shoulder kinematics. In other words, posture and shoulder impairment are not directly related but linked by movement dysfunction (Borstad, 2006:549). Sahrman (2002b:377) draws a parallel between biomechanical systems and mechanical systems, thus making optimal alignment necessary for optimal movement. She theorises that postural deviations may therefore change the biomechanical system's ability to produce precise movement and over time or with exposure to repetitive tasks cause pain as a response to these imprecise movements. Based on Sahrman's (2002b:378) work, Borstad (2006:550) explains that if a link exists between postural deviations and pain, it is unlikely to be determined without also examining the relationships between posture and movement and between movement and pain.

Aberrant scapular kinematics including increased scapular internal rotation (Ludewig & Cook, 2000:276), decreased scapular posterior tilting (Lukasiewicz, 1999:575) and decreased scapular upward rotation (Ludewig & Cook, 2000:276) have all been observed in subjects with impingement compared to subjects who were asymptomatic. These scapular motion adaptations are believed to

decrease the subacromial space by failing to move the acromion away from the humeral head during arm elevation (Brosmann, 1996:1511) resulting in increased compressive loads on the tendons of the rotator cuff or long head of the biceps muscle (Borstad, 2006:550).

The mechanism responsible for scapular alterations displayed in subjects with impingement has not been clearly defined, but one potential mechanism is an adaptively short pectoralis minor muscle (Lukasiewicz, 1999:578). In theory, forward shoulder posture results in adaptive shortening of the pectoralis minor muscle by approximating the muscle's insertion sites on the coracoid process and ribs 3,4, and 5 (Kendall, 1993:106). Decreased pectoralis minor muscle resting length would result in an increase in the muscle's passive tension during arm elevation, restricting normal scapular upward rotation, posterior tipping, and external rotation. This potential effect of pectoralis minor muscle resting length on scapular kinematics has been examined between groups of subjects who were asymptomatic for shoulder pathology (Borstad & Ludewig, 2005:229). This study on a group of subjects with a relatively shorter pectoralis minor muscle resting length demonstrated increased scapular internal rotation during arm elevation and decreased scapular posterior tilting at higher arm elevation angles (90° and 120°) when compared with a group of subjects with a relatively longer pectoralis minor resting length. These scapular motion alterations are consistent with those previously demonstrated by subjects with impingement in Lukasiewicz (1999:578) and Ludewig and Cook (2000:276).

It appears that the literature provides sufficient proof that a relationship exists between poor posture (cervical and thoracic), and shoulder pathology among members of the non-rugby playing community. Despite the fact that research regarding the posture of rugby players is limited, Erasmus (2006:401) and Bruwer (2007:56) indicate that weaknesses occur with regards to posture, shoulder positioning and ROM among rugby players. It must be stated that the research of Erasmus (2006:236) was done on adolescent rugby players and his observations could be attributed to the developmental phase in which these players were at that stage. When considering the relationship between non-athletes' posture and the incidence of shoulder pathology, and the nature of the game of rugby, the amount and intensity of collisions and tackles that occur during a match, it stands to reason that rugby players with a kyphotic posture may be extremely susceptible to future shoulder injuries. This may be due to the fact that if non-rugby playing individuals display symptoms of shoulder pathology during day-to-day activities, rugby players with poor posture could experience more symptoms and discomfort based on the strenuous nature of rugby laying activities and a higher

repetitive rate in shoulder movements during training and games played that may exacerbate predisposed joints. Even though this deduction might be feasible, there are those who are of the opinion that contact sport athletes with abducted scapulae and rounded shoulders may benefit from this posture due to the fact that they can assume a tuck or covered-up position before running into defenders (Kritz & Cronin, 2008:21).

Posture can be regarded as an intrinsic risk factor for injury among rugby players. Various studies have proven that a connection exists between poor posture and shoulder pathology among the non-athletic community and certain athletes. As stated earlier, studies investigating this connection among rugby players are limited. Another intrinsic risk factor among athletes that has enjoyed a fair amount of attention from the research community is isokinetic strength. Various athletes of different sporting codes have been investigated regarding this risk factor, but it once again seems that the literature regarding this risk factor among rugby players is limited.

## **2.7 Isokinetic muscle strength as a risk factor for shoulder injuries**

According to Schlumberger *et al.* (2006:3), the term muscular imbalance “commonly describes a distinct level of muscular performance lying outside the continuum of an assumed normal physiological muscle function”. The effect of muscle imbalance on performance and injury prevention, especially in athletic activities, has become a topic of considerable interest (Chandler *et al.*, 1992:455; Hadzic *et al.*, 2012: 83). These muscle imbalances have been described as either “naturally occurring” or “training induced” (Chandler *et al.*, 1992:455). More than two decades ago, Cook *et al.* (1987:459) suggested that muscle imbalances may increase the risk of injury to athletes. As this has seemingly proven to be the case (Edouard *et al.*, 2011a:759; Wang *et al.*, 2000:42; Leroux *et al.*, 1994:108; Burnham *et al.*, 1993:240; Chandler *et al.*, 1992:457), it seems essential to have the necessary means to identify these imbalances. According to Mayer *et al.* (2001:19), the objective recording of shoulder strength is of the utmost importance when gathering information with regards to diagnostic and rehabilitation purposes.

The extensive use of isokinetic dynamometry for the quantitative assessment of glenohumeral shoulder musculature is well documented (Cook *et al.*, 1987:453, Ellenbecker & Roetert, 1999:276, Mayer *et al.*, 2001:19). Peak force values as well as mean force values are not the only measurements that supply relevant information regarding the shoulders’ status. Agonist-antagonist ratios are also deemed to be extremely useful measurements when evaluating muscular performance

and muscular balance or imbalance (Ellenbecker & Roetert, 1999:276; Hadzic *et al.*, 2012: 83). As a matter of fact, various studies have demonstrated the reliability of isokinetic dynamometry for measuring glenohumeral muscle performance (Durall *et al.*, 2000:7; Frisiello *et al.*, 1994:344; Feiring *et al.*, 1990:300). In particular, the evaluation of isokinetic glenohumeral external and internal rotation movements is considered an appropriate tool for the investigation of muscle performance in injured shoulders (Cools *et al.*, 2004:64).

Wang *et al.* (2000:41) set out to determine the value of strength ratios (especially in terms of low eccentric strength of external rotators) as predictors of shoulder injury for athletes. After the conclusion of their study, they suggest that the functional weakness of external rotators and muscle imbalance may well relate to shoulder overuse injuries. Shoulder rotator strength ratio (internal/external or external/internal ratios) has also been suggested as a significant predictor of the likelihood of shoulder injury by Leroux *et al.* (1994:108). Mikesky *et al.* (1995:642) state that arm and shoulder (internal and external rotators) strengths (and specifically their role in the stabilisation of joints) play a significant role in the prevention of injury. In their study done on elite tennis players, Mont *et al.* (1994:517) conclude that tennis players may experience a theoretical prophylaxis against injury brought upon by isokinetic training. Mikesky *et al.* (1995:642) also urge “future” investigators to study the possible relationship between isokinetic strength and injury rates. Thus, according to the literature, there appears to be a link between glenohumeral internal and external rotation muscle strengths and ratios, and future shoulder injury.

The question arises, which structures are responsible for glenohumeral internal and external rotation? According to Shklar and Dvir (1995:372), it is well established that the shoulder joint suffers from an inherent insufficiency of primary restraints. These restraints include a weak capsule and relatively weak ligamentous structures (Shklar & Dvir, 1995:372). Consequently the stability of the joint depends to a great extent on the integrity of the dynamic controllers, in this case, the rotator cuff (Shklar & Dvir, 1995:372). Due to the instability of the shoulder joint, the muscles of the rotator cuff are activated during almost every movement of the upper limb (Shklar & Dvir, 1995:372). The rotator cuff is a group of muscles that create a hood over the glenohumeral joint and its capsule, and they include the subscapularis, supraspinatus, the infraspinatus and the teres minor muscles (Malcarney & Murrell, 2003:994). According to Malcarney and Murrell (2003:994) the rotator cuff controls and positions the upper extremity by allowing elevation and rotation about the glenohumeral joint. The subscapularis functions as an internal rotator of the glenohumeral joint, and

also acts as an active and passive stabiliser to anterior glenohumeral translation (Malcarney & Murrell, 2003:994). The supraspinatus provides stability to the glenohumeral joint by compressing the humeral head into the glenoid, and initiates elevation of the arm, while the infraspinatus acts as the primary external rotator of the glenohumeral joint (Malcarney & Murrell, 2003:995). According to Malcarney and Murrell (2003:995) the teres minor functions as an external rotator and posterior stabiliser. According to Ellenbecker (1988:64), the rotator cuff's mode of contraction may often be eccentric, and this eccentric contraction becomes more prevalent where deceleration of the arm is needed.

From the literature we have thus established that muscle imbalances may increase the risk of injury to athletes (Burnham *et al.*, 1993:240; Chandler *et al.*, 1992:457; Leroux *et al.*, 1994:108; Wang *et al.*, 2000:42; Edouard *et al.*, 2011a:759), that various studies have demonstrated the reliability of isokinetic dynamometry for measuring glenohumeral muscle performance (Durall *et al.*, 2000:7; Feiring *et al.*, 1990:300; Frisiello *et al.*, 1994:344; Hadzic *et al.*, 2012: 83; Mandalidis *et al.*, 2001:101), in particular, the evaluation of isokinetic glenohumeral external and internal rotation movements (Cools *et al.*, 2004:64), and that the rotator cuff muscles are responsible for rotation of the glenohumeral joint (Malcarney & Murrell, 2003:994).

Therefore, the assumption can be made that imbalances among the rotator cuff muscles (with regards to glenohumeral internal and external rotation) could increase the risk of injury to athletes. But how does one define muscle imbalance or, put differently, when is a shoulder internal/external rotation ratio regarded as normal? As stated earlier, evaluation of isokinetic glenohumeral external and internal rotation movements is considered an appropriate tool for the investigation of muscle performance (Cools *et al.*, 2004:64). This relationship can be quantified as a shoulder rotator strength ratio (internal/external or external/internal ratios) (Leroux *et al.*, 1994:108).

Numerous researchers have aimed at determining normative values in terms of shoulder rotator strength ratios among various population groups and subjects. Wilk *et al.* (2009:40) believe that an important isokinetic value is the unilateral muscle ratio. This ratio describes the antagonist-agonist muscle strength ratio of one shoulder, and a sufficient balance between agonist and antagonist muscle groups apparently provides dynamic stabilisation to the shoulder joint (Wilk *et al.*, 2009:40). In order to provide sufficient muscle balance, Wilk *et al.* (2009:40) found that the glenohumeral joint external rotators should be at least 65% of the strength of the internal rotator muscles. For

optimal muscle balance this ratio needs to be between 66% and 75% (Wilk *et al.*, 2009:40). In their study done on subjects from the general population, Mayer *et al.* (1994:21) found that the normal ratios for this group, tested at 60°/sec (external to internal rotation of the shoulder), were 57% on the dominant side and 61% on the non-dominant side. Beach *et al.* (1992:265) did a study on competitive swimmers and found ratios of 70% (dominant side) and 71% (non-dominant side) for concentric external to internal rotation of the shoulder. Wang *et al.* (2000:42) also studied the external to internal rotation ratios of the shoulders of a certain population group. In this case the researchers focused on volleyball players. Wang *et al.* (2000:42) found the ratios to be 67% and 98% for concentric tests done on the dominant and non-dominant arms respectively. Van Cingel *et al.* (2006:238) also tested asymptomatic elite volleyball players, and found values comparable to those in the study of Wang *et al.* (2000:42). Van Cingel *et al.* (2006:242) found that the external rotation/internal rotation ratio of the dominant arm was 68.1%, and for the non-dominant arm 77.1%. Due to the difference in population groups and the different sports the subjects participated in, one needs to proceed with caution when comparing data in these studies. However, Wang *et al.* (2000:42) refer to the studies of Mayer *et al.* (1994:21) and Beach *et al.* (1992:265) and state that the differences in strength between the internal rotators (IR) and external rotators (ER) in the dominant arms are comparable with each other.

Van Cingel *et al.* (2007:289) found that among elite badminton players, an ER/IR ratio of 72.2% existed on the dominant side, and a ratio of 68.4% on the non-dominant side. Mikesky *et al.* (1995:638) investigated twenty-five collegiate baseball pitchers to determine their shoulders' ER/IR ratio. The concentric strength of the dominant and non-dominant shoulder external rotators was on average 71% (range, 65% to 72%) and 76% (range, 75% to 76%), respectively, of the torque generated by the shoulder internal rotators (Mikesky *et al.*, 1995:640). According to Mikesky *et al.* (1995:640), the ratios found in their study are comparable with previously found ratios for the dominant (range, 61%-71%) and non-dominant (range, 65%-81%) arms of high school, college, and professional pitchers. Apparently, the reason for the internal rotators' larger concentric torque capabilities appear to be the result of their inherently larger muscle size and not a training adaptation that comes from throwing. (Mikesky *et al.*, 1995:640). Mikesky *et al.* (1995:640) state that this finding is supported by ratios for the non-dominant side, which are the same as the dominant side.

When muscle contraction is described as concentric, this refers to when that particular muscle shortens, and the resulting joint movement is in the same direction as the net torque generated by the

muscles (Hall, 2007:163). Concentric strength has commonly been used to determine whether or not an athlete is functionally ready to return to full activity after the occurrence of an injury (Mikesky *et al.*, 1995:642). However, Mikesky *et al.* (1995:642) comment that concentric strength reveals only a part of the muscle's function. Eccentric contractions are also an integral part of sports performance and are responsible for the high-force outputs that are needed for the high-speed deceleration of limb segments during most sports (Mikesky *et al.*, 1995:642). Eccentric muscle contractions take place when the muscle is contracting while it is lengthening (Hall, 2007:163), and the external force in that particular instance is greater than the internal force produced by the muscles (Stanish *et al.*, 2000:35). The combined efforts of contractile and non-contractile tissues during eccentric work produce increased internal muscle tension and force (Ellenbecker *et al.*, 1988:64). Ellenbecker *et al.* (1988:64) state that eccentric muscular contractions play a role in functional activities and athletics that is equally significant to concentric contractions. As stated earlier, Ellenbecker (1988:64) states that the rotator cuff's mode of contraction may often be eccentric, and this eccentric contraction becomes more prevalent where deceleration of the arm is needed. A good example of this is the function of the infraspinatus and teres minor during a throwing motion. According to Duda (1985:183), these muscles need to undergo high decelerative eccentric contractions to preserve healthy joint arthrokinematics. According to Mikesky *et al.* (1995:642), eccentric strength is probably as important if not more important than concentric strength in collegiate baseball pitchers.

With reference to rotator cuff dysfunction specifically, various studies (Glousman *et al.* 1988:220; Warner *et al.*, 1990:366) have referred to the concentric strength ratio of the external versus the internal rotators (Shklar & Dvir, 1995:373). Glousman *et al.* (1988:220) and Warner *et al.* (1990:372) found a general weakness of the external rotators. However, as Shklar and Dvir (1995:373) point out, "the true dynamic nature of the proposed muscular failure could not be discerned due to the absence of eccentric profiling of these muscles". Shklar and Dvir (1995:373) refer to Warner *et al.* (1990:372) and state that the specific significance of eccentric performance and its rehabilitation, particularly with respect to the rotator group, has been emphasised. Therefore the availability of findings based on eccentric testing adds a different viewpoint to shoulder joint dynamics and muscular conditioning (Shklar & Dvir, 1995:373). As an example, Shklar and Dvir (1995:373) refer to their own study and point out that the ratio: concentric external rotation/eccentric internal rotation is approximately its inverse: concentric internal rotation/eccentric external rotation. In practical terms this means that the internal rotators are much more powerful in dynamically

controlling external rotation than the other way round. Shklar and Dvir (1995:373) state that their finding is in agreement with the higher prevalence of anterior glenohumeral instability.

Concentric and eccentric strength, and concentric and eccentric strength ratios, play an important role in the normal function of the shoulder. Eccentric/concentric ratios also seem to display significance in terms of shoulder function and predisposition to shoulder injury. To assess shoulder joint function in a more functional approach, Bak and Magnusson (1997:457) applied the dynamic control ratio (DCR) to the shoulder joint. The DCR is most relevant in situations where agonist and antagonist are working simultaneously to avert potential injury to a specific joint. This is especially relevant in overhead sports (Noffal, 2003:537). The tackle is the phase of play in which most rugby injury events occur (Brooks *et al.*, 2005:765; Bathgate *et al.*, 2002:268; Holtzhausen, 2001:9; Bird *et al.*, 1998:323; Garraway & Macleod, 1995:1487), and typically, the movements that are found in most overhead sports are not present in rugby. However, one study did classify rugby as an overhead sport due to the fact that within the tackle situation, the arm of the contact shoulder is placed at approximately ninety degrees of abduction (Horsley *et al.*, 2012:2). The relevance of the DCR for rugby may be that no previous study has proven whether isokinetic shoulder strength, and more specifically the DCR of the shoulder joint, could predict the occurrence of shoulder injury among rugby players.

Coetzee *et al.* (2002:25) aimed to determine the difference between the concentric agonist/antagonist muscle ratios of the shoulder girdle complex between rugby forwards, rugby backs, cricket players, and a sample of non-athletic individuals. Their results indicated a concentric external/internal rotator muscle ratio of 64% for the rugby backs, and 57% for the rugby forwards. These results were lower than those obtained by other investigators (Mikesky *et al.*, 1995:638; Wang *et al.*, 2000:42). Coetzee *et al.* (2002:25) put forward various possible explanations for these differences. These include the differences in the sport the subjects participated in, or possibly the differences of testing position and equipment, rather than the sample of subjects (Coetzee *et al.*, 2002:24). More recently Edouard *et al.* (2009:863) aimed to establish the profiles of the IR and ER shoulder strength of rugby players by isokinetic strength assessment, and also investigated if rotator cuff muscle imbalances occurred among rugby players. Edouard *et al.* (2009:865) found that the mean ER/IR ratio among the rugby players was 67% and that no imbalances were found among their shoulder rotator muscles. The authors are also of the opinion that playing rugby has no effect on the strength balance between the rotator muscles, and that the influence of playing rugby on

rotators' strength would therefore not be likely to lead to another risk factor of glenohumeral injury in addition to body contacts and collisions.

As stated earlier, players participating in rugby appear to have a high risk of injury per exposure time (Babić *et al.*, 2001:392; Bird *et al.*, 1998:319; Bottini *et al.*, 2000:94; Brooks *et al.*, 2005:765). A possible explanation for this phenomenon is the fact that a large number of collisions takes place during a game and this in turn leads to a large number of musculoskeletal injuries, especially to the shoulder (Bathgate *et al.*, 2002:268). When studying the different phases of rugby, Bathgate *et al.* (2002:268) and Brooks *et al.* (2005:765), singled out the tackling phase as the phase of rugby that is associated with the highest risk of injury. Despite this, published research regarding the anatomical and biomechanical stresses that are placed on the shoulder during the execution of a tackle, appears to be scant (Herrington *et al.*, 2008:68). As research regarding this matter appears to be lacking, one has to speculate that various factors may contribute to the occurrence of injuries during the tackle situation, especially to the shoulder. It must be stated that all of the shoulder injuries that occur during a rugby match (or practice) are not restricted to the tackle situation. However, due to the high percentage of injuries (especially to the shoulder) that occur during a tackle, the "tackle situation" is referred to frequently in this chapter.

Hancock and Hawkins (1996:90) state that the ballistic action accompanying throwing sports especially puts a great amount of eccentric load on the shoulder rotator cuff muscles, which predisposes athletes to injury. Hawkins and Mohtadi (1994:623) go on to state that it is accepted that rotator cuff impingement and shoulder instability are often second-hand phenomenon in athletes. These conditions are apparently caused by eccentric overloading of the cuff and glenohumeral joint capsule when overhead sports are played (Hawkins and Mohtadi, 1994:623).

It is unknown if eccentric overloading of the cuff and the glenohumeral joint is restricted to overhead sports such as swimming, volleyball and baseball. It seems reasonable to assume that this eccentric overload could be present during a rugby match and especially during a tackle situation, and only for the internal rotators and horizontal adductor muscles. According to Herrington *et al.* (2008:70), the most common mechanism of injury for injuries involving disruption of the anterior structures of the glenohumeral joint is one where the arm is forced into a position of abduction and maximal external rotation, leading to an excessive anterior translation of the humeral head and disruption of the anterior structures of the glenohumeral joint. As stated earlier, the glenohumeral

joint is regarded as one of the least stable joints within the body, despite a highly integrated passive (capsule and ligamentous structures) and active (rotator cuff) control system (Herrington *et al.*, 2008:67). According to Herrington *et al.* (2008:67), the passive ligamentous and capsular structures are often exposed to harmful loads due to the failure of the active muscular control systems of the glenohumeral joint.

When considering the opinion of Herrington *et al.* (2008:67) it seems likely that a compromise in the active control system of the glenohumeral joint (the rotator cuff muscles) may contribute to severe injury such as the disruption of the anterior structures of the glenohumeral joint, not to mention less severe injuries such as impingement syndrome. Once again the relevance of the Coetzee *et al.* (2002:25) study comes to fore. Despite the fact that the eccentric strength of shoulder internal rotators appears to be important in terms of the occurrence of shoulder injury, the concentric strength of these muscles, or lack of it, may also prove to be important. As referred to earlier, Edouard *et al.* (2009:867) conclude that the activity of rugby causes no modification to the ER/IR rotator muscle ratio, when compared to non-rugby playing subjects. As a consequence, the authors state that no rotator muscle imbalance was present to serve as an intrinsic risk factor for glenohumeral injury. Edouard *et al.* (2009:867) do, however, identify the need for further studies to compare the muscular balance of subjects with pathology and those without.

Therefore, it stands to reason that the concentric and eccentric isokinetic strength of rugby players' internal and external rotators needs to be investigated, but shoulder pathology needs to be brought into the equation. Concentric and eccentric agonist/antagonist ratios should also be determined as well as functional work ratios for the internal and external rotators. By monitoring the occurrence of shoulder injuries during a regular season, one could determine whether or not these isokinetic muscle strengths and ratios prove to be significant in the occurrence or prevention of these injuries.

Herrington *et al.* (2008:67) also performed a study to determine if a tackling task effects shoulder joint position sense (a component of proprioception) among rugby players. The authors found that rugby players displayed superior shoulder joint position sense (JPS) when compared with a matched control group. However, Herrington *et al.* (2008:67) found shoulder JPS to be significantly reduced among rugby players following a fatiguing task. In this specific case the fatiguing task was a repetitive tackling simulation. Herrington *et al.* (2008:68) therefore postulate that a fatiguing task could decrease end of range JPS, and that this could potentially expose the passive structures of the

shoulder to increased loading and consequent injury. Thus, it is evident that fatigue may well play a role in compromising the highly intergrated passive (capsule and ligamentous structures) and active (rotator cuff) control system of the glenohumeral joint.

The literature indicates that strength imbalances among the rotator cuff muscles may predispose sportsmen and sportswomen to future shoulder injuries. Although no studies have proven this theory to be true among rugby players, it does seem feasible. The presence of shoulder strength imbalance may also lead to poor posture and/or imbalances in shoulder kinematics. The poor shoulder kinematics may consequently influence and affect muscle activation patterns.

## **2.8 Muscle activation patterns of the shoulder joint**

Due to the fact that a number of muscles participate in movements of the shoulder girdle and arm, either directly or indirectly, it is a challenge to determine the specific function of each muscle (Brunnstrom, 1941:263). For this reason, the use of electromyography (EMG) is considered valuable for investigating neuromuscular performance in healthy and injured shoulders (Hancock, 1996:84). According to Basmajian and De Luca (1985:1), EMG is the study of muscle function through the inquiry of the electrical signal the muscles emanate. EMG has been utilised as a tool for analysing the function of muscles for a number of decades, in both normal and injured subjects (Herrington & Horsley, 2009:1). As said previously, shoulder muscle strength is commonly measured by means of isokinetic dynamometers (David *et al.*, 2000:96). Healthy subjects were used during most of these studies, but only a limited number of studies incorporated patients in their methodology (Bak & Magnusson, 1997:454). Furthermore, interpretations or clinical deductions based on isokinetic strength-related parameters are limited due to the failure to isolate and specify the muscle being tested (David *et al.*, 2000:96). Thus, according to David *et al.* (2000:96), a combination of EMG with isokinetic dynamometry could provide relevant information regarding the function of shoulder musculature. One of the major functions of muscular activity is enhancing joint stiffness (David *et al.*, 2000:96). Riemann and Lephart (2002:80) state that increased muscle stiffness is likely to augment joint stiffness and so enhance the functional stability of the joint. With regards to joint stiffness, David *et al.* (2000:96) state that knowledge of muscle timing patterns in the shoulder is vitally important to our understanding of the behaviour of the joint system, particularly under demanding circumstances. Herrington and Horsley (2009:2) also state that early and appropriate activation of muscles is likely to increase joint stability.

In certain sports, the demands that are put upon the shoulders are extremely high. In these cases, the quality of shoulder movement depends upon the interaction between scapular and glenohumeral kinematics (Cools *et al.*, 2002:221). It is commonly accepted that the scapula plays an important role in the stability and mobility of the shoulder joint (Kibler, 1998:325; Lear and Gross, 1998:146; Wilk and Arrigo, 1993:368). A good understanding of the muscular coordination of the scapular rotators is, according to Bagg and Forrest (1986:111), basic to a more complete appreciation of movement in the shoulder region. Codman (as cited by Bagg & Forrest, 1986:111) states that “the accuracy of motion at the shoulder joint depends on a group of muscles which must be ‘absolutely coordinated’ and always working together to some extent”. Wadsworth and Bullock-Saxton (1997:623) argues that it is not only the intensity of the muscle contraction that determines the scapulothoracic function, but that the timing of muscle activity around the scapula also plays a significant role. Meyers *et al.* (2006:200) argue that the balance of muscle force couples around the shoulder complex has been shown to be more important than muscle strength to establish normal joint function. Belling Sørensen and Jørgensen (2000:271) also stress the importance of optimal coordination of the dynamic stabilisers of the scapulothoracic joint to shoulder movement, and identify them as the serratus anterior, trapezius, and rhomboid muscles. Reinold *et al.* (2009:112) state that the serratus anterior works in combination with the pectoralis minor to protract the scapula and with the upper and lower trapezius muscles to upwardly rotate the scapula. The trapezius muscles’ general functions include scapular upward rotation and elevation for the upper trapezius, retraction for the middle trapezius, and upward rotation and depression for the lower trapezius (Reinold *et al.*, 2009:113).

Inman and his co-workers emphasised the importance of the muscular force couple as an essential principle in the mechanics of rotation in the scapulothoracic joint (Inman *et al.*, 1996:7). Bagg and Forrest (1986:122), Kamkar *et al.* (1993:213) and Kibler (1998:327) concur that the important function of the upper-, lower- and middle trapezius muscles and the serratus anterior muscle is to act as force couples providing the dynamic stability of the scapula. Inman *et al.* (1996:7) believe that the glenohumeral and scapulothoracic joints require three essential forces in order for rotation to occur. In order to counteract the weight of the shoulder girdle, one force needs to act in an upward direction (Inman *et al.*, 1996:7), while the other two forces need to produce the scapular rotary couple. This is achieved by one of the forces pulling medially in the area of the acromion process, and the other pulling anterolaterally from the inferior angle. According to Inman *et al.* (1996:7) the force acting medially on the acromion is in part active and in part passive. The upper portion of the

trapezius is responsible for the active part, as well as supporting the weight of the shoulder girdle, while the passive component is formed by the antagonistic pressure of the clavicle. The serratus anterior predominantly represents the force that is pulling anterolaterally from the inferior angle, according to Inman *et al.* (1996:7).

According to Bagg and Forrest (1986:122) the lower part of the serratus anterior muscle exhibits a gradual increase in activity between 0° and 160° of arm abduction, with a brief plateau occurring as the arm angle approaches 90° of abduction. It seems that the lower part of the serratus anterior plays a contributing role in scapular rotation during the middle phase of arm elevation (Bagg & Forrest, 1986:122). The serratus anterior has previously been described as multifaceted in that it helps produce scapular upward rotation, posterior tilt and external rotation while stabilising the medial border and inferior angle of the scapula (Ludewig *et al.*, 1996:60). According to Kibler and Sciascia (2010:301), scapular stabilization and motion on the thorax involves coupling of the upper and lower fibres of the trapezius muscle with the serratus anterior and rhomboid muscles. Inman *et al.* (1996:18) suggest that the upper trapezius muscle changes its role from a supporting muscle to a rotator of the scapula during arm abduction. The activity patterns of the scapular rotators noticed during the study of Bagg and Forrest (1986:122) indicate that the upper trapezius, lower serratus anterior, as well as lower trapezius, make important contributions to scapular rotation during the middle phase of arm elevation. According to Kamkar *et al.* (1993:213), the upper and lower fibres of the trapezius and the lower digitations of the serratus anterior serve as the major upward rotators of the scapula. Bagg and Forrest (1986:122) found the lower trapezius to display a small amount of activity until abduction of 90°. Beyond this point activity increases quite rapidly with the progressing abduction (Bagg & Forrest, 1986:122). Bagg and Forrest (1986:122) also state that the lower trapezius may play a more significant role than that of the other three muscles. According to the authors, the muscle gains a steadily improving mechanical advantage with the progression of arm elevation. Due to this fact, the lower trapezius enhances the rotation forces that are already at work (Bagg & Forrest, 1986:122).

According to Johnson *et al.* (1994:48), the upper, middle, and lower trapezius muscles participate differently within these force couples. Johnson *et al.* (1994:48) conclude that the trapezius muscle's actions could be derived on the basis of its fascicular anatomy. When contraction of the serratus anterior muscle takes place, the scapula tends to draw laterally around the chest wall. This movement is counteracted by the lower fibres of the trapezius muscle, which operate at a constant

length to stabilise the axis of rotation. Furthermore, the upper fibres of the trapezius muscle exert an upward rotation moment about the axis, which complements the force of the serratus anterior muscle. According to Johnson *et al.* (1994:49), the fibres of the middle trapezius muscles lie close to the axis of rotation of the scapula, and even though these muscles are very strong, their ability to generate an upward rotary moment is compromised by relatively short moment arms. Johnson *et al.* (1994:49) conclude that the lower and middle fibres of the trapezius muscle maintain the horizontal and vertical equilibrium of the scapula rather than generating net torque. According to Kibler and Sciascia (2010:301) the lower trapzius muscle has often been described as an upward rotator of the scapula, but it also play a stabilising role when the arm is lowered from an elevated position. Simons *et al.* (1999:278) also report that the trapezius muscle has varying muscle fibre directions. It seems that these differences may reflect different functional demands on the trapezius muscle sections in various movements.

The scapula plays an important role in shoulder function (Kibler, 1998:325) in sports where high demands are put on the shoulders, because the quality of movement depends on the interaction between scapular and glenohumeral kinematics (Cavallo & Speer, 1998:18). According to Cools *et al.* (2003:543), the functional stability of the scapula requires optimal positioning, smooth muscular balance in the force couple around the scapula, and the correct timing of the muscle activity of the scapular rotators. Kibler (1998:327) states that the sequence of recruitment and the level to which each muscle is activated during movement are important factors in coordinating scapular motion with humeral elevation. To be more specific, Magarey and Jones (2003:250) postulate that an early activation of the stabilising muscles at the proximal scapulothoracic joint in relation to prime mover activation at the glenohumeral joint is important for maintaining proper scapulothoracic stability throughout glenohumeral movement. Cools *et al.* (2003:547) state that “optimal functioning of the stabilising muscles depends not only on the force production of these muscles in relation to synergists, antagonists, and prime movers of a joint, but also on the correct timing of muscle activation”. In the light of this, Cools *et al.* (2002:222) evaluated the muscle latency times of the deltoid and trapezius muscles in response to a sudden arm movement. Healthy shoulders were selected because the aim of their study was to determine a normal muscle recruitment sequence in the trapezius muscle. According to the authors, the trapezius muscles seem to react as a unit in order to stabilise the scapula in response to a sudden arm movement in normal shoulders. Even though their results indicated a recruitment sequence within the trapezius muscles, with a delay in activation of the lower trapezius, it was not found to be statistically significant (Cools *et al.*, 2002:226).

Wadsworth and Bullock-Saxton (1997:620) measured muscle activity and the recruitment order of the scapular muscles during voluntary movements in injured and noninjured swimmers. The findings of their study indicated that the average temporal recruitment pattern of the scapular rotators consisted of initial activity of the upper trapezius prior to arm abduction, followed by serratus anterior activation after abduction began. It was also revealed that the lower trapezius was not activated until the shoulder was abducted to 15°. At the conclusion of their study, Wadsworth and Bullock-Saxton (1997:622) found a significantly increased variability in the timing of activation in the upper and lower part of the trapezius muscle in the injured shoulders, which reflected inconsistent or poorly coordinated muscle activation.

According to Herrington and Horsley (2009:1) there are no studies that report on muscle activity around the shoulder girdle during the tackle situation within rugby football. Consequently Herrington and Horsley (2009:2) performed a study to define the sequence of muscle activation patterns in selected shoulder girdle muscles during a “front on” tackle in asymptomatic subjects. The authors state that with regards to a tackle situation “the shoulder is part of a kinetic chain of energy, in which the body is considered as a linked system of articulated segments. The force is transmitted through the kinetic chain, to the shoulder girdle at the point of impact within the tackle, whereby rapidly developing deceleration forces will be developed within the shoulder girdle that should be decreased by a coordinated recruitment of the muscles”. (Herrington & Horsley, 2009:2) The findings of Herrington and Horsley (2009:5) indicate a consistently earlier activation of the serratus anterior muscle prior to impact during a tackle, when compared with the other muscles. The other muscles included pectoralis major, biceps brachii, latissimus dorsi and infraspinatus (Herrington & Horsley, 2009:5).

Horsley *et al.* (2010:1) performed a similar study where the objective was to assess the influence of a SLAP lesion on the onset of EMG activity in shoulder muscles during a “front-on” rugby tackle. In accordance with the findings of Herrington and Horsley (2009:5), Horsley *et al.* (2010:8) found that serratus anterior had an earlier onset of activation when compared with infraspinatus, latissimus dorsi, pectoralis major and biceps brachii, on both the injured and uninjured sides. Horsley *et al.* (2010:8) found, however, that a delay of onset time occurred among the muscles pertaining to the injured shoulder with the exception of an associated earlier onset of activation of the serratus anterior muscles. According to Horsley *et al.* (2010:1) this could possibly be a coping strategy to protect glenohumeral stability and thoraco-scapular stability.

It is evident that muscle recruitment patterns play a significant role in the normal functioning of the shoulder, but muscle recruitment pattern is not the only important factor in play (Wadsworth & Bullock-Saxton, 1997:618). Various authors (Glousman *et al.* 1998:225; Inman *et al.* 1944:28; Kibler, 1998:327) agree that weakness in one or more scapular rotators may cause muscular imbalance in the force couples around the scapula, leading to abnormal kinematics. Scapulothoracic dysfunction is often seen in patients with shoulder injuries (Cools *et al.* 2003:548; Lukasiewicz *et al.* 1999:582; Glousman *et al.* 1998:225; Kibler, 1998:325; Wadsworth & Bullock-Saxton, 1997:618; Kamkar, *et al.*, 1993:212). A current belief is that weakness of the scapular musculature will affect normal scapular positioning. It has been suggested that excessive motion of the scapula may increase the stress on the glenohumeral capsular structures and lead to increased glenohumeral instability. Malpositioning of the scapula for any given arm configuration may also influence the instantaneous centre of the shoulder rotation, which can significantly alter moments of force generation about the shoulder (McQuade, 1998:80).

Sahrmann (2002a:214) explains that due to the scapula's critical role in controlling the position of the glenoid, relatively small changes in the action of the scapulothoracic muscles can affect the alignment and forces involved in movement around the glenohumeral joint. These changes can lead to tensile overload of the rotator cuff and to impingement syndromes (Kuhn, 1995:319; Morrison, 2000:286). According to Cools *et al.* (2003:543), athletes with pathological conditions of the shoulder consistently demonstrate abnormalities in scapular rotator muscle activity. This has been proven by means of clinical experience (Kamkar *et al.*, 1993:212; Wilk *et al.*, 2002:136) as well as through the generation of scientific data (Ludewig and Cook, 2000:289; Wadsworth & Bullock-Saxton, 1997:623). The intensity of muscle activity in the scapular muscles has been investigated in healthy shoulders (Ludewig *et al.*, 1996:57; Moseley *et al.* 1992:129), shoulders with impingement (Ludewig & Cook, 2000:276) and shoulders with glenohumeral instability (McMahon *et al.*, 1996:119). Ludewig and Cook (2000:276) and Wadsworth and Bullock-Saxton (1997:623) suggest that alterations in muscle activity in the upper trapezius, lower trapezius, and serratus anterior muscles may exist in patients with symptoms of impingement. As referred to earlier, Wadsworth and Bullock-Saxton (1997:620) investigated temporal scapular muscle recruitment patterns in relation to voluntary movement in swimmers who displayed sub-acromial impingement. The findings of their study suggested that injury reduced the consistency of muscle recruitment in relation to controlled voluntary movement. Various studies (Ludewig & Cook, 2000:289; Lukasiewicz *et al.*, 1999:582 McMahon *et al.*, 1996:121; Wadsworth and Bullock-Saxton,

1997:623) have thus found that muscle activity in terms of the intensity of the muscle contraction, as well as the timing of muscle activity around the scapula, may contribute to pathology around the shoulder joint.

Electromyography enables researchers to determine the activity levels of various muscles, as well as their recruitment patterns in terms of a specific movement or motion. It has also come to the fore that the scapula plays an instrumental role in normal shoulder function. Furthermore, for the scapula to perform optimally, the various scapular stabilisers (trapezius, serratus anterior and rhomboids) need to work in a synchronised and effective manner. The literature indicates that injured shoulders, whether the injury is clinical instability or impingement syndrome, display aberrant recruitment patterns or weakening of the scapular stabilisers (Horsley *et al.*, 2010:8; Wadsworth & Bullock-Saxton, 1997:622). Furthermore, the findings of Herrington and Horsley (2009:5) and Horsley *et al.* (2010:8) indicate the consistent early activation of serratus anterior prior to impact in the rugby tackle situation, when compared with other muscles. When considering this information the question is raised as to whether or not the altered recruitment patterns of serratus anterior, as well as the other scapulothoracic stabilisers, are also related to shoulder injuries in rugby.

The study of Cools *et al.* (2002:227) suggests that muscular fatigue affects the onset of muscle activity in the trapezius and deltoid muscle after sudden movement of the arms. According to Cools *et al.* (2002:227), a possible mechanism explaining the delay in muscle onset time might be a decrease in motorneuron firing rates during muscle fatigue. Delayed muscle onset time due to fatigue may have considerable clinical implications. If one were to assume that muscles are fatigued during sports movements, one could credit that fatigue could possibly lead to altered scapular kinematics. (Cools *et al.* (2002:227) Thus the repetitive nature of sports activities may subject the upper extremity to overuse injuries related to fatigue in the scapular muscles. (Cools *et al.*, 2002:227) This phenomenon may present itself during a rugby game or practice, where tackling and other contact situations occur repeatedly. Even though muscle fatigue sets in during a rugby game or practice and the majority of rugby injuries seem to occur during the last quarter of the match (Brooks *et al.*, 2005:762), no studies have tried to determine if this state affects scapular muscles to such a degree that scapular kinematics may be compromised, consequently resulting in shoulder injury. As a matter of fact, no study done on rugby players has proven that abnormal scapular kinematics contributes to future shoulder injury, regardless of fatigue.

## **2.9 Summary**

The game of rugby union has undergone various changes throughout the last century, none more influential than the advent of professionalism in the sport. During this period rugby players' body mass and athletic ability have increased. In correspondence with this, so has the incidence of their injury, specifically shoulder injuries. The literature indicates that possible correlations exist between poor thoracic posture, isokinetic shoulder muscle strength imbalances, altered scapular recruitment patterns, and shoulder pathology. However, none of these correlations were sufficiently studied or proved among rugby union players. Future research is therefore needed to investigate the thoracic posture, shoulder muscle isokinetics strength and shoulder muscle activation pattern in rugby union players in order to determine if these variables are related to one another and if they contribute to future shoulder injuries. This information could be significant for constructing prevention protocols for rugby players because risk factors, as well as their relationships with other variables might be identified pro-actively. This information could also help to determine what the most relevant pre-season tests are to identify possible risk factors towards shoulder injury.

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# CHAPTER 3

## THORACIC POSTURE, SHOULDER MUSCLE ACTIVATION PATTERN AND ISOKINETIC STRENGTH OF SEMI-PROFESSIONAL RUGBY UNION PLAYERS

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# Thoracic posture, shoulder muscle activation patterns and isokinetic strength of semi-professional rugby union players

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**Background.** Shoulder injuries are the most severe injuries in rugby union players, accounting for almost 20% of injuries related to the sport and resulting in lost playing hours.

**Objective.** To profile the thoracic posture, scapular muscle activation patterns and rotator cuff muscle isokinetic strength of semi-professional rugby union players.

**Methods.** Using the hand-behind-the-neck and -back methods, we manually tested the range of motion (ROM) of the shoulder joints of 91 uninjured semi-professional rugby union players who consented to participate in the study. Profiling and classification of thoracic posture was performed according to the New York Posture Test. Activation patterns of the upper and lower trapezius, serratus anterior and infraspinatus scapular muscles were determined by electromyography. The isokinetic muscle strength of the rotator cuff muscles was determined at 60°/sec by measuring the concentric and eccentric forces during internal rotation (IR) and external rotation (ER).

**Results.** Participants presented with non-ideal or unsatisfactory internal (59%) and external (85%) rotators of the shoulder. A slightly abnormal or abnormal forward head posture was observed in 55% of participants, while 68% had an abnormal shoulder position in the lateral view. The muscle activation sequence of the rotator cuff muscles was: (i) serratus anterior, (ii) lower trapezius, (iii) infraspinatus, and (iv) upper trapezius. The isokinetic ER/IR muscle-strength ratio during concentric muscle contraction was 64% (standard deviation (SD) ±14) for the left shoulder and 54% (SD ±10) for the right shoulder. The ER/IR ratio for eccentric muscle contraction was 67% (SD ±12) and 61% (SD ±9) for the left and right shoulders, respectively.

**Conclusions.** Non-ideal or unsatisfactory flexibility of the external rotators of the shoulder, a forward shoulder posture in the lateral view, and weakness of the external rotators did not result in an abnormal rotator cuff muscle activation pattern in this study. Postural deviations may, however, increase the risk of shoulder injury in rugby union players in the long term, and should be corrected.

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Poor posture, scapular dyskinesia, altered scapular muscle recruitment patterns and shoulder-strength weaknesses or imbalances may be associated with shoulder injuries in athletes;<sup>[1]</sup> however, this has not been proven conclusively for rugby players. Despite the fact that rugby union enjoys increasing worldwide popularity, it has one of the highest reported incidences of injury.<sup>[2]</sup> The shoulder is the second most common site of injury in the rugby union player, accounting for almost 20% of injuries related to the sport.<sup>[3]</sup>

Despite correlations between rounded shoulders, severe kyphosis and forward head posture with inter-scapula pain among the general population,<sup>[4]</sup> similar findings are limited with regard to rugby union players. There have been reports, however, of a relationship between postural deviation and incorrect shoulder kinematics.<sup>[5]</sup>

Knowledge of the patterns of shoulder muscle timing and the functional capabilities of the scapular rotators is vitally important to understanding the behaviour of the joint system, particularly

under demanding circumstances such as participation in sport.<sup>[6,7]</sup> Scapulothoracic dysfunction is often seen in patients with shoulder problems.<sup>[1,8]</sup> Among swimmers with shoulder injuries, there is significantly increased variability in the timing of activation in the upper and lower part of the trapezius muscle,<sup>[1]</sup> reflecting inconsistent or poorly co-ordinated muscle activation.<sup>[1]</sup> With regard to rugby players, in a study to define muscle-activation patterns in selected shoulder girdle muscles during a front-on tackle in asymptomatic subjects,<sup>[9]</sup> a consistently earlier activation of the serratus anterior muscle was observed prior to impact, compared with the pectoralis major, biceps brachii, latissimus dorsi and infraspinatus.<sup>[9]</sup>

A combination of electromyography (EMG) and isokinetic dynamometry could provide information regarding the function of shoulder musculature in sport.<sup>[6]</sup> It has been suggested that the functional strength of the rotator cuff muscles and the rotator-strength ratio are significant predictors of the likelihood of shoulder injury.

The unilateral muscle ratio – the antagonist/agonist muscle-strength ratio of the infraspinatus and teres minor muscles v. the subscapularis and supraspinatus muscles on the ipsilateral side – is also believed to be important in isokinetic testing.<sup>[10]</sup> A sufficient balance between agonist and antagonist muscle groups apparently provides dynamic stabilisation to the shoulder joint.<sup>[10]</sup> To provide optimal muscle balance and functional capability for overhead athletes, the strength of the external rotators of the glenohumeral joint should be 65 - 75% of that of the internal rotator muscles.<sup>[10]</sup> Muscle-strength ratios that lie outside the proposed normative ranges may increase the risk of injury to athletes.<sup>[11]</sup> Furthermore, there is evidence that rugby union players, especially forwards, display poor antagonist/agonist muscle-strength ratios with regard to their shoulder rotator muscles.<sup>[12]</sup>

Previous research has indicated a possible association between posture, isokinetic strength, scapular muscle recruitment patterns and injury among the general population and overhead athletes.<sup>[1]</sup> However, there are few available profiles of rugby union players with regard to the aforementioned factors and the possible associations thereof with injury. The compilation of such profiles for uninjured players could, in theory, assist in the identification of rugby union players who are more likely to be at risk of future injury to the shoulder area. The aim of our study was, therefore, to profile rugby union players accordingly, to assist in the identification of possible musculoskeletal weaknesses.

Here we report on part of a larger study into the occurrence of shoulder injuries during the 2010 rugby union season at North-West University (NWU)-Puk Rugby Institute. The shoulder is the most injured body region in backline players at the institute. Previous work has implicated certain biomechanical and postural aspects, such as tight shoulder internal rotators and adductors, high body mass and kyphosis, as possible intrinsic risk factors for these shoulder injuries; however, the practical significance of these correlations was limited by small sample sizes. We subsequently performed a descriptive study to profile the thoracic posture, scapular muscle activation patterns and rotator cuff muscle isokinetic strength of right-hand-dominant semi-professional rugby union players.

## Methods

### Participants

Ninety-five uninjured male rugby union players aged 17 - 31 years were recruited for the study. All participants were PUK U19 A/B, PUK U21 A/B (NWU-Puk Rugby Institute) or Leopards Rugby Union senior players (Provincial) based in the North West Province. All participants gave informed consent to participate in the study following an explanation of the test procedure and study protocols. The Ethics Committee of NWU approved the study (NWU-00048-11A1). All participants were tested in the pre-season to ensure that they were uninjured during the test phase. Left-hand-dominant participants ( $n=4$ ) were excluded from the analysis.

### Measurements

#### Demographic information

The stature of each participant was measured to the nearest 0.1 cm with a stadiometer (Seritex) using the stretch-stature method. Body mass was measured to the nearest 0.1 kg with an electronic weighing scale (Micro). Participants completed an information sheet surveying age, position of play, dominant side and previous injuries.

### Shoulder range of motion

Biomechanical tests were performed according to a *pro forma* protocol compiled from various sources. Shoulder range of motion (ROM) was determined by the hand-behind-the-neck and -back tests. During both tests, participants stood in an upright position. In the hand-behind-the-neck test, participants were instructed to reach over their ipsilateral shoulder with one hand and place it as far down the spinal column as possible. The end-point of movement was marked (representing the most inferior point) with the shoulder in a position of external rotation (ER). Using the same technique, the contra-lateral hand was placed as far down the spinal column as possible, and the end-point was marked. The distance between the two marks was measured. The players were classified in terms of the discrepancies between the left- and right-shoulder ROMs: a difference <1 cm was classified as ideal, differences of 1 - 3 cm were classified as non-ideal, and differences >3 cm were classified as unsatisfactory. During the hand-behind-the-back test, the same principles were applied; however, participants were instructed to place their hands as high as possible on the spinal column (representing the most superior point), with the shoulder in a position of internal rotation (IR).

### Thoracic posture

The New York Posture Test, designed for identifying 13 categories of deformities,<sup>[13]</sup> was used for the evaluation and identification of possible postural deformities in the participants. Assessments were performed by capturing high-quality digital photographs of the lateral and posterior view of each participant. The camera was placed at a 90° angle to the shoulders to ensure accurate calculation of angles. The photographs were analysed with Dartfish software (version 4.06.0; DARTFISH, Switzerland). A score of 5 (normal posture), 3 (slightly abnormal posture/moderate deviation) or 1 (abnormal posture/major deviation) was assigned to forward head, winged scapulae/round shoulders and kyphosis aspects of the postures. Uneven shoulders were measured by placing bright-yellow markers, 1 cm in diameter, on the posterior-lateral edges or acromial angles of the left and right acromions. Uneven shoulders were defined by the angle formed between the line connecting the inferior edges of the markers and a true horizontal line. To reduce the degree of subjectivity, New York Posture Test criteria were used to score uneven shoulders as follows: 5 (0 - 2°); 3 (2.1 - 4.0°) and 1 (>4°).

### Scapular muscle activation patterns

EMG activities of the scapulothoracic muscles were registered by means of bilateral and simultaneous abduction of both arms in the scapular plane (30° in front of the coronal plane).<sup>[1]</sup> The output of muscle activation was measured in microvolts (mV). The firing sequence of the muscles was determined by measuring latency times (ms). Consequently, the frequency (percentage of times) that a specific muscle group fired in a specific order was calculated. Accordingly, the muscles were classified in terms of firing sequence. Data were obtained with the Myotrace 400 Biofeedback system (Noraxon USA Inc.), which operates by means of a 4-channel transmitter that allows for simultaneous data collection from 4 strategically placed electrodes. EMG electrodes were attached unilaterally to the upper and lower trapezius, serratus anterior and infraspinatus muscles, respectively, in accordance with Surface ElectroMyography for the Non-Invasive

Assessment of Muscles (SENIAM) guidelines.<sup>[14]</sup> The overlying skin on the muscles was carefully prepared by abrading the outer epidermal layer and removing oil and dirt with alcohol pads.<sup>[15]</sup> As only 4 channels were available to do the tests, the 4 muscles were measured unilaterally, after which the test was repeated on the contra-lateral side. The participants started the required movement with their arms resting next to their sides. Bilateral arm abduction in the scapular plane was performed to a point of 180° of abduction, after which adduction was performed to the original starting point. The test was standardised for both sides by regulating the tempo of abduction and adduction. Participants performed the total abduction-adduction sequence in 7 seconds. No resistance was used or applied during the movement.

#### Rotator cuff isokinetic muscle strength

The torque/peak power and muscle agonist/antagonist ratios of the shoulder were tested with the Kin-Com 500H isokinetic dynamometer (Chattanooga, Tennessee) with torque/power expressed in Newton meters (Nm). Torque scores are representative of the moment of force produced by muscle contraction for rotation around a joint.<sup>[12]</sup> During shoulder IR and ER, the participant was seated and strapped to the seat. Testing was performed with the arms positioned along the scapular plane, at 90° of abduction and with 90° of elbow flexion. The contra-lateral arm was held static against the chest throughout the test and the feet were placed on a footrest. The shoulder axis of rotation was aligned with the dynamometer's axis of rotation. The 2 rotation points were connected with an imaginary line that runs from the dynamometer's axis of rotation, through the humerus, towards the acromion process. Each test started from the point of full ER. Participants warmed up using the Monark 881E Rehab Trainer (Monark, Sweden) for 3 min. Before the test commenced, each participant was informed about the test procedure. Three sub-maximal warm-up repetitions preceded the true test. Verbal encouragement was given during the test to ensure maximal torque output. The actual test consisted of a range of 6 concentric and eccentric maximal contractions. The maximal concentric and eccentric torque levels (in Nm) of the shoulder-girdle complex were determined at speeds of 60°/sec for IR and ER. The above-mentioned values were used to calculate the different isokinetic ratios that were used to evaluate shoulder-muscle performance: the antagonist/agonist ratio and bilateral strength deficit ratio for concentric and eccentric contractions. Furthermore, the functional strength ratio was expressed as the eccentric ER torque production divided by the concentric IR torque production of a shoulder. This functional ratio appears to be relevant among overhead athletes, due to the fact that an increased activity of the external rotators is required to decelerate the humerus to centre the humeral head during a ballistic action.<sup>[16]</sup> The dominant and non-dominant shoulders of each participant were measured.

#### Statistical analysis

SPSS software (version 17.0; IBM, New York) was used for statistical analyses. Descriptive statistics were performed to determine the characteristics of the participants as well as the profiles of the different variables. Frequencies and means with standard deviations (SDs) were calculated. Paired *t*-tests were performed to determine the differences between the measurements of dominant and non-dominant sides of the same individual. The level of significance was set at *p*<0.05.

## Results

Participant characteristics (Table 1) indicated that 42% played rugby union as forwards. Statistically significant differences were found between forwards and backline players with regard to stature or height, weight, body mass index (BMI) and previous injuries to the shoulder joint. Twenty-eight per cent of the participants had suffered previous injuries to the shoulder, including previous surgery, dislocations or subluxations, and any injury that required the player to seek medical attention for intervention. The injuries could have been sustained at any stage, up until the end of the preceding season.

ROM tests were performed to determine the comparative flexibility of the shoulder internal and external rotators (hand-behind-the-neck and -back tests, respectively) (Table 2). Sixty-one per cent of the participants displayed non-ideal or unsatisfactory flexibility of their internal rotators when compared bilaterally. With regard to external rotator flexibility, upon bilateral comparison 84% of the participants were classified as non-ideal or unsatisfactory.

From the New York Posture Test<sup>[13]</sup> used to evaluate thoracic posture (Fig. 1), more than half of the participants displayed a slightly abnormal or abnormal forward head position and a normal classification regarding a rounded back. The majority of the participants displayed normal posture with regard to uneven shoulders. Notably, 67% of the participants were classified as slightly abnormal or abnormal regarding their forward shoulder position.

In terms of the average firing order of muscle activation on the dominant side, the consensus sequence was: (i) serratus anterior, (ii) lower trapezius, (iii) infraspinatus and (iv) upper trapezius (Fig. 2; *x*-axis indicates the firing order, *y*-axis indicates the frequency of that order). The serratus anterior had the highest frequency for firing first (40%) and the lower trapezius had the highest frequency for firing second (42%). A similar firing order was observed on the

**Table 1. Participant characteristics**

Variable	Mean (±SD)		
	All (N=91)	Forwards (N=40)	Backs (N=51)
Age (years)	20.8 (±2.9)	20.8 (±2.7)	20.7 (±3.0)
Stature (cm)	182.0 (±8.1)	186.5 (±7.9)*	178.4 (±6.4)*
Mass (kg)	91.5 (±15.1)	103.3 (±13.3)*	82.2 (±8.6)*
Previous injury, %	27.5	40	17.6
BMI (kg/m <sup>2</sup> )	27.5 (±3.3)	29.7 (±3.5)*	25.8 (±1.7)*

SD = standard deviation; BMI = body mass index.

\*Significant difference (*p*<0.05).

**Table 2. Frequency of shoulder flexibility (non-dominant v. dominant)**

ROM test	Ideal	Non-ideal	Unsatisfactory
	%	%	%
Hand-behind-the-neck	39.3	42.7	18.0
Hand-behind-the-back	15.7	23.6	60.7

ROM = range of motion.

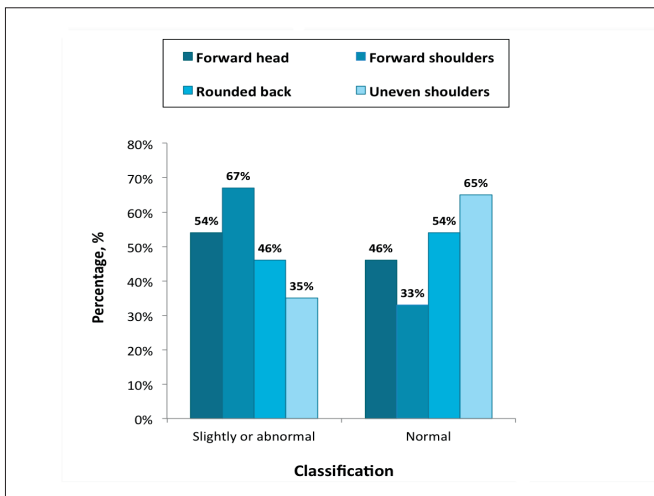


Fig. 1. Thoracic postural profile of participants according to the New York Posture Test.<sup>[20]</sup>

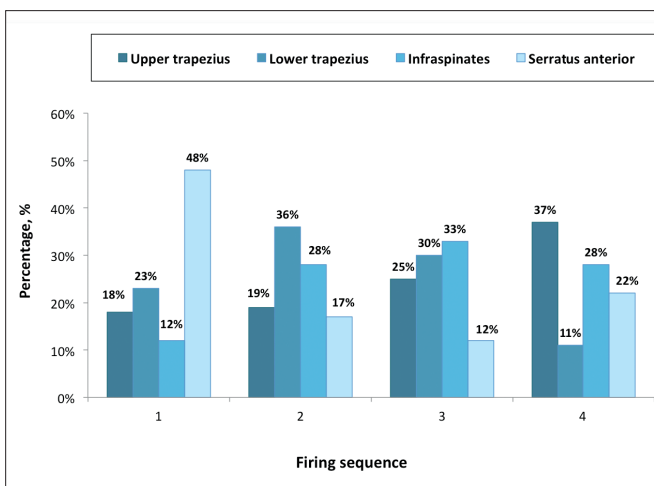


Fig. 2. Percentage of times that the dominant upper trapezius, lower trapezius, infraspinatus and serratus anterior muscles fired in a specific order during abduction in the scapular plane.

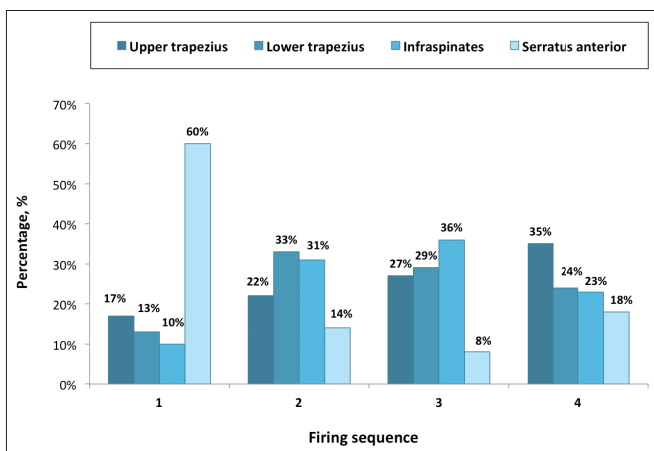


Fig. 3. Percentage of times that the non-dominant upper trapezius, lower trapezius, infraspinatus and serratus anterior muscles fired in a specific order during abduction in the scapular plane.

non-dominant side, despite the fact that different frequencies were observed (Fig. 3).

The results of testing the isokinetic shoulder strengths with the dynamometer (Table 3) were that the antagonist/agonist ratio regarding concentric shoulder rotation of the non-dominant shoulder was slightly lower than what is regarded as acceptable (64%). The corresponding ratio for the dominant shoulder was even lower. A statistically significant difference was observed between the values for the right and left sides. A statistically significant difference was also found between the antagonist/agonist ratio regarding eccentric shoulder rotation of the non-dominant shoulder and the antagonist/agonist ratio regarding eccentric shoulder rotation of the dominant shoulder. The bilateral deficit during concentric IR indicated that the participants' non-dominant shoulders were generally stronger than their dominant shoulders during IR. With regard to concentric ER, the participants' shoulders also appeared to be stronger on the non-dominant side. The bilateral deficit during eccentric IR shows that this right-dominant group was stronger on the dominant side. When one considers the ER component, it seems that there is parity between the average strength of the dominant and non-dominant shoulders.

Table 3. IR and ER isokinetic muscle-strength ratios

Muscle movement	Mean ( $\pm$ SD)
CND ER/IR	64.14 ( $\pm$ 14.41)*
CD ER/IR	54.55 ( $\pm$ 10.18)*
END ER/IR	67.24 ( $\pm$ 11.62)*
ED ER/IR	61.52 ( $\pm$ 9.73)*
ND/DcIR	90.65 ( $\pm$ 12.82)
ND/DcER	106.17 ( $\pm$ 19.50)
ND/DeIR	92.85 ( $\pm$ 11.74)
ND/DeER	101.03 ( $\pm$ 15.68)

IR = internal rotation; ER = external rotation; SD = standard deviation; CND ER/IR = concentric non-dominant external rotation/internal rotation; CD ER/IR = concentric dominant external rotation/internal rotation; END ER/IR = eccentric non-dominant external rotation/internal rotation; ED ER/IR = eccentric dominant external rotation/internal rotation; ND/DcIR = non-dominant/dominant concentric internal rotation; ND/DcER = non-dominant/dominant concentric external rotation; ND/DeIR = non-dominant/dominant eccentric internal rotation; ND/DeER = non-dominant/dominant eccentric external rotation.

\*Significant difference ( $p < 0.05$ ).

## Discussion

The main objective of this study was to profile semi-professional rugby union players in terms of thoracic posture, scapular muscle activation patterns and rotator cuff isokinetic muscle strength. The results indicated that the majority of the players of the Leopards Rugby Union and NWU-Puk Rugby Institute had less than ideal or unsatisfactory flexibility of their external shoulder rotators when the left and right shoulders were compared. Testing the flexibility of the shoulder internal rotators indicated that only a small percentage of the players had ideal flexibility when their left and right shoulders were compared. This supports the findings of a previous study<sup>[17]</sup> of a diminished glenohumeral rotation range among professional rugby players in comparison with a control group. Another study also reported deficiencies in rugby players' ROM, possibly attributed to

age, playing position, body mass index (BMI) or a history of injury. It was previously found that age could be a risk factor for decreased flexibility of shoulder rotators.<sup>[17]</sup> This could be related to the ageing of the glenohumeral soft tissue, which may be accelerated by the training and injuries associated with rugby.<sup>[17]</sup> Deficiencies in ROM can be regarded as a risk factor for future injuries. The areas affected by decreased ROM are obviously less mobile. Consequently, the joint's supporting structures are dynamically loaded and susceptible to intrinsic injury.

The results further indicate a higher prevalence of abnormal thoracic posture than reported in the literature for a non-sporting population. In the latter, 66% of subjects had a forward head, 60% had thoracic spine kyphosis, and 38% had rounded shoulders.<sup>[2]</sup> This higher prevalence could have been attributed to the poor flexibility of certain anatomical structures, incorrect strength training, or incorrect conditioning techniques applied among the players. To our knowledge, no research has been done on incorrect training techniques among rugby union players and the association thereof with poor posture. However, it has been found that decreased resting length of the pectoralis minor muscle could have a negative influence on scapular kinematics. Therefore, a strength programme where there is an imbalance between pectoralis major strengthening (too much) v. latissimus dorsi strengthening (insufficient), may contribute towards a shortened pectoralis major muscle. This may also be exaggerated by insufficient stretching of the pectoralis major muscle. This could result in a scenario where posture, and consequently scapular kinematics, may be negatively influenced, ultimately increasing the risk of injury. However, there is an argument that certain postural deviations such as abducted scapulae and rounded shoulder posture may be advantageous for contact sport athletes. The theory is that this posture allows the athlete to assume a tuck or covered-up position quickly before making contact with defending players. However, this seems to be a matter of opinion, and no sufficient scientific data exist to confirm this theory. Some believe that a link exists between posture and ROM. ROM loss may be directly attributed to changes in thoracic posture. Such changes may cause a reduction in the sub-acromial space, which may cause impingement of supra-humeral soft tissue and subsequently reduce the overall ROM and increase the likelihood of injury. Theoretically, the high percentage of postural deformities within this group, given the high physical demands placed on rugby union players, could make this group susceptible to future shoulder injury. Poor posture, therefore, not only influences ROM but also impedes optimal scapular kinematics.

Knowledge of scapular muscle timing patterns is vitally important in terms of our understanding of the behaviour of the joint system, particularly under demanding circumstances. It is relevant to profile rugby union players with regard to these patterns. EMG analyses present information on the sequence in which the scapular stabilisers fire during shoulder movement along a scapular plane. In this study the consensus sequence was: (i) serratus anterior, (ii) lower trapezius, (iii) infraspinatus, and (iv) upper trapezius. Previous research regarding EMG analysis of rugby players' scapulothoracic muscles is limited, but the sequence of muscle activation patterns in selected shoulder girdle muscles during a front-on tackle in asymptomatic rugby players has previously been investigated.<sup>[5]</sup> The authors found a consistently earlier activation of serratus anterior compared with the pectoralis major,

biceps brachii, latissimus dorsi and infraspinatus. In accordance with our study, even though different movements were measured, the results also indicated that the serratus anterior was the first muscle to fire before the other muscles tested. The influence of a superior labral tear from anterior to posterior (SLAP lesion) on the onset of EMG activity in shoulder muscles during a front-on tackle among professional rugby union players has also been investigated.<sup>[18]</sup> Again, results indicated that the onset of serratus anterior muscle activity occurred significantly earlier than the other muscles examined. This was seen, despite a trend towards a delay in activation time of all the other muscles within the injured group.<sup>[19]</sup> It is obvious that serratus anterior plays a significant role in the initial stabilisation of the scapulothoracic joint in a simulated tackle situation. It is postulated that a delay in the activity of serratus anterior, and the subsequent impairment in scapular control, would allow the humeral head to translate anteriorly and superiorly when the humerus reached an abducted position in the tackle situation. This could ultimately have a detrimental effect on the dynamic stability of the glenohumeral joint.<sup>[19]</sup>

During our study the most frequent firing order for the trapezius muscles was the lower trapezius second and the upper trapezius fourth. It has been postulated that an early activation of the stabilising muscles at the proximal scapulothoracic joint is important for maintaining proper scapulothoracic stability throughout glenohumeral movement, and that the correct sequence of these muscles' activity is critical for normal scapular kinematics.<sup>[11]</sup> The muscles that aid the serratus anterior in providing dynamic stability to the scapula, provide a force by coupling around the scapula.<sup>[8]</sup> The infraspinatus plays a role in posterior glenohumeral joint stability, but its ability to provide early support to this joint is apparently impaired by injury. It has been shown that the infraspinatus activates significantly earlier than the pectoralis major and latissimus dorsi during a simulated tackle situation, but that this earlier activation is not seen among injured players. This may be indicative of a failure of the local control system that could possibly lead to increased stress on the shoulder support structures. All the muscles that were tested by means of EMG during this study have important functions regarding the normal shoulder function of rugby players, and it has been shown that the correct timing of the activation of these muscles is significant.<sup>[1,8,19]</sup> Altered muscle activation patterns could contribute towards scapular dyskinesia or indicate underlying injury, but normative data regarding correct muscle activation patterns could possibly aid in identifying potential weaknesses among scapular stabilisers before injury occurs.

During this particular study, the antagonist/agonist ratio regarding concentric isokinetic shoulder rotation of the right shoulder was only 55%, while that of the left shoulder was 64%. These findings are comparable with those of another study<sup>[17]</sup> where a concentric external/internal rotator muscle ratio of 64% and 56% was reported for rugby backline and forward players, respectively. In both studies, the suggested antagonist/agonist muscle-strength ratio of 65%<sup>[16]</sup> was not found. This could be relevant due to the fact that muscle imbalances around a specific joint may increase the risk of injury to athletes.<sup>[16]</sup> The statistically significant difference between the players' dominant and non-dominant antagonist/agonist ratios in the current study is also noticeable. It is unclear why the dominant shoulders generally tended to have weak antagonist/agonist ratios. The tackle is the phase of play in which most game injury events occur.<sup>[20]</sup> If rugby players

generally tend to tackle with their dominant shoulder, the possibility could exist that training and tackling over a period of time may have a detrimental effect on the soft-tissue supporting structures around the shoulder joint. This may impair normal functioning and, even though players may not perceive being injured, the wear and tear may be manifested in inadequate shoulder-strength ratios. Another area of interest lies in the fact that bilateral comparisons displayed that the participants had, on average, stronger concentric IR and ER strength on the non-dominant than the dominant side. Despite the fact that varied results have been found regarding dominant v. non-dominant shoulder strengths for overhead athletes, it has generally been found that the dominant side is as strong as,<sup>[21]</sup> or stronger than,<sup>[22]</sup> the non-dominant side. The findings of our study are therefore contrary to those of previous research and may be indicative of the weakness of our participants' dominant concentric IR and ER strength.

### Study limitations

Certain limitations of our study should be acknowledged. We employed the New York Posture Test due to a lack of objective posture-measurement techniques; however, this test was initially designed to classify adolescents and is therefore not ideal for our group of participants, of whom a large proportion were beyond the adolescent stage (range 17 - 31 years). Secondly, regarding ROM measurement, a more scientific and objective method is required than employed in this study. Lastly, with regard to the measurement of scapular muscle activation patterns, the information would be more relevant if the muscles were to be tested during more functional, rugby-applicable movements, such as tackling, for instance.

### Conclusion

A large percentage of the participants in our study displayed non-ideal or unsatisfactory flexibility of the shoulder internal rotators. More than two-thirds displayed forward shoulders and more than half of the participants had unsatisfactory or non-ideal head positions. These are all indicative of a kyphotic posture. The firing sequence in abduction in a scapular plane and in both shoulders was: (i) serratus anterior, (ii) lower trapezius, (iii) infraspinatus, and (iv) upper trapezius. As the participants were uninjured, this firing order may indicate the normal sequence of rugby players' scapular stabilisers during abduction in a scapular plane. It appears that the firing order of serratus anterior, prior to those of the other muscles studied, may be important for rugby players to maintain healthy shoulder function. The isokinetic shoulder-muscle strength and ratios indicated a possible deficiency with regard to ER strength in the dominant shoulder. This is possibly manifested in an unsatisfactory antagonist/agonist shoulder rotation ratio. The profile of the thoracic posture of the participants presents an image of a kyphotic rugby player with an inappropriate ROM. This, in combination with an apparent weakness of right shoulder external rotator strength among the players, could have an impact on the prevalence of future injury from a biomechanical point of view, especially in the game of rugby with ever-increasing physical demands placed on players. By identifying these apparent musculoskeletal weaknesses, it may be possible to rectify them pro-actively with rehabilitation.

**Conflict of interest.** The authors have no conflicts of interest to declare.

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# CHAPTER 4

## THE RELATIONSHIP BETWEEN THORACIC POSTURE, ISOKINETIC SHOULDER STRENGTH AND SCAPULAE MUSCLE ACTIVATION PATTERNS AMONG RUGBY PLAYERS

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## ABSTRACT

**Objective.** Posture influences shoulder movement patterns and shoulder strength, which may influence shoulder joint movement. This inter-relationship have not been studied before among rugby union players. The aim of this study is to determine how these variables influence each other among a cohort of rugby players.

**Methods.** Ninety-one (91) uninjured semi-professional rugby union players participated. Shoulder joint range of motion (ROM) was manually tested with the hand-behind-the-neck and hand-behind-the-back method. Thoracic posture was profiled and classified according to the New York Posture Test. Scapular muscle activation patterns were determined with electromyography (EMG) measuring the activation sequence of the upper and lower trapezius, serratus anterior and infraspinatus muscles. The isokinetic muscle strengths of the rotator cuff muscles were determined at 60°/sec (Kin-Com 500H) measuring concentric and eccentric forces during internal and external rotation in 90 degrees abduction.

**Results.** Median muscle onset times of the backline players' non-dominant infraspinatus muscles was slowest for the non-ideal external rotators' ROM (95.20 ms). Median firing orders of the forwards' dominant lower trapezius muscle was 3 for ideal, 1 for non-ideal, and 2 for unsatisfactory external rotators ROM. Among the forward shoulder group and the normal shoulder position group of the forwards respectively, the median muscle onset time of their non-dominant infraspinatus muscle was 113 ms and 42 ms. Their non-dominant serratus anterior muscles' median onset time was 78.85 ms among the players with a rounded back, and 31.90 ms among the players with a normal thoracic curvature. The backline players displayed a median non-dominant serratus anterior onset time of 47.45 ms (uneven shoulder group) versus 32.75 ms (even shoulder group). The median firing order of the backline players' non-dominant infraspinatus muscle was third in the normal-curved back group. Median firing order changed to second in the group with abnormal rounded back . The median external rotation/internal rotation isokinetic strength ratio of the forward players was 63% (forward shoulders), versus 56.50% (normal shoulder position). This was for their non-dominant shoulders.

**Conclusions.** A positive relationship exists between certain postural abnormalities (forward shoulders, rounded back and uneven shoulders) and the delay of muscle onset times of infraspinatus and serratus anterior muscles among rugby players, as well as the firing order of infraspinatus. Forward shoulders also increase antagonist/agonist isokinetic shoulder rotation strength ratios. Non-ideal flexibility of shoulder external rotators has a positive relationship with altered infraspinatus

muscle onset times and altered lower trapezius muscle firing order. No clinically significant correlations were found between isokinetic shoulder strength ratios and scapulae muscle activation patterns.

Key words: Shoulder, posture, EMG, isokinetic, injury

## INTRODUCTION

Rugby union enjoys increasing worldwide popularity despite the fact that it has one of the highest reported incidences of injury (Brooks *et al.*, 2005; Fuller, 2010; Gabbett, 2008). The shoulder is reported to be the second most common site of injury in the rugby player, contributing to almost 20% of all rugby injuries (Funk & Snow, 2007).

The literature indicates that poor posture (Finley & Lee, 2003), scapular dyskinesia or altered scapular muscle recruitment patterns (Horsley *et al.*, 2010) and shoulder strength weaknesses or imbalances (Wang *et al.*, 2000) may contribute towards shoulder injury. What seems to be unclear at this stage, however, is what the relationship between posture, scapular muscle recruitment patterns and shoulder rotational isokinetic strength among rugby union players may be.

The literature provides sufficient proof that a relationship exists between poor posture (cervical and thoracic) and shoulder pathology (Finley & Lee, 2003; Greenfield *et al.*, 1995; Griegel-Morris *et al.*, 1992; Kebaetse *et al.*, 1999), and that rounded shoulders and forward head posture changes the normal orientation of the scapular plane (Greenfield *et al.*, 1995). Inman *et al.* (1996) states that the critical early phase of shoulder motion seems to depend upon the habitual position the scapula is in during rest. This could imply that the resting posture may be of great importance when looking at normal shoulder function and possibly the restoration of normal shoulder function. Bruwer (2006) more recently stated that a postural factor such as kyphosis may be considered as an intrinsic risk factor for shoulder injury among rugby players. However, due to small sample sizes involved, Bruwer's (2006) correlations were not proven to be practically significant.

Bullock *et al.* (2005), Grimsby and Gray (1997) and Solem-Bertoft *et al.* (1993) state that an increased thoracic curvature accompanying thoracic kyphosis may influence scapular kinematics, and that a slouched posture may cause limitations in shoulder flexion. Grimsby and Gray (1997) suggested that an exaggerated thoracic kyphosis may adversely influence length-tension relationships of the shoulder girdle muscles, and that this may cause abnormal shoulder kinematics due to mal tracking of the humeral head within the glenoid fossa. According to Kebaetse *et al.* (1999), an increased thoracic kyphosis may lead to anteriorly tilted scapulae. The extent of thoracic kyphosis and anteriorly tilted scapulae may be exaggerated, when in combination with an excessive cervical flexion (due to tension in the levator scapulae), thus resulting in the limitation of shoulder

flexion (Bullock *et al.*, 2005). These findings suggest that there is a relationship between postural deviations and flawed shoulder kinematics.

In certain sports the demands that are put upon the shoulders are extremely high, and the quality of shoulder joint movement therefore depends upon the interaction between the scapular and glenohumeral kinematics (Cools *et al.*, 2002). The classic work of Inman *et al.* (1996) underlines the important role of the scapulohumeral rhythm as well as its necessity for normal shoulder function. It is accepted that the scapula plays an important role in the stability and mobility of the shoulder joint (Kibler, 1998; Lear & Gross, 1998; Wilk & Arrigo, 1993). According to Paine and Voight (1993) the scapula provides a stable base from which glenohumeral mobility originates, and stability at the scapulothoracic joint relies upon the effectiveness of the scapular stabilizing muscles. Apparently these scapular muscles play a role in positioning the glenoid so that efficient glenohumeral movement can occur (Paine & Voight, 1993). Belling, Sørensen and Jørgensen (2000) identify the dynamic stabilisers of the scapulothoracic as the serratus anterior, trapezius, and rhomboid muscles. Kibler (1998) states that the sequence of recruitment and the level to which each muscle is activated during movement are important factors in coordinating scapular motion with humeral elevation. Belling, Sørensen and Jørgensen (2000) also stress the importance to shoulder movement of the optimal coordination of the dynamic stabilisers of the scapulothoracic joint. It therefore appears that altered muscle recruitment patterns of scapular muscles, or the weakening of these stabilizers, may result in the deterioration of normal shoulder function.

Apart from the apparent link between posture and scapular kinematics, there is also an evident relationship between posture and shoulder strength (Smith *et al.*, 2006), and shoulder strength and scapular movement patterns (Ebaugh *et al.*, 2006; McQuade *et al.*, 1995; Tsai *et al.*, 2003). The scapula plays a critical role regarding normal and pain-free shoulder function, as well as providing a stable base from which the rotator cuff muscles can function (Smith *et al.*, 2006). Smith *et al.* (2006) demonstrated for the first time that scapular position affects shoulder rotation force-generation capabilities. The findings of their study indicate that scapular protraction significantly reduces isometric shoulder internal rotation strength and to a lesser degree external rotation strength. Internal rotation strength was on average 20% greater in the subjects with a neutral scapula position as against subjects with a protracted scapula test posture (Smith *et al.*, 2006).

Ebaugh *et al.* (2006) contributed to the findings by Smith *et al.*, (2006) by indicating that fatigue of shoulder external rotators caused altered scapulothoracic and glenohumeral kinematics. These alterations caused a decrease in scapular posterior tilt and - humerus external rotation, which in turn could lead to a decrease in the subacromial space and subsequent soft tissue damage due to increased compression forces, especially to rotator cuff tendons (Ebaugh *et al.*, 2006). When studying the possible correlation between rotator cuff strength and scapulothoracic and glenohumeral kinematics, it would be inaccurate to assume that fatigue is the equivalent of a loss of force production. However, according to Ebaugh *et al.* (2006) a reduction in the force output of the shoulder external rotators could well explain the decreased humeral external rotation. This view could possibly be supported by the fact that a common consequence of fatigue appears to be a decrease in force output (Stackhouse *et al.*, 2003). Taking this information into consideration, it appears that a link between shoulder rotator cuff strength and shoulder kinematics may be feasible. Even though the studies of Ebaugh *et al.* (2006) and Smith *et al.* (2006) were conducted on the general population, it would be of interest to note whether or not these patterns are repeated among rugby players.

Prior studies have provided evidence that relationships exist between posture and scapulothoracic and glenohumeral kinematics (Bullock *et al.*, 2005; Greenfield *et al.*, 1995; Solem-Bertoft *et al.*, 1993), between posture and rotator cuff strength (Smith *et al.*, 2006), and between muscle strength and shoulder joint kinematics (Ebaugh *et al.*, 2006). Studies investigating the inter-relationships between posture, scapular muscle recruitment patterns and shoulder strength among semi-professional rugby union players could not be located in the literature. The aim of this study was therefore to determine the relationships between posture, shoulder joint kinematics muscle activation and shoulder strength among rugby union players. The outcomes of this study will contribute to the knowledge available on the expected abnormalities in shoulder biomechanics related to specific postural abnormalities among rugby union players. This may help to identify factors that could contribute towards faulty biomechanics more effectively, thus being able to act more pro-actively in terms of shoulder injury prevention.

## **MATERIALS AND METHODS**

### **Participants**

Ninety-five (95) uninjured participants, all based in the North-West Province and playing for the Leopards Rugby Union and North-West University PUK Rugby Institute (NWU PUK RI), were recruited to participate in the study. The participants were the PUK U/19 A and B, PUK U/21 A and B and Leopards Senior players (Provincial) between the ages of 17 and 31 years. An informed consent document was signed by all the participants after the test procedure and study protocols had been explained to them. Approval for performing the study was obtained from the Ethics Committee of the NWU (NWU-00048-11-A1). All participants were tested in the pre-season to ensure that all participants were uninjured during testing. Left hand dominant participants (n = 4) were excluded from the analysis in this study.

### **Study Design**

This observational analytical cohort study included semi-professional rugby union players who consented to participate in this study, which formed part of a larger study investigating the occurrence of shoulder injuries during the 2010 rugby season. Players were included in the study when they were contracted to the Leopards Rugby Union or Puk Rugby Institute of the North-West University and if they were injury free with regards to shoulder injuries. Exclusion criteria included previous surgical intervention regarding one or both shoulders and current injury of the upper body, specifically to the shoulders, back and neck. Injury was defined as any discomfort that prevented players from completing a regular training session or match. All the test were performed in the laboratory of the Biokinetics Institute of the North-West University, Potchefstroom campus, with the room temperature regulated at 21° Celcius. All the tests were performed by the same researcher.

### **Measurements**

#### *Demographic Information*

The stature of each participant was measured to the nearest 0.1 cm, with a stadiometer (Seritex) using the stretch stature method (ISAK 2001). Body mass was measured to the nearest 0.1 kg with an electronic weighing scale (Micro) (ISAK, 2001). Participants completed an information sheet recording their age, position of play, dominant side and previous rugby injury history.

### *Shoulder range of motion differences*

Biomechanical tests were performed according to a pro-forma compiled from various sources (Bruwer, 2006; Erasmus, 2007; Kapandji, 1970). Shoulder range of motion (ROM) was determined prior to a warm-up by the “hand-behind-the-neck” and “hand-behind-the-back” tests (Erasmus, 2007; Kapandji, 1970; Ozunlu, 2011). Measurements were taken after one maximal effort of each movement. During both these tests participants were standing in an upright position. In the case of the “hand-behind-the-neck” test participants reached with one of their hands over their ipsilateral shoulder and placed their hands as far down their spinal columns as possible, with a mark being placed at the end point of movement. In this case the end point would refer to the most inferior point, with the shoulder in a position of external rotation. After this, using the same technique, the contralateral hand was also placed as far down the spinal column as possible with the end point also being marked. The distance between the two marks to the nearest millimeters were classified in terms of the relative differences between the left and right shoulders’ ROM. A difference of less than one centimeter was classified as ideal. Differences between one and three centimeters were classified as non-ideal, while differences of more than three centimeters were classified as unsatisfactory. During the “hand-behind-the-back” test, the same principles and classifications were applied. However, in this case the participants aimed to place their hands as high as possible on their spinal columns (the most superior end point), with the shoulder in a position of internal rotation.

### *Thoracic posture analysis*

The New York Posture Test, which is designed for identifying thirteen categories of deformities, was used for the evaluation and identification of possible postural deformities in rugby players (Kendall, 1993; Magee, 2002:1020). Thoracic postural assessment was performed by taking high quality photographs with a digital camera (Canon A2000 IS Power Shot, Canon USA Inc.) from a lateral and posterior view of each participant. The camera was placed at a ninety degrees angle to the subject’s shoulders to ensure the accurate calculation of angles. These digital photos were then analysed with the Dartfish computer software programme version 4.06.0 (DARTFISH, Switzerland). 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, winged scapulae/round shoulders, and thoracic kyphosis. Uneven shoulders were measured by placing bright yellow markers, 1 cm in diameter, on the posterior-lateral edges or acromial angles of the left and right acromions of the participants. Uneven shoulders were defined by the angle formed

between the line connecting the inferior edges of the markers placed on the left and right acromial angles and a true horizontal line. To reduce the degree of subjectivity the following criteria are provided by the New York Posture Test to score uneven shoulders: 5 = 0-2 degrees; 3 = 2.1-4 degrees; and 1 >4 degrees.

### *Scapular muscle activation patterns*

Electromyographic (EMG) activity of the scapulothoracic muscles were registered by means of bilateral and simultaneous abduction of both arms in the scapular plane (thirty degrees in front of the coronal plane) (Wadsworth & Bullock-Saxton, 1997). The output of muscle activation was measured in microvolt ( $\mu\text{V}$ ). The firing order of the muscles were obtained by firstly measuring latency times (ms) and consequently determining the sequence of the firing order. This was done by calculating the percentage of times (the frequency) that a specific muscle group fired in a specific order. According to these percentages, the muscles were then classified in terms of the firing order sequence. Data was obtained by means of the Myotrace 400 Biofeedback system (Noraxon EMG and Sensor Systems, Noraxon USA Inc., Scottsdale, Arizona, USA). The system operates by means of a 4-channel transmitter; thus allowing for simultaneous data collection from 4 strategically placed electrodes. EMG electrodes (Model 93-0101-00, Mindware Technologies LTD), one cm in diameter, were attached unilaterally to the subjects' upper and lower trapezius, serratus anterior and infraspinatus muscles respectively, in accordance with SENIAM guidelines (Hermens *et al.*, 2009). The overlying skin on the muscles was carefully prepared, the outer layer of epidermal cells abraded, and oil and dirt removed from the skin with alcohol pads (Hunter *et al.*, 2003). Due to the fact that only four channels were available to do the tests, the four muscles were measured unilaterally, after which the test was repeated on the contra-lateral side. The participants started the required movement with their arms hanging next to their sides. They did bilateral arm abduction in the scapular plane, with their thumbs facing in an upward direction, to a point of one hundred and eighty degrees of abduction, after which they immediately performed adduction until reaching the original starting point. The test was standardized for both sides by regulating the tempo at which the abduction and adduction took place. This was done with the help of a timer that is a function on the Noraxon EMG and Sensor System. They did the total abduction-adduction sequence in seven seconds, and no resistance was used or applied during the movement. No pilot study was done with regards to the EMG testing but to achieve reliability and accuracy of testing the EMG signals were

full wave rectified, low and high-pass filtered, with cut-off frequencies of 500 and 10 Hz, respectively, and recorded at a sampling rate of 1000 Hz.

#### *Rotator cuff isokinetic muscle strength testing*

The peak torque and muscle agonist/antagonist ratios of the shoulder were tested with the Kin-Com 500H isokinetic dynamometer (Isokinetic International, Tennessee, USA) with torque/power expressed in Newton.meter (Nm) (Oman, 2004). Torque scores are representative of the moment of force produced by muscle contraction for rotation around a joint (Coetzee, 2002). During shoulder internal and external rotation, the participant was seated and strapped to the seat. Testing was performed with the player's arms positioned along the scapular plane, at ninety degrees of abduction, with ninety degrees of elbow flexion. The participant's contra-lateral arm was held against his chest and was static throughout the test. The feet were placed on a footrest. The axis of rotation of the shoulder was aligned with the dynamometer's axis of rotation. These two rotation points were connected with an imaginary line that runs from the dynamometer's axis of rotation, through the humerus, towards the acromion process. Each test started from full external rotation and the effect of gravitation was compensated for during testing. Participants performed a warm-up exercise on the Monark 881E Rehab Trainer (Monark, Sweden) for three minutes prior to isokinetic testing. Before the test commenced, each participant was informed about the testing procedures. Three sub-maximal warm-up repetitions preceded the true test. Verbal encouragement was given during the test to ensure maximal torque output. The actual test consisted of a series of six concentric and eccentric maximal contractions. The maximal concentric and eccentric torque levels (Nm) of the shoulder-girdle complex were determined at 60°/sec for internal and external rotation (Oman, 2004). These values were used to calculate the different isokinetic ratios that were used to evaluate shoulder muscle performance. The ratios determined included antagonist/agonist ratios and bilateral strength deficit ratios for concentric and eccentric contractions. Furthermore, the functional strength ratios were expressed as the eccentric external rotational torque production divided by the concentric internal rotational torque production of the shoulder rotators. This functional ratio appears to be relevant among overhead athletes, due to the fact that an increased activity of the external rotators is required to decelerate the humerus and to centre the humeral head during a ballistic action (Bak & Magnusson, 1997). Both the dominant and the non-dominant shoulders were measured among all the participants.

## Statistical analysis

IBM's SPSS Vers.19.0 (IBM, New York, 1989, 2010) statistical software programme was used for the statistical analyses. A *p* value of less than 0.05 was considered as statistically significant. Bivariate analyses were performed by means of independent T-tests to compare normally distributed continuous baseline measurements between forward and backline players. Non-parametric analysis was performed using the Mann-Whitney U test for the biomechanical measurements which were not normally distributed in order to compare them between two independent groups. Kruskal-Wallis tests were performed for the three groups of ROM classifications. Similarly, continuous variables were correlated by using Spearman's rank correlation coefficient.

## RESULTS

The mean age of the ninety-one participants in the study was  $20.8 \pm 2.9$  years (Table 1). The mean height of the participants was  $182 \pm 8.1$  centimeters with the forwards being significantly taller than the backline players. Participants' mean weight was  $91.5 \pm 15.1$  kilograms. The forwards were also significantly heavier than the backline players. Twenty-seven percent of the participants had shoulder injuries from which they have recovered at some point in their careers.

**Table 1: Participants' characteristics**

<b>Variables</b>	<b>Forwards</b>	<b>Backline</b>		<b>Total</b>
	<b>Mean <math>\pm</math> SD</b>	<b>Mean <math>\pm</math> SD</b>	<b><i>p</i></b>	<b>Mean <math>\pm</math> SD</b>
<b>Age (years)</b>	$20.8 \pm 2.7$	$20.7 \pm 3.0$	0.96	$20.8 \pm 2.9$
<b>Stature (cm)</b>	$186.5 \pm 7.9$	$178.4 \pm 6.4$	<0.001	$182.0 \pm 8.1$
<b>Weight (kg)</b>	$103.3 \pm 13.3$	$82.2 \pm 8.6$	<0.001	$91.5 \pm 15.1$
<b>Body mass Index (kg/m<sup>2</sup>)</b>	$29.7 \pm 3.5$	$25.8 \pm 1.7$	<0.001	$27.5 \pm 3.3$

Results of this study indicate that the mean muscle onset times of the left infraspinatus muscles were significantly longer among the forwards with abnormally forward shoulders than with the forwards with normal positioned shoulders (Table 2). Statistically significant differences were also found between the mean left serratus anterior muscle onset times when forwards with an abnormally rounded back were compared to those displaying normal thoracic curvature. The "normal"

participants therefore displayed faster muscle onset times within the non-dominant infraspinatus and serratus anterior muscles (Table 2).

Table 3 displays the same information as does Table 2, but it pertains to the backline players in the study only. Once again the left serratus anterior mean muscle onset times differ when players with normal characteristics are compared to those with abnormal characteristics. The backline players with uneven shoulders display statistically significant slower mean muscle onset times than the participants with even shoulders.

The mean firing orders of infraspinatus muscles among backline players with abnormally rounded backs are statistically significantly earlier than in players with normally rounded backs. These findings are displayed in Table 4.

Table 5 displays various isokinetic muscle strength values and their relationship with the biomechanical variables that are included in Tables 2 – 4. The only statistically significant difference that is displayed in this table is the difference between normal and abnormally forward shoulder positions, and this occurs during concentric left shoulder rotation. The left concentric external rotation/internal rotation strength ratio for the forwards with abnormally forward shoulders was higher than that of the normal group.

**TABLE 2: The median muscle onset times of the forwards' scapular stabilisers for selected normal and abnormal postural variables, measured in milliseconds**

	Forward head		Forward shoulders		Rounded back		Uneven shoulders	
	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal
<b>UT Onset (ND)</b>	75.40	77.20	79.50	75.15	86.70	67.60	75.40	77.20
<b>LT Onset (ND)</b>	82.90	73.20	82.90	58.70	106.85	56.30	97.70	56.95
<b>IF Onset (ND)</b>	91.90	89.05	113.00*	42.00*	104.30	62.90	191.00	75.15
<b>SA Onset (ND)</b>	50.20	40.50	46.20	31.40	78.85*	31.90*	59.70	44.70
<b>UT Onset (D)</b>	100.00	86.10	85.60	113.00	93.05	88.10	120.50	85.60
<b>LT Onset (D)</b>	104.00	87.20	87.80	80.10	79.85	111.00	111.00	81.75
<b>IF Onset (D)</b>	108.00	88.10	88.10	109.00	99.80	94.00	100.30	94.00
<b>SA Onset (D)</b>	47.60	81.90	63.40	63.60	47.60	81.90	67.15	63.50

\* Significant difference at  $p < 0.05$  between the normal and abnormal participants' characteristics

UT : Upper Trapezius; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant; D : Dominant; ms : milliseconds

**TABLE 3: The median muscle onset times of the backline players' scapular stabilizers for certain normal and abnormal postural variables, measured in milliseconds**

	Forward head		Forward shoulders		Rounded back		Uneven shoulders	
	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal
<b>UT Onset (ND)</b>	76.70	65.40	75.70	79.60	97.85	65.90	82.90	74.75
<b>LT Onset (ND)</b>	58.10	48.30	48.90	68.25	53.70	57.50	53.70	57.50
<b>IF Onset (ND)</b>	89.00	76.30	78.20	89.00	99.00	78.20	78.20	88.80
<b>SA Onset (ND)</b>	42.00	32.90	38.50	38.60	42.00	36.80	47.45*	32.75*
<b>UT Onset (D)</b>	88.10	94.80	92.85	96.50	94.90	90.90	94.20	94.80
<b>LT Onset (D)</b>	61.70	83.20	75.60	57.45	59.70	72.90	44.10	72.90
<b>IF Onset (D)</b>	90.50	92.10	90.60	101.00	92.10	90.60	90.50	92.10
<b>SA Onset (D)</b>	52.65	39.85	56.55	37.20	39.20	53.65	38.30	55.10

\* Significant difference at 0.05 level between the normal and abnormal participants' characteristics

UT : Upper Trapezius; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant; D : Dominant

**TABLE 4: The median firing orders of the backline players' scapular stabilizers for certain normal and abnormal postural variables**

	Forward head		Forward shoulders		Rounded back		Uneven shoulders	
	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal
<b>UT (ND)</b>	3	3	3	4	3	3	3	3
<b>LT (ND)</b>	3	2	2	3	3	2	3	2
<b>IF (ND)</b>	3	3	3	2	2*	3*	2	3
<b>SA (ND)</b>	1	1	1	1	1	1	2	1
<b>UT (D)</b>	3	3	3	4	3	3	3	3
<b>LT (D)</b>	2	2	2	2	2	2	2	2
<b>IF (D)</b>	3	3	3	3	3	3	3	3
<b>SA (D)</b>	1	1	2	1	1	1	1	2

\* Significant difference at 0.05 level between the normal and abnormal participants' characteristics

UT : Upper Trapezius; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant; D : Dominant

**TABLE 5: The median isokinetic strength ratios of the forward players for certain normal and abnormal postural variables, portrayed as percentages**

	Forward head		Forward shoulders		Rounded back		Uneven shoulders	
	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal	Normal
<b>ER/IR C (ND)</b>	61.00	61.00	63.00*	56.50*	63.00	61.00	60.50	62.50
<b>ER/IR C (D)</b>	57.00	58.00	57.00	57.00	56.00	57.50	56.00	57.00
<b>ER/IR E (ND)</b>	69.00	65.00	66.00	66.50	70.00	64.50	65.00	69.50
<b>ER/IR E (D)</b>	60.00	62.00	61.00	60.00	60.50	61.00	60.00	61.50
<b>ND/D C IR</b>	97.00	100.00	98.50	98.50	103.50	93.50	102.50	97.00
<b>ND/D C ER</b>	106.00	104.00	100.00	107.50	103.50	104.50	106.00	101.00
<b>ND/D E IR</b>	102.00	96.00	96.50	105.50	101.50	95.50	99.50	97.50
<b>ND/D E ER</b>	97.00	106.00	101.00	105.50	101.00	103.00	99.50	104.50

\* Significant difference at 0.05 level between the normal and abnormal participants' characteristics

ER : External rotation; IR : Internal rotation; C : Concentric; E : Eccentric; ND : Non-dominant; D : Dominant

Table 6 shows the different mean muscle onset times of the backline players' scapula stabilizers and how they are distributed among the different categories of the hand-behind-the-neck and hand-behind-the-back tests. It has been shown in this table that the distribution of the infraspinatus muscle's firing order was not the same across the different categories of the hand-behind-the-back tests.

**TABLE 6: The median muscle onset times of the backline players' scapular stabilizers for the different ROM classifications**

Stabilising muscles	ROM Behind Neck			ROM Behind Back		
	0	1	2	0	1	2
UT Onset (ND) (ms)	67.50	95.50	102.00	64.45	73.80	90.20
LT Onset (ND) (ms)	38.85	55.40	78.40	57.20	56.75	42.50
IF Onset (ND) (ms)	57.30	92.00	116.00	35.90*	95.20*	93.90*
SA Onset (ND) (ms)	34.00	39.90	38.45	35.55	47.05	33.40
UT Onset (D) (ms)	84.50	96.30	111.00	89.15	96.85	95.55
LT Onset (D) (ms)	53.60	66.90	60.10	88.95	67.30	46.95
IF Onset (D) (ms)	86.80	91.30	129.00	86.80	90.50	94.95
SA Onset (D) (ms)	53.65	50.65	38.15	65.00	52.20	33.40

\* Significant difference at 0.05 level between the participants' distribution

UT : Upper Trapezius; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant  
D : Dominant

**TABLE 7: The median firing orders of the forwards' scapular stabilizers for the different ROM classifications**

Stabilising muscles	ROM Behind Neck			ROM Behind Back		
	.00	1.00	2.00	.00	1.00	2.00
UT (ND)	3	2	3	2	4	2
LT (ND)	3	3	2	3	3	3
IF (ND)	3	3	3	4	3	3
SA (ND)	1	2	1	1	1	2
UT (D)	2	4	2	1	3	3
LT (D)	2	2	3	3*	1*	2*
IF (D)	3	2	3	2	2	3
SA (D)	2	1	3	2	4	2

\* Significant difference at 0.05 level between the participants' distribution

UT : Upper Trapezius ; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant  
D : Dominant

**Table 8: The correlations between isokinetic shoulder strength ratios and the firing orders of the scapulae stabilizers of semi-professional rugby players**

	ER/IR C (ND)		ER/IR C (D)		ER/IR E (ND)		ER/IR E (D)		ND/D C IR		ND/D C ER		ND/D E IR		ND/D E ER	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
<b>UT (ND)</b>	.045	.696	.093	.420	.023	.842	.045	.697	-.111	.334	-.068	.555	.007	.950	-.013	.913
<b>LT (ND)</b>	-.046	.691	-.040	.727	.105	.360	.097	.396	.042	.714	.052	.651	.066	.566	.114	.320
<b>IF (ND)</b>	.003	.977	-.095	.406	-.043	.709	-.040	.728	.239	.035*	.144	.207	.196	.085	.046	.688
<b>SA (ND)</b>	-.026	.820	.059	.608	-.050	.662	-.074	.517	-.106	.357	-.109	.344	-.210	.064	-.154	.177
<b>UT (D)</b>	.184	.095	.292	.007*	.149	.179	.237	.031*	.012	.911	-.029	.794	.016	.888	.113	.308
<b>LT (D)</b>	-.088	.431	-.141	.205	.057	.611	.057	.607	-.046	.683	.071	.525	-.084	.450	-.064	.564
<b>IF (D)</b>	-.015	.893	-.031	.780	-.046	.679	-.069	.538	.125	.258	-.105	.347	.098	.377	.081	.467
<b>SA (D)</b>	-.083	.462	-.165	.142	-.129	.250	-.231	.038*	-.065	.563	.023	.841	-.018	.871	-.144	.198

\* :  $p < 0.05$  = Statistical significance; UT : Upper Trapezius; LT : Lower Trapezius; IF : Infraspinatus; SA : Serratus Anterior; ND : Non-dominant; D : Dominant  
ER : External rotation; IR : Internal rotation; C : Concentric; E : Eccentric

The distribution of the forwards' scapula stabilizers' mean firing orders with regards to the hand-behind-the-neck and hand-behind-the-back tests are displayed in Table 7. The table shows that the distribution of the dominant lower trapezius muscle's firing order is uneven across the different categories of the hand-behind-the-back test.

The results also indicate (Table 8) that positive statistically significant correlations were found between the non-dominant infraspinatus firing order and the non-dominant/dominant concentric internal rotation strength ratio ( $r = 0.239$ ;  $p = 0.035$ ); the dominant upper trapezius firing order and the dominant shoulder external/internal rotation concentric strength ratio ( $r = 0.292$ ;  $p = 0.007$ ); and the dominant upper trapezius firing order and the eccentric external/internal rotation strength ratio for the same shoulder ( $r = 0.237$ ;  $p = 0.031$ ). Statistically significant negative correlations were found between the dominant serratus anterior firing order and the dominant shoulder eccentric external/internal rotation strength ratio ( $r = -0.231$ ;  $p = 0.038$ ), as well as the dominant infraspinatus muscle onset time with the non-dominant eccentric external/internal rotation strength ratio ( $r = -0.262$ ;  $p = 0.016$ ). These statistically significant correlations did not, however, prove to be of any clinical significance.

## DISCUSSION

It has been suggested that posture influences shoulder movement patterns (Solem-Bertoft *et al.*, 1993 and Bullock *et al.*, 2005) as well as shoulder strength (Smith *et al.*, 2006). Shoulder strength conversely may also have an influence on shoulder movement patterns (Ebaugh *et al.*, 2006). Despite the fact that these correlations exist, no study has been done on rugby players to determine the relationship among these different factors.

The findings of this study suggest that forward rugby players' infraspinatus muscle onset times differ significantly among participants who display forward shoulders, as against those who do not. To be more specific, it appears that forwards with abnormally forward shoulders display delayed muscle activation of their non-dominant infraspinatus muscles. Those participants who presented with abnormally rounded backs also displayed delayed muscle onset times of the non-dominant serratus anterior muscles. To our knowledge, the correlations between rugby players' postural characteristics and their scapular muscle recruitment patterns have not been investigated before. However, the scapular muscle activation patterns among injured and uninjured rugby players during a simulated tackle situation have previously been investigated (Horsley *et al.* 2010; Herrington and

Horsley 2009). What seemed evident from those studies was that serratus anterior played a prominent role in scapular stabilization during a tackle situation, but also that serratus anterior displayed significantly earlier activation than other stabilizing muscles among injured participants (Horsley *et al.* 2010; Herrington & Horsley 2009). Under normal circumstances the serratus anterior muscle's contribution towards optimal shoulder function is protraction of the scapula, lateral rotation of the inferior angle of the scapula, and depressing the medial border of the scapula against the rib cage (Kendall, 1993). Therefore a delay in serratus anterior activity could impair scapular control in terms of these scapular movements (Horsley *et al.* 2010). In terms of relevance in a typical rugby situation, this would allow the humeral head to translate anteriorly and superiorly (Allecrucci *et al.*, 1995) when the humerus reached an abducted position at the tackle (Horsley *et al.* 2010). The authors explain that this may contribute towards a resultant loss of an optimal length-tension relationship within the rotator cuff muscles, and that this could detrimentally affect the dynamic stability of the glenohumeral joint (Horsley *et al.* 2010). If serratus anterior plays an important role in stabilizing the shoulder joint prior to any tackle situation, that may be the reason why forwards with rounded shoulders displayed delayed serratus anterior muscle onset times. The evidence suggests that these players could be at a higher risk of shoulder injury. Cheshomi *et al.* (2011) states that a thoracic kyphosis or an abnormally rounded back has significant correlations with scapular protraction as well as with the functional disability of muscles including serratus anterior. The relationship between a rounded back and altered serratus anterior activity can be explained by the fact that the protracted position of the scapula causes serratus anterior to tighten and shorten and therefore influences its function (Cheshomi *et al.*, 2011). Adaptations to the other scapular stabilizers in terms of their length-tension relationship could also influence the force couples of these muscles, which could ultimately have a detrimental effect on coordinated muscle function, as well as on scapula function.

The primary function of the infraspinatus muscle is to laterally rotate the shoulder (Kendall, 1993), but an apparent early activation of the infraspinatus muscle that produces glenohumeral stability in the healthy shoulder has also been described in previous studies (Saha, 1971). It has further been postulated that the infraspinatus aids in preventing posterior translation of the humeral head due to its posterior location. Therefore the muscle also aids in posterior joint stability (Oveson & Nielson, 1986). The early activation of the infraspinatus muscle is therefore to be expected, as the coordinated activation of the rotator cuff muscles pre-empt humeral head movement within the glenoid cavity, which ensures that the humeral head stays within the glenoid fossa during this

movement (Sharkey *et al.*, 1994). As said earlier, the forwards in this study who displayed abnormally forward shoulders manifested delayed muscle activation of their non-dominant infraspinatus muscles. A rounded shoulder posture is described by Ebaugh *et al.* (2006) as a forward deviation of the shoulder, a condition which may be associated with a protracted scapula. According to Kendall (1993) a forward shoulder position is caused by a muscular imbalance between shortened pectoralis major and lengthened middle and lower trapezius muscles. This altered position of the shoulder apparently compromises the effectiveness of certain scapula stabilizing muscles regarding normal scapular kinematics (Kibler *et al.*, 2008; Cools *et al.*, 2007). Considering also the apparent importance of the timely and coordinated contraction of this muscle, this delay may be detrimental to healthy shoulder functions. In a study performed specifically on rugby players, an otherwise significantly earlier activation of infraspinatus was absent among the participants who presented with a SLAP lesion as compared to the uninjured participants (Horsley *et al.* 2010). According to the authors this may be indicative of a failure of the local control system that could lead to increased stress on the shoulder support structures (Horsley *et al.* 2010). However, we found no significant relationships between similar variables.

The backline players in this study with uneven shoulders displayed delayed serratus anterior muscle onset times as compared to the backline players with even shoulders. The possibility therefore exists that within this group, the occurrence of uneven shoulders might contribute towards delayed serratus anterior muscle activation. This was seen only in the non-dominant shoulder. No previous studies have investigated how the occurrence of uneven shoulders influences the scapular muscle activation patterns of rugby players. There appear to be different opinions regarding postural asymmetry, specifically uneven shoulders, and when it is deemed to be normal or abnormal. Despite the fact that postural asymmetries may be related to abnormalities (Burkhart *et al.*, 2003; Kibler 1991), many clinicians agree that asymmetric findings in shoulder posture are quite common, regardless of the presence of abnormalities (Kendall, 1992; Magee, 2002). It is argued that asymmetric scapular posture between the dominant and non-dominant sides in unilateral overhead athletes might be normal and is not necessarily related to injury (Ozunlu *et al.*, 2011). It is stated that the dominant shoulder is typically positioned lower than the non-dominant shoulder in the majority of people (Kendall, 1992), and that this could be put down to the stretching of the ligaments, joint capsules, and muscles from the more frequent use of the dominant shoulder (Magee, 2002). However, injured overhead athletes may display more postural asymmetry than healthy athletes, and there may be what has been called a pathologic threshold for scapular posture asymmetry at which an asymmetry

becomes problematic (Oyama 2008). Burkhart *et al.* (2003) also suggests that injured people, specifically overhead athletes, typically present with an asymmetrically dropped shoulder on the affected side, and that this is caused by increased scapular protraction, anterior tilting, and internal rotation. It is further stated that this asymmetry is a sign of the underlying alteration in the muscles' activation that is associated with various shoulder conditions (Burkhart *et al.*, 2003). This alteration of muscles' firing patterns or activation supports our findings that serratus anterior's onset of muscle activity is altered by uneven shoulders. This could partly be explained by the adaptive weakening of serratus anterior that is associated with scapular positioning and dyskinesia under certain circumstances (Burkhart *et al.*, 2003). This occurrence may also be indicative of a compromised feed forward mechanism that is often seen among rotator cuff muscles prior to glenohumeral movement (David *et al.*, 2000).

Our findings also indicate a significant difference between the players with an abnormally rounded back and those with a normal thoracic curvature in terms of the non-dominant infraspinatus firing order. It appears that the infraspinatus mean firing order for backline players with an abnormally rounded back is second when compared to the other scapular stabilizers, while the firing order for this muscle is third among players with a normal thoracic curvature. The data therefore suggests that within this group thoracic curvature influences infraspinatus firing order. Previously it has been found that scapular stabilizer muscles in injured swimmers' shoulders displayed significantly increased variability in their timing of activation (Wadsworth and Bullock-Saxton, 1997). However, injury does not seem to be the only culprit. It has also been argued that an abnormally rounded back could negatively influence the coordination and functionality of the scapular stabilizers, and therefore influence scapular kinematics (Cheshomi, 2011). This may happen due to the fact that force couples are influenced by the altered habitual position in which these muscles now find themselves. Apparently a hyperkyphotic position leads not only to shortened and tightened pectoralis major and minor, serratus anterior and latissimus dorsi muscles, but also to stretched and weakened erector spinae, rhomboids and trapezius muscles (Cheshomi, 2011). If the lower trapezius muscles are indeed stretched and weakened due a player's posture, this will probably impair its function during shoulder abduction. As stated earlier, the primary function of the infraspinatus muscle is to laterally rotate the shoulder rather than to act as a scapular stabilizer (Kendall, 1993). It seems possible, then, that an injury or altered posture might not influence the function of infraspinatus in the same way it does the scapular stabilizers. A possible explanation for the apparent switch of the infraspinatus firing order from three in the group of players who display

normal thoracic curvature to two in the abnormally rounded back group could perhaps be due to the fact that the lower trapezius muscle's function or activation time was altered by a hyperkyphotic posture. The data does indicate that lower trapezius muscle firing order changes from two in the normal posture group to three in the abnormal posture group. This difference was not statistically significant, but this may mean that the delayed activation of the lower trapezius caused infraspinatus to fire "earlier" in terms of the firing order. Therefore it is possible that a healthy infraspinatus muscle may fire earlier than the lower trapezius because its function is not compromised, or because it is compensating for the weakness of some of the scapular stabilizers.

A sufficient balance between the strength of the agonist and antagonist muscle groups is necessary to provide dynamic stabilisation to the shoulder joint (Wilk *et al.*, 2009). In order to provide optimal muscle balance and functional capability for overhead athletes, the glenohumeral joint external rotators should be between 65% and 75% of the strength of the internal rotator muscles (Wilk *et al.*, 2009). It has been found that muscle strength ratios that lie outside the proposed normative ranges may increase the risk of injury to athletes (Wang *et al.*, 2000; Leroux *et al.*, 1994). The forward players involved in this study (as against the backs) demonstrated different internal rotation/external rotation strength ratios when the forward shoulder position group was compared to the normal shoulder position group. The concentric strength ratios for the non-dominant side of these participants indicated lower percentage values in the group with normal shoulder positions than in the group with forward shoulders. In fact, the abnormally forward shoulder group's median ratio was 63%, while the normal shoulder position group displayed a median value of 57%. Despite the fact that no optimal external/internal rotation isokinetic strength ratio has been put forward specifically for rugby players, one would still expect that an acceptable ratio would be close to 65% and that the group with a normal group's ratio would be higher than the abnormal group's ratio. Our findings seem to contradict these expectations. In order for the normal shoulder position group to display this relatively low ratio, the players' external rotators have to be weaker than the norm, or the internal rotators have to be stronger than what is expected. Possibly the latter may be a better explanation for this phenomenon. The possibility exists that the rugby-specific activities that are more common for forward players than backline players condition them in such a way that their shoulder internal rotators are adaptively stronger. These activities include scrumming, driving and mauling. It is interesting to note that there is evidence that suggests that forward rugby players display poorer antagonist/agonist muscle strength ratios with regards to their shoulder rotator muscles than backline players (Coetzee *et al.*, 2002). The authors found that the mean

external/internal rotation ratio of forward players in their study was 56% versus the 64% for backline players. This percentage is very similar to the median value of forwards with a normal shoulder position in our study, and opens up the possibility that perhaps the normative external/internal rotation ratio for forward players could be 56-57%. However, our values regarding the external/internal rotation ratio pertaining to all the other postural variables appear to be higher than the 56.50% we found for forwards with normal shoulder positions. Therefore the ratio for external/internal rotation among forward players in our study appears to be the exception to the rule, and can probably not be explained as a form of adaptation that results from their participation in rugby. This adaptation could even be caused by a specific type or form of training that is found among this group of players, and because this is a specific population, it might not be found among all rugby players.

The backline players in this study displayed significantly uneven distribution of infraspinatus muscle onset times across the different classifications of shoulder external rotator ROM (in the hand-behind-the-back test). Participants who manifested with bilateral ROM differences of one centimeter and more displayed significantly delayed infraspinatus muscle onset times compared to participants with a bilateral difference of less than one centimeter. This was found on the participants' non-dominant side. The data therefore suggests that participants with poor external rotator flexibility of one shoulder experience delays in infraspinatus muscle onset times. To our knowledge, no other study has investigated the possible relationship between shoulder ROM and scapular muscle recruitment patterns among rugby players. However, there have been studies (such as Fernández *et al.*, 2011) that found a diminished glenohumeral rotation range in professional rugby players when compared with a control group. Other studies (Bruwer, 2006; Erasmus, 2006) on rugby players have also found deficiencies regarding rugby players' ROM. The possible reasons for these deficiencies among rugby players that have been investigated include age, playing position, BMI, and the history of injury. Previously it has been found that age could be a risk factor for the decreased flexibility of shoulder rotators (Fernández *et al.*, 2011). It is postulated that this could be related to the aging of the glenohumeral soft tissue, and that it might be accelerated by the training and injuries that are associated with rugby (Fernández *et al.*, 2011). If such deteriorations of the rotator muscles do in fact take place among rugby players, this so-called wear and tear could possibly explain the variation found, in this case the delay of infraspinatus' firing order. It is difficult to pinpoint what the exact reason for this phenomenon may be, but it seems likely that the poor flexibility of shoulder external rotators could compromise scapula stability by altering scapula

stabilizers' muscle onset times. The same discrepancies regarding shoulder external rotator ROM could influence the lower trapezius muscles' firing orders among the group of forwards in this study, specifically on the dominant side. It appears that the mean muscle onset times of the lower trapezius decreases as the ROM of the external rotators deteriorates. This could partly explain the significantly uneven distribution of the lower trapezius firing order across the ROM categories. It appears that the most significant discrepancy might be between players with ideal ROM when compared to non-ideal ROM. Therefore, as was the case with infraspinatus, compromised external rotator ROM appears to alter the muscle onset times of the lower trapezius muscles. The factors that possibly contribute towards the deterioration of soft tissue ROM are probably the very factors that have a negative impact on the firing order, and therefore the functionality of these structures.

To conclude, certain postural abnormalities may contribute towards the delay of the muscle onset times of infraspinatus and serratus anterior muscles among rugby players, as well as the firing order of infraspinatus. Forward shoulders could also alter antagonist/agonist isokinetic strength ratios. The non-ideal or unsatisfactory flexibility of players' shoulder external rotators may contribute towards the altering of the infraspinatus and lower trapezius muscle firing order. No significant correlations of clinical importance were found between isokinetic strength ratios and scapulae muscle activation patterns.

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# CHAPTER 5

## THORACIC POSTURE, SHOULDER MUSCLE ACTIVATION PATTERNS AND ISOKINETIC STRENGTH AS PREDICTORS OF SHOULDER INJURY IN SEMI-PROFESSIONAL RUGBY UNION PLAYERS

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Running head: Possible predictors of shoulder injuries among rugby players.

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## ABSTRACT

**Objective.** Shoulder injuries in rugby union players are the most severe injuries in terms of lost playing hours. The main aim of this study was to determine if posture, muscle activation patterns or isokinetic shoulder muscle strength would predict shoulder injury in semi-professional rugby players.

**Methods.** Ninety-one (91) uninjured semi-professional rugby union players' shoulder joint range of motion (ROM) differences were manually tested with the hand-behind-the-neck and hand-behind-the-back method. The profiling and classification of thoracic posture was performed using the New York Posture Test. Scapular muscle activation patterns were determined with electromyography (EMG) measuring the activation of the upper and lower trapezius, serratus anterior and infrapinatus muscles. The concentric and eccentric isokinetic muscle strength of the rotator cuff muscles were determined at 60°/sec (Kin-Com 500H) during internal and external shoulder rotation in the scapular plane, at ninety degrees of abduction, with ninety degrees of elbow flexion.

**Results.** Retrospective analyses indicated that injured players were older ( $p = 0.02$ ) and taller ( $p = 0.40$ ) than uninjured players, and that their non-dominant/dominant concentric external rotation ratios were higher ( $p = 0.03$ ). Their age (1.34 times increase for each year older), insufficient shoulder external rotator ROM differences (16.15 times increase if unsatisfactory ROM present), uneven shoulders (4.43 times increase if shoulders were abnormally uneven) and non-dominant/dominant concentric external rotation strength ratio (1.42 times increase for every 10% of the ratio increases) displayed statistically significant predictive values towards future shoulder injury.

**Conclusion.** In conclusion, external rotator ROM asymmetry presented the highest prediction for future shoulder injury, with posture (uneven shoulders), shoulder strength imbalance (non-dominant/dominant concentric external rotation ratio) and increasing age contributing significantly to the likelihood of future shoulder injury in semi-professional rugby players.

Keywords. Shoulder, posture, EMG, isokinetic, injury

## INTRODUCTION

The game of rugby union enjoys increasing worldwide popularity, but unfortunately it has one of the highest reported incidences of injury (Brooks *et al.*, 2005). It has been determined that the shoulder is the second most common site of injury in the rugby player. As a matter of fact, almost 20% of all rugby injuries are shoulder injuries (Funk & Snow, 2007). Poor posture, altered scapular muscle recruitment patterns and shoulder strength weaknesses or imbalances may be associated with shoulder injury in athletes (Wadsworth & Bullock-Saxton, 1997; Wang *et al.*, 2000; Finley & Lee, 2003; Edouard *et al.*, 2009).

The literature provides sufficient proof that a relationship exists between poor posture (cervical and thoracic) and shoulder pathology among non-rugby playing persons (Griegel-Morris *et al.*, 1992; Greenfield *et al.*, 1995; Kebaetse *et al.*, 1999; Finley & Lee, 2003). However, there also seems to be a relationship between poor posture and a decrease in shoulder joint range of motion (ROM) (Bullock *et al.*, 2005). Greenfield *et al.* (1995) asks if a lack of mobility around the shoulder joint, rather than static posture, may be a more significant dysfunction regarding shoulder pathology. Information regarding the posture of rugby players is limited but there are some studies that indicate that rugby players manifest poor posture, forward shoulder position and a lack of a range of motion (ROM) in the shoulder area (Erasmus, 2006; Bruwer, 2007). These postural deviation may give rise to poor biomechanics that may predispose the players to become injured. The modern rugby player therefore needs to pay attention to his total biomechanical position (Erasmus, 2006).

In a sport such as rugby, the demands that are put upon the shoulders are extremely high. Because the quality of shoulder movement depends upon the interaction between scapular and glenohumeral kinematics (Cools *et al.*, 2002), it is important for this interaction to be maintained despite the challenging environment. Belling, Sørensen and Jørgensen (2000) stress the importance of optimal coordination of the dynamic stabilisers of the scapulothoracic joint to shoulder movement, and identify them as the serratus anterior, trapezius, and rhomboid muscles. An existing argument is that it is not only the intensity of the muscle contraction that determines the scapulothoracic function, but that the timing of muscle activity around the scapula also plays a significant role (Wadsworth & Bullock-Saxton, 1997).

Wadsworth and Bullock-Saxton (1997) measured muscle activity and the recruitment order of the scapular muscles during voluntary movements in injured and noninjured swimmers and found a significant increased variability in the timing of activation in the upper and lower part of the trapezius muscle of the injured shoulders compared to non-injured shoulders. These

findings reflected inconsistent or poorly coordinated muscle activation in the shoulder. A study assessing the influence of a superior labral anterior-posterior (SLAP) lesion on the onset of electromyographic (EMG) activity in shoulder muscles during a “front-on” rugby tackle, found a delay of onset time among the muscles pertaining to the injured shoulder with the exception of an associated earlier onset time of activation of the serratus anterior muscles (Horsley *et al.*, 2010). As serratus anterior plays a significant role in the initial stabilization of the scapulothoracic joint in a simulated tackle situation, it is postulated that a delay in the activity of serratus anterior and the subsequent impairment in scapular control would allow the humeral head to translate anterior and superior when the humerus reached an abducted position in the tackle situation (Horsley *et al.*, 2010). This could ultimately have a detrimental effect on the dynamic stability of the glenohumeral joint. Current evidence suggests that there is an association between prior injury and altered scapular muscle activation patterns among rugby players. However, these alterations were evident only after an injury had already been sustained, and no evidence currently suggests that altered scapular muscle activation patterns predispose rugby players to future injury, although the possibility exists in theory.

Beside the timing of muscle activity and the intensity of the muscle contraction that determines scapulothoracic function (Wadsworth & Bullock-Saxton, 1997), it has also been proven that muscle imbalances may increase the risk of injury to athletes (Cook *et al.*, 1987; Chandler *et al.*, 1992; Burnham *et al.*, 1993; Leroux *et al.*, 1994; Wang *et al.*, 2000; Markou & Vagenas, 2006). Numerous researchers have aimed at determining normative values in terms of shoulder rotator strength ratios among various population groups. An important isokinetic value is the unilateral muscle ratio that describes the antagonist/agonist isokinetic muscle strength ratio of one shoulder, with a suggested optimal muscle balance between 65% and 75% (Wilk *et al.*, 2009). A South African study aimed at determining the concentric antagonist/agonist muscle ratios of the shoulder girdle complex of rugby forwards and backline players respectively found a concentric external/internal rotator muscle ratio of 64% for backline players and 56% for forwards (Coetzee *et al.*, 2002). These results were lower than the suggested “optimal muscle balance” of between 65% and 75% of Wilk *et al.* (2009), which would theoretically have made them more susceptible to future shoulder injury. Due to the nature of rugby, high levels of stress are placed on the passive stabilisers of the shoulder joint. In addition to these demands, decreased active stabilization due to isokinetic muscle imbalances among rugby players could increase the risk of glenohumeral injury (Edouard *et al.*, 2009).

The literature indicates that poor posture, isokinetic shoulder weakness or imbalance, and altered scapular muscle recruitment patterns have a relationship with shoulder injury, especially among overhead athletes. Despite the existing indications that these associations also apply to rugby players, the literature proving these associations remains limited. The current literature also lacks evidence of the role that poor posture, isokinetic shoulder weakness or imbalance and altered scapular muscle recruitment patterns plays in predicting future shoulder injury. These variables and their association with injuries need to be investigated in order to determine which of the variables could possibly be the most accurate predictor of future shoulder injuries. The aim of this study therefore is to determine which of poor posture, isokinetic shoulder weakness or imbalance, and altered scapular muscle recruitment patterns plays the most significant role in the occurrence of future shoulder injury. The findings from this study will supply information to assist in the identification of players at risk of shoulder injury and the implementation of pre-habilitation to pro-actively prevent shoulder injuries in semi-professional rugby players.

## **MATERIALS AND METHODS**

### **Participants**

Ninety one (91) uninjured participants, all based in the North-West Province and playing for the Leopards Rugby Union and North-West University PUK Rugby Institute (NWU PUK RI), were recruited to participate in the study. The participants were the PUK U/19 A and B, PUK U/21 A and B and Leopards Senior players (Provincial) between the ages of 17 and 31 years. An informed consent document was signed by all the participants after the test procedure and study protocols had been explained to them. Approval for the study was obtained from the Ethics Committee of the NWU (NWU-00048-11-A1). All participants were tested in the pre-season to ensure minimum interference from high intensity training and injuries. Left hand dominant participants (n = 4) were excluded for the purposes of this analysis.

### **Study Design**

This retrospective observational analytical cohort study included semi-professional rugby union players who consented to participate in this study, and this article forms part of a larger study where the occurrence of shoulder injuries during the 2010 rugby season was recorded. Players were included in the study when they were contracted to the Leopards Rugby Union or Puk Rugby Institute of the North-West University and if they were injury free with regards

to shoulder injuries. The exclusion criteria included previous surgical intervention regarding one or both shoulders and current injury of the upper body - specifically of the shoulders, back and neck. Injury was defined as physical discomfort that prevented players from completing a regular training session, whether it was weight training or a contact or field session. All the tests were performed in the laboratory of the Biokinetics Institute of the North-West University, Potchefstroom campus, with the room temperature regulated at 21° Celcius. All the tests were performed by the same researcher at the start of the 2010 rugby season. The follow-up period for the monitoring of injured players was one season (2010) and the monitoring and identification of injured players was performed on a bi-weekly basis by a sports physician and/or an orthopaedic surgeon. Participants were classified as injured or uninjured at the end of the season for the purpose of statistical analysis.

## **Measurements**

### *Demographic Information*

The stature of each participant was measured to the nearest 0.1 cm, with a stadiometer (Seritex) using the stretch stature method (ISAK 2001). Body mass was measured to the nearest 0.1 kg with an electronic weighing scale (Micro) (ISAK, 2001). Participants completed an information sheet recording their age, position of play, dominant side and previous rugby injury.

### *Shoulder range of motion differences*

Biomechanical tests were performed according to a pro-forma compiled from various sources (Bruwer, 2006; Erasmus, 2007; Kapandji, 1970). Shoulder range of motion (ROM) was determined prior to a warm-up by the “hand-behind-the-neck”- and “hand-behind-the-back” tests (Erasmus, 2007; Kapandji, 1970; Ozunlu, 2011). Measurements were taken after one maximal effort of each movement. During both of these tests participants stood in an upright position. In the case of the “hand-behind-the-neck” test, participants reached with one of their hands over their ipsilateral shoulder and placed their hands as far down their spinal columns as possible, with a mark being placed at end point of movement. In this case the end point would refer to the most inferior point, with the shoulder in a position of external rotation. After this, using the same technique, the contra-lateral hand was also placed as far down the spinal column as possible with the end point also being marked. The distance between the two marks to the nearest millimeters were classified in terms of the relative differences between the left and right shoulders’ ROM. A difference of less than one centimeter was classified as

ideal. Differences between one and three centimeters were classified as non-ideal, while differences of more than three centimeters were classified as unsatisfactory. During the “hand-behind-the-back” test the same principles and classifications were applied. However, in this case the participants aimed to place their hands as high as possible on their spinal columns (the most superior end point), with the shoulder in a position of internal rotation.

#### *Thoracic posture analysis*

The New York Posture Test, which is designed for identifying thirteen categories of deformities, was used for the evaluation and identification of possible postural deformities in rugby players (Kendall, 1993 and Magee, 2002:1020). Thoracic postural assessment was performed by taking high-quality photographs with a digital camera (Canon A2000 IS Power Shot, Canon USA Inc.) from a lateral and posterior point of view of each participant. The camera was placed at a ninety degrees angle to the subject’s shoulders to ensure the accurate calculation of angles. These digital photographs were then analysed with the Dartfish computer software programme version 4.06.0 (DARTFISH, Switzerland). 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, winged scapulae/round shoulders, and thoracic kyphosis. Uneven shoulders were measured by placing bright yellow markers, 1 cm in diameter, on the posterior-lateral edges or acromial angles of the left and right acromions of the participants. Uneven shoulders were defined by the angle formed between the line connecting the inferior edges of the markers placed on the left and right acromial angles and a true horizontal line. To reduce the degree of subjectivity, the following criteria are provided by the New York Posture Test to score uneven shoulders: 5 = 0-2 degrees; 3 = 2.1-4 degrees; and 1 >4 degrees.

#### *Scapular muscle activation patterns*

The electromyographic (EMG) activity of the scapulothoracic muscles were registered by means of bilateral and simultaneous abduction of both arms in the scapular plane (thirty degrees in front of the coronal plane) (Wadsworth & Bullock-Saxton, 1997) measuring the output in microvolt ( $\mu\text{V}$ ). The firing order of the muscles was obtained by firstly measuring latency times (ms) and consequently determining the sequence of the firing order. This was done by calculating the percentage of times (the frequency) that a specific muscle group fired in a specific order. According to these percentages, the muscles were then classified in terms of firing order sequence. Data was obtained by means of the Myotrace 400 Biofeedback system (Noraxon EMG and Sensor Systems, Noraxon USA Inc., Scottsdale, Arizona, USA).

The system operates by means of a 4-channel transmitter; thus allowing for simultaneous data collection from 4 strategically placed electrodes. EMG electrodes (Model 93-0101-00, Mindware Technologies LTD), one cm in diameter, were attached unilaterally to the subjects' upper and lower trapezius, serratus anterior and infraspinatus muscles in accordance with SENIAM guidelines (Hermens *et al.*, 1999). The overlying skin on the muscles was carefully prepared, the outer layer of epidermal cells abraded, and oil and dirt removed from the skin with alcohol pads (Hunter *et al.*, 2003). Due to the fact that only four channels were available to do the tests, the four muscles were measured unilaterally, even though a bilateral movement was performed. After the one side had been tested the electrodes were placed on the contralateral side, after which the test was repeated. The participants started the required movement with their arms hanging next to their sides. They did bilateral arm abduction in the scapular plane, with their thumbs facing in an upward direction, to a point of one hundred and eighty degrees of abduction, after which they performed adduction until they reached the original starting point. The test was standardised for both sides by regulating the tempo at which the abduction and adduction took place. This was done with the help of a timer that is a function on the Noraxon EMG and Sensor System. They did the total abduction-adduction sequence in seven seconds, and no resistance was used or applied during the movement. EMG signals were full wave rectified to achieve reliability and accuracy of testing, low and high-pass filtered, with cut-off frequencies of 500 and 10 Hz, respectively, and recorded at a sampling rate of 1000 Hz.

#### *Rotator cuff isokinetic muscle strength testing*

The peak torque and muscle agonist/antagonist ratios of the shoulder were tested with the Kin-Com 500H isokinetic dynamometer (Isoknetic International, Tennessee, USA) with torque/power expressed in Newton.meter (Nm) (Oman, 2004). Torque scores are representative of the moment of force produced by muscle contraction for rotation around a joint (Coetzee, 2002). During shoulder internal and external rotation, the participant was seated and strapped to the seat. Testing was performed with the player's arms positioned along the scapular plane, at ninety degrees of abduction, with ninety degrees of elbow flexion. The participant's contra-lateral arm was held against his chest and was static throughout the test. The feet were placed on a footrest. The axis of rotation of the shoulder was aligned with the dynamometer's axis of rotation. These two rotation points were connected with an imaginary line that runs from the dynamometer's axis of rotation, through the humerus, towards the acromion process. Each test started from full external rotation and the effect of

gravitation was compensated for during testing. Participants performed a warm-up exercise on the Monark 881E Rehab Trainer (Monark, Sweden) for three minutes prior to the isokinetic testing. Before the test commenced, each participant was informed about the testing procedures. Three sub-maximal warm-up repetitions preceded the true test. Verbal encouragement was given during the test to ensure maximal torque output. The actual test consisted of a series of six concentric and eccentric maximal contractions. The maximal concentric and eccentric torque levels (Nm) of the shoulder-girdle complex were determined at 60°/sec for internal and external rotation (Oman, 2004). These values were used to calculate the different isokinetic ratios that were used to evaluate shoulder muscle performance. The ratios determined included antagonist/agonist ratios and bilateral strength deficit ratios for concentric and eccentric contractions. Furthermore, the functional strength ratios were expressed as the eccentric external rotational torque production divided by the concentric internal rotational torque production of the shoulder rotators. This functional ratio appears to be relevant among overhead athletes, due to the fact that an increased activity of the external rotators is required to decelerate the humerus and to centre the humeral head during a ballistic action (Bak & Magnusson, 1997). Both the dominant and the non-dominant shoulders were measured among all the participants.

### **Statistical analysis**

The SPSS Statistics Version. 19.0 (IBM, New York, 1989, 2010) computer software programme was used for the statistical analyses. Statistical significance was set as  $p = 0.05$ . Bivariate analyses were performed by means of independent T-tests to determine significant difference retrospectively between the baseline variables of injured and uninjured participants later in the season. Non-parametric analysis was performed through the Mann-Whitney U test for the biomechanical measurements. Similarly, categorical predictors were compared between injury groups using Pearson's chi square tests. Predictors which were significantly associated with injury on bivariate analysis were entered into a backward stepwise logistic regression model in order to determine which variables were most likely to predict the occurrence of shoulder injury during the season, whilst controlling for confounding factors. The confounding factors included all the other factors which were included in the model.

### **Results**

Ninety-five rugby players participated in this study. After the exclusion of the four left-hand dominant participants from the study, twenty-three of the ninety-one participants (25%)

sustained shoulder injuries during the relevant season. The injured participants (Table 1) were significantly older than the uninjured participants, with the difference more pronounced in the backline players. The injured backline players were also significantly taller and heavier than the uninjured participants.

The results derived from the postural analyses indicate that the percentage of participants with even shoulders who sustained injuries was 17.24%, while 39.39% of the participants with uneven shoulders sustained injuries. This difference in percentage proved to be statistically significant ( $p = 0.019$ ).

A comparison of the scapular muscle onset times (Table 2) between injured and uninjured participants indicated no statistically significant differences between the two groups. However, the mean onset time of the dominant serratus anterior muscle activation for injured forwards compared to the uninjured reached statistical significance ( $p = 0.054$ ). The results of the isokinetic strength ratios comparison between the injured and uninjured forward and backline players respectively (Table 3) indicated no statistically significant differences. However, the injured participants had statistically significant ( $p = 0.03$ ) higher non-dominant/dominant concentric external rotation ratios than uninjured participants (Table 4).

Table 5 displays the statistically significant correlations that certain variables have with shoulder injury sustained during the season as determined by a backward stepwise logistic regression analysis. It appears that a participants' age, discrepancies between a participant's left and right shoulder external rotators' flexibility, a rounded back, uneven shoulders and the strength ratio of non-dominant/dominant shoulders regarding concentric external rotation have statistically significant correlations with shoulder injury. The presence of a rounded back appears to have an inverse correlation with the incidence of shoulder injury. Table 5 also displays the odds ratios of the variables, which gives an indication of the prediction of probability of that specific variable predicting future shoulder injury. The data indicates that the risk of a shoulder injury increased 1.34 times for every one year's increase in the players' age. Among backline players the chance is 3.03 times greater that they will sustain a shoulder injury than for a forward player. Participants who displayed a three centimeter or bigger difference between left and right shoulder external rotator flexibility were 16.15 times more at risk of shoulder injury than the participants who had flexibility differences of one centimeter or less. Participants with an abnormally rounded back were less prone to sustain an injury. However, this correlation was not statistically significant ( $p = 0.08$ ). Individuals with abnormally uneven shoulders were 4.43 times more likely to be injured. Finally, for every 10

percent increase in non-dominant/dominant concentric external rotation ratio, the risk of injury increases 1.42 times.

**Table 1: Demographic characteristics of the rugby players who were injured during the season, compared to the characteristics of uninjured players**

Variables	Forward player			Backline player			Total group		
	Injured (N=7)	Uninjured (N=33)	<i>p</i>	Injured (N=16)	Uninjured (N=35)	<i>p</i>	Injured (N=23)	Uninjured (N=68)	<i>p</i>
	M (SD)	M (SD)		M (SD)	M (SD)		M (SD)	M (SD)	
Age (years)	22.1 (4.0)	20.5 (2.4)	0.33	22.3 (3.5)	20.0 (2.4)	0.03	22.3 (3.6)	20.3 (2.4)	0.02
Height (cm)	186.4 (10.0)	186.6 (7.6)	0.97	181.8 (5.6)	176.8 (6.1)	0.01	183.2 (7.4)	181.5 (8.4)	0.40
Weight (kg)	104.9 (13.3)	103.0 (13.5)	0.74	86.6 (9.4)	80.1 (7.4)	0.01	92.2 (13.6)	91.2 (15.7)	0.80
BMI (kg/m <sup>2</sup> )	30.2 (3.3)	29.6 (3.6)	0.70	26.2 (2.3)	25.6 (1.3)	0.24	27.4 (3.2)	27.5 (3.33)	0.86

Significance was set at  $p < 0.05$ ; M=mean; SD=standard deviation

**Table 2: Differences in muscle activation onset times between injured and uninjured participants**

Muscles tested	FORWARD PLAYERS				BACKLINE PLAYERS			
	Injured		Uninjured		Injured		Uninjured	
	Median	CI [25%-75%]	Median	CI [25%-75%]	Median	CI [25%-75%]	Median	CI [25%-75%]
ND UT (ms)	81.25	71.90-97.40	74.90	45.90-95.90	72.85	44.35-115.00	75.70	48.70-109.00
ND LT (ms)	52.15	27.30-82.90	78.60	49.10-149.00	68.65	34.40-147.50	54.55	31.30-82.70
ND IF (ms)	145.70	28.30-237.00	90.70	41.50-127.00	103.50	47.30-179.00	78.00	39.60-108.00
ND SA (ms)	44.70	27.00-79.50	43.70	27.75-110.45	33.90	30.80-199.00	40.60	25.30-51.40
D UT (ms)	162.00	63.20-222.00	85.60	68.00-114.00	95.55	78.95-116.00	89.50	77.10-130.00
D LT (ms)	52.40	28.10-217.00	104.00	55.30-135.00	81.15	39.90-104.80	62.85	37.90-90.30
D IF (ms)	109.00	71.10-226.00	91.60	59.40-131.00	97.05	84.15-143.00	90.00	74.20-125.00
D SA (ms)	41.20	26.20-52.40	81.90	43.10-164.00	50.65	23.75-113.95	47.10	26.50-73.90

ND : Non-dominant; D : Dominant; UT : Upper trapezius; LT : Lower trapezius; IF : Infraspinatus; SA : Serratus anterior; ms : milliseconds;  
C.I.: Confidence interval

**Table 3: Differences in isokinetic strength ratios between injured and uninjured forwards and backline players**

Isokinetic ratio's	FORWARD PLAYERS				BACKLINE PLAYERS			
	Injured		Uninjured		Injured		Uninjured	
	Median	CI [25%-75%]	Median	CI [25%-75%]	Median	CI [25%-75%]	Median	CI [25%-75%]
ER/IR C Ndom (%)	71.01	[56.62-78.69]	60.78	51.0970.24	61.00	[55.59-70.49]	65.56	[54.69-76.53]
ER/IR C Dom (%)	58.17	[52.02-62.35]	57.14	48.7560.80	51.02	[46.91-58.19]	54.61	[46.05-60.47]
ER/IR E Ndom (%)	67.37	[65.46-90.51]	65.10	57.9773.91	62.63	[58.25-70.25]	65.22	[60.41-75.80]
ER/IR E Dom (%)	60.96	[58.88-68.84]	60.20	58.2363.31	57.88	[51.32-66.04]	61.63	[56.44-69.92]
Ndom/Dom CIR (%)	112.60	[110.50-145.39]	109.05	95.67118.15	104.86	[96.00-117.52]	108.00	[97.98-118.79]
Ndom/Dom CER (%)	112.62	[94.34-119.23]	96.80	91.95105.98	108.04	[102.72-124.48]	104.55	[97.44-118.37]
Ndom/Dom EIR (%)	84.92	[82.78-92.31]	92.98	87.0497.96	97.59	[91.51-105.49]	97.04	[81.98-100.00]
Ndom/Dom EER (%)	101.72	[92.09-115.32]	102.26	91.11106.21	104.98	[96.35-109.63]	99.03	[92.25 103.20]

Values expressed in percentages

ER: External rotation; IR: Internal rotation; C: Concentric; E: Eccentric; Ndom: Non-dominant; Dom: Dominant; C.I.: Confidence interval

**Table 4: Differences in isokinetic shoulder strength ratios of injured compared to uninjured participants**

	Injured		Uninjured	
	Median	CI [25%-75%]	Median	CI [25%-75%]
ER/IR C ND (%)	61.73	57.14-78.38	62.83	53.55-73.40
ER/IR C D (%)	52.45	49.46-60.16	55.36	46.73-60.63
ER/IR E ND (%)	65.46	58.54-78.67	65.16	60.07-75.27
ER/IR E D (%)	60.29	52.11-67.14	60.69	56.57-65.34
ND/D C IR (%)	110.50	96.16-118.95	108.07	96.43-118.47
ND/D C ER (%)	108.16*	102.04-122.81	100.00*	93.34-112.12
ND/D E IR (%)	92.31	90.19-101.04	94.55	83.48-99.55
ND/D E ER (%)	103.94	92.70-111.30	99.59	92.22-106.04

\*: Statistically significant (p=0.027)

ER: External rotation; IR: Internal rotation; C: Concentric; E: Eccentric; Ndom: Non-dominant; Dom: Dominant; C.I.: Confidence interval

**Table 5: Odds ratio for future shoulder injury in semi-professional rugby players**

Variables	B	S.E.	p	OR	95% C.I. for OR
Age (years)	.292	.10	.004	1.35	1.10 - 1.63
Backline players vs. Forwards	1.123	.68	.099	3.07	.81 - 11.68
Hand behind back (0)			.015		
Hand behind back (1)	.637	1.46	.662	1.89	.11 - 32.90
Hand behind back (2)	2.782	1.29	.031	16.15	1.30 - 201.45
Abnormally round back vs. normal	-1.222	.70	.079	.30	.08 - 1.15
Uneven vs. even shoulders	1.489	.66	.024	4.43	1.22 - 16.10
ND/D C ER (%)	.035	.02	.041	1.42	1.00 - 1.07
Constant	-14.051	3.71	.000	.00	

OR : Odds ratio; C.I. : Confidence interval

## Discussion

The aim of this study was to determine which of posture, muscle activation patterns or isokinetic strength best predicts shoulder injury in rugby players at semi-professional level.

The predictors of future injury in the studied population were age, a three centimeter or more bilateral difference between shoulder external rotators' ROM, abnormal posture in the form of an abnormally rounded back and uneven shoulders, and the strength ratio of non-dominant/dominant shoulders in terms of concentric external rotation. All of these displayed statistically significant correlations with the occurrence of injury.

The injured players in this study were significantly older than the uninjured players. These findings support the findings of various authors where an increased rate of injury appears to accompany a higher level of play (Waller *et al.*, 1994; Bathgate *et al.*, 2002 and Brooks *et al.*, 2005). Furthermore, every year a player increased in age increased the likelihood of sustaining an injury 1.34 times. The participants of this study were all members of three “age groups”, namely under nineteen, under twenty and “senior”. Therefore, as a player moves from one age group to the next, there is an increase in the intensity of the rugby being played, which accords with the previous studies that found that an increased rate of injury appears to accompany a higher level of play. The fact that the injured backline players were significantly heavier and taller than the uninjured backline players is partially supported by other findings (Bird *et al.*, 1998; Quarrie *et al.*, 2001). Several explanations for this pattern have been put forward and they include the increased size and strength of players, the higher levels of competitiveness, and the differences in the body composition of players (Bird *et al.*, 1998). It has also been postulated that the greater body mass of players at a higher level of play may be one of the factors contributing to the increase in injury rates (Bird *et al.*, 1998; Quarrie *et al.*, 2001). No differences were found between the height and weight of the injured as against the uninjured forward players in this study. In the present study, of the 25.3% of the players who sustained shoulder injuries, 17.6% of the injuries were sustained by backline players, while the other 7.7% were injuries sustained by forward players. It is concluded that 31.4% of all the backline players who participated in the study sustained a shoulder injury and that 17.5% of the forwards who participated in the study sustained a shoulder injury. Other studies reported that upper limb injuries account for 34% of the severe injuries (Bathgate *et al.*, 2002). There are contrasting findings in the literature with regards to which playing position represents the biggest risk of injury. Babić *et al.* (2001) and Bathgate *et al.* (2002) found that forward players were more likely to sustain injuries,

Brooks *et al.*, (2005) and Holtzhausen (2001) found no significant relation between the incidence of injury and a player's position, while Fuller *et al.* (2010) found that midfield backs are more prone to injury when tackling than are other players. Possible explanations as to why this present study and the one of Fuller *et al.* (2010) found backline players to be more prone to injuries is the fact that backline players generally run and tackle at higher speeds than forwards, and according to Fuller *et al.* (2010) collisions at high speed and the consequent heavy impacts present as possible risk factors for injuries specifically in the tackle situation.

Results derived from the postural analyses indicate that the injured players presented with a higher baseline prevalence of uneven shoulders than the uninjured players. As stated earlier, 39.4% of the players with uneven shoulders sustained shoulder injuries in comparison with the 17.3% of players with even shoulders who sustained injuries. We are currently unaware of published research that has investigated the presence of uneven shoulders among rugby players. It is therefore difficult to compare our results with those of other studies. Apart from the baseline differences, the results from this study also indicate that a player with uneven shoulders was 4.43 times more likely to sustain a shoulder injury during the forthcoming season. No previous studies have found uneven shoulders to be a predictor of future shoulder injury. To our knowledge, the predictive ability of uneven shoulders towards the incidence of future shoulder injury among rugby players has been investigated on only one previous occasion (Bruwer, 2007), when it failed to display correlations or predictive ability. There are several factors that may contribute towards the presence of uneven shoulders (Akel *et al.* 2008; Oyama *et al.*, 2008; Emrani *et al.*, 2009; Gummerson & Millner, 2011). These factors include scoliosis or muscle imbalances due to atrophy or over-development unilaterally. Scoliosis is described by Emrani *et al.* (2009) as a three dimensional deformity of the spine that may result in abnormal bends and twists in the torso that may present as asymmetries of the shoulders. The most common form of scoliosis is idiopathic scoliosis (Lewis, 2012) and occurs mainly among adolescents (Gummerson & Millner, 2011; Lewis, 2012). Every participant in this study was subjected to a full postural analysis, although only the upper body findings were reported. Scoliosis was not present in any of the participants.

Despite the fact that shoulder asymmetry, in this case uneven shoulder height, is generally believed to be indicative of some form of pathology (Kibler, 1991; Burkhart *et al.*, 2003) and might be a sign of an underlying alteration in the muscle activation that is associated with various shoulder conditions (Burkhart *et al.*, 2003), that might not always be the case. Various clinicians and

researchers agree that asymmetric findings in shoulder posture are quite common, regardless of the presence of abnormalities (Kendall *et al.* 1993; Magee, 2002), and that asymmetric resting scapular posture exists in certain populations of athletes (Oyama *et al.*, 2008; Ozunlu *et al.* 2011). Despite their findings, Oyama *et al.* (2008) state that injured overhead athletes may display more asymmetry than healthy overhead athletes, and that a pathological threshold for scapular posture asymmetry may exist, at which point an asymmetry becomes problematic.

It is clear that there are two schools of thought with regards to uneven or asymmetrical shoulders. It is either indicative of current or possibly previous injury, or it is more common than originally thought and a part of natural adaptation due to dominance or the demands of sport participation. Participants in this study were uninjured during the time period of the tests, and had to be free of pathology at the time of testing. Applying deductive reasoning, the possibilities that remain are that the phenomenon of uneven shoulders may have been natural adaptation due to dominance of one side of the body, or adaptation to the sport, or to previous sports. We cannot conclude that adaptation due to dominance was the reason for uneven shoulders as the shoulders weren't classified or allocated with respect to a specific shoulder i.e. if the left shoulder was higher than the right shoulder etc. The most feasible argument is that adaptation to rugby or a previous sport or the muscle changes that occur due to conditioning programmes could be a reason for the uneven shoulders among the rugby players. It could well be that the body's natural ability to adapt to certain conditions, or the conditioning programmes that are designed to improve and protect rugby players, may in actual fact contribute to the occurrence of future injuries.

The injured players also displayed statistically significant baseline differences with regards to the bilateral isokinetic strength ratio during concentric external rotation. As the ratio is the value of non-dominant/dominant values for that particular movement and contraction, a ratio of 108.2% implies that the injury-bound players had higher median non-dominant concentric external rotator strength values than their dominant concentric external rotator strength values, whereas the players who did not become injured in the shoulder region had a corresponding ratio of 100%, implying that their median non-dominant concentric external rotator strength values were lower than the corresponding mean dominant side values. The implications are that the injury-bound players had strength deficiencies in terms of their dominant concentric internal rotation strength when the season commenced. This assumption could be confirmed by the fact that a player's risk of shoulder injury proved to increase 1.42 times for every 10 percent increase in the non-dominant/dominant shoulder

strength ratio for concentric external rotation. It also emphasizes the importance of the relative strength of the dominant shoulder's external rotators. Despite the variation in previous dominant versus non-dominant shoulder strength ratios for overhead athletes found and published by previous researchers, in general the dominant side is as strong as the non-dominant side, (Wilk & Arrigo, 1993; Mikesky *et al.*, 1995) or stronger than the non-dominant side (Chandler, 1992; Codine *et al.*, 1997). The rotator cuff muscles are prime movers in shoulder rotation and also work to pre-set or stabilize the shoulder before activating motion (David *et al.* 2000). More specifically, the infraspinatus muscle functions as an external rotator of the glenohumeral joint, while the teres minor muscle also functions as an external rotator as well as a posterior stabiliser (Malcarney & Murrell, 2003). The findings in our study therefore contradict previous research and may be indicative of weakness in this particular population's dominant shoulders' concentric external rotation strength. The results of this study may indicate that the players who are prone to sustain shoulder injury during the season may have had underlying impaired infraspinatus and teres minor muscle function. Previous research has indicated that muscle imbalances and weaknesses may increase the risk of injury to athletes (Chandler *et al.*, 1992; Burnham *et al.*, 1993; Leroux *et al.*, 1994; Wang *et al.*, 2000). It therefore seems reasonable to argue that an apparent pre-season weakness of the injured players' external rotators may have contributed to injury in the same season.

Our calculations show that the variable that has the highest probability of predicting shoulder injury is the bilateral difference between the shoulder's external rotators' ROM. The results derived from this study indicate that a player who has a bilateral difference of three centimeters or more with regards to shoulder external rotation ROM has a 16.2 times better chance of sustaining a shoulder injury than a player who displays a bilateral difference of less than one centimeter. Various other studies have found that rugby players display diminished glenohumeral rotation range (Erasmus, 2006; Fernandez *et al.*, 2011). Possible reasons for this could be increased age (Fernandez *et al.*, 2011), the intensity and frequency of tackling within the game of rugby (Fuller *et al.*, 2010), and a greater amount of weight training (Fuller *et al.*, 2010). Age may be a risk factor for the occurrence of diminished glenohumeral ROM (Fernandez *et al.*, 2011). Even though a possible correlation between age and ROM was not specifically investigated in our study, increased age and diminished ROM might predict the incidence of future injury. Therefore it seems possible that both variables might pose as risk factors for future injury and that age may have some correlation with the diminished ROM that certain players display. The presence of an abnormally rounded back may be one of the reasons for the impaired ROM that was observed in the participants. This phenomenon

may be explained by the fact that the areas that are affected by decreased ROM are obviously less mobile. Consequently the supporting structures around the joints are dynamically loaded and are therefore susceptible to intrinsic injury (Erasmus, 2006).

One of the limitations in this study was that a specific cohort was investigated, a fact which makes it impossible to generalize the findings. And muscle activation patterns were determined in a laboratory setting, while the ideal situation would have been during the tackle situation.

In conclusion, the finding of this study is that in this semi-professional cohort of rugby players, older players with an increased non-dominant/dominant concentric external rotation ratio, uneven shoulders and insufficient ROM are more inclined to sustain shoulder injuries during a competitive playing season. Abnormalities in these variables should be identified pre-season in order that corrective and appropriate rehabilitation may be performed to prevent shoulder injury. Further research is needed to determine if pre-season interventions will result in a decrease in the number of injuries sustained.

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# CHAPTER 6

## SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

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### **6.1 Summary**

The purpose of this study is to profile semi-professional rugby players of the North-West University's PUK Rugby Institute and Leopards Rugby Union in terms of thoracic posture, isokinetic shoulder muscle strength and scapular muscle recruitment patterns. Furthermore, the association between the above mentioned variables is investigated as well as which of the thoracic posture, isokinetic shoulder muscle strength and scapular muscle recruitment potentially has the best predictive value regarding future shoulder injury.

In Chapter 1 the problem statement, aim and hypotheses of the study are stated and the structure of the study explained. In Chapter 2 a literature review is presented to explain how the game of rugby union has evolved into a game with a high incidence of overall and shoulder injury. The literature indicates the probable correlations between posture and shoulder pathology among the general population as well as overhead-sport athletes especially. Furthermore, evidence is presented regarding the value of isokinetic strength in testing shoulder muscle strength, as well as its positive correlations with the appearance of shoulder pathology. Over the years certain normative values regarding isokinetic muscle strength and muscle ratios have been established. One normative value that appears to be important with regards to optimal shoulder function is the unilateral muscle ratio that describes the antagonist-agonist muscle strength ratio of one shoulder. It has been suggested that the glenohumeral joint external rotators should be at least 65% of the strength of the internal rotator muscles for optimal muscle balance. The literature on the

shoulder's scapular muscle activation patterns indicate that among rugby players, serratus anterior had an earlier onset of activation when compared with infraspinates during a simulated tackle situation. Among the general population and among certain athletes it has been proven that muscle activation patterns become compromised not only in the involved side, but also in the uninvolved side of the patient. While a significant amount of literature regarding these variables is available, it is noticeable in the literature that the number of studies of similar topics with rugby players as the subjects is limited.

The literature indicates that there is a lack of information on rugby players in terms of posture, scapulae muscle activation patterns and isokinetic strength profiles, as well as on the influence of these factors on future shoulder injury. Further research was needed to contribute knowledge to the existing body of knowledge. This resulted in the collection of related data from semi-professional rugby union players. The findings from the research were then reported in the format of 3 research manuscripts. Chapter 3, the first such manuscript, focused on the first objective of this study, which was to profile the posture, isokinetic shoulder muscle strength and shoulder muscle activation patterns of the typical semi-professional rugby player in North-West University's PUK Rugby Institute and Leopards Rugby Union. Mean values indicate that the players display abnormalities regarding external rotator ROM and forward shoulder position, and that they also have deficiencies regarding shoulder external rotation strength.

In Chapter 4 the relationship between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns among 91 semi-professional rugby players of the North-West University's PUK Rugby Institute and Leopards Rugby Union was studied. The results indicate that certain postural abnormalities such as forward shoulders, uneven shoulders and a rounded back could contribute to the delay of muscle onset times of serratus anterior and infraspinates muscles among rugby union players. A rounded back could also influence the firing order of a player's infraspinates muscle. Postural deviation such as forward shoulders could also alter antagonist/agonist isokinetic strength ratios in the semi-professional rugby union players. Furthermore, non-ideal or unsatisfactory external shoulder joint rotation flexibility may contribute towards the altering of the infraspinates and lower trapezius muscle firing order.

In Chapter 5 the predictive value of thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns in semi-professional rugby players of the Leopards Rugby Union and North-West University's PUK Rugby Institute regarding shoulder girdle injuries was determined. The ROM of shoulder internal and external rotators, age, and the playing position of a player were included in the analyses for injury prediction. By means of a logistic regression model, the

odds ratios for each of the variables were determined. The results of this study indicated that participants with unsatisfactory external rotation ROM had a 16.15 times bigger probability of sustaining an injury during the season than participants who were classified as having ideal external rotation ROM. Players with uneven shoulders had a 4.43 times bigger probability of sustained an injury than the players who displayed normal shoulder heights. In addition, for every year of increased age the probability of sustained a shoulder injury increased 1.34 times. The results also indicate that for every 10% that a player's non-dominant/dominant concentric external rotation strength ratio increases, the likelihood of future shoulder injury increases by 1.42 times.

The conclusion that can be drawn from this study will be presented by testing the hypothesis set for this study.

## **6.2 Conclusions**

The conclusion of this study is derived from the stated hypotheses.

### **6.2.1 Hypothesis 1**

**Hypothesis 1 states that an abnormal kyphotic thoracic posture is observed, isokinetic shoulder strength ratios are within the normal range, and improper scapulae muscle activation patterns exist among semi-professional rugby players.**

In 55% of the participants thoracic posture evaluations presented with a slightly abnormal and abnormal forward head, while 68% of the participants presented with abnormal shoulder position in the lateral view. Eighty-five percent of the participants of this study presented with non-ideal or unsatisfactory shoulder external rotator ROM. The isokinetic external/internal rotation (ER/IR) ratio for shoulder muscle strength during concentric muscle contraction was 64% for the non-dominant and 54% for the dominant shoulder. The sequence of muscle activation of the rotator cuff muscles was found to be: serratus anterior; lower trapezius; infraspinates and then upper trapezius.

To conclude, non-ideal or unsatisfactory flexibility of the players' shoulder external rotators, abnormally forward shoulders, and weakness of the shoulder external rotators were found. These variables, however, did not appear to result in abnormal scapular stabilisers muscle activation patterns. Based on these results and the conclusion, hypothesis 1 is therefore rejected.

### **6.2.2 Hypothesis 2**

**Hypothesis 2 states that a significant positive relationship is found between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns among semi-professional rugby players.**

According to the results certain postural abnormalities such as forward shoulders, uneven shoulders and a rounded back display statistically significant relationships with the altered scapulae muscle activation patterns of the serratus anterior and infraspinates muscles. Posture in the form of forward shoulders also displays a significant relationship with antagonist/agonist isokinetic strength ratios. No correlations of clinical significance were found between isokinetic shoulder strength and scapulae muscle activation patterns among the participants. Non-ideal or unsatisfactory flexibility of shoulder external rotators displays significant correlations with the altered scapulae muscle activation patterns of the infraspinates and lower trapezius muscles.

To conclude, certain postural abnormalities may contribute towards the delay of muscle onset times of infraspinates and serratus anterior muscles among rugby players, as well as the firing order of infraspinates. Forward shoulders could also alter antagonist/agonist isokinetic strength ratios. Non-ideal or unsatisfactory flexibility of their shoulder external rotators may contribute towards the alteration of the infraspinates and lower trapezius muscle firing order.

Therefore the first part of the hypothesis, that states that thoracic posture displays significant relationships with isokinetic shoulder strength as well as with scapulae muscle activation patterns, is accepted. However, the second part of the hypothesis, that states that a significant relationship is found between isokinetic shoulder strength and scapulae muscle activation patterns among semi-professional rugby players, is rejected.

### **6.2.2 Hypothesis 3**

**Hypothesis 3 states that thoracic posture will be the most significant predictor of shoulder girdle injuries among semi-professional rugby players, compared to isokinetic shoulder strength and scapulae muscle activation patterns.**

The participants in this study who sustained shoulder injuries during the season differed significantly from those who did not sustain injuries with regards to the following baseline measurements: age, height and non-dominant/dominant concentric external rotation strength ratio. Among backline players baseline differences occurred within age (injured players were older), weight (injured players were heavier), height (injured players were taller) and body mass

index (BMI) (injured players had a higher BMI). The variables that displayed statistically significant predictive values towards future injury were age, insufficient shoulder external rotator ROM, uneven shoulders and the non-dominant/dominant concentric external rotation strength ratio.

Despite the fact that a lack of external rotator ROM proved to be the most significant predictor of shoulder girdle injuries among the participants, posture did indeed prove to be more predictive of shoulder girdle injury than isokinetic shoulder strength and scapulae muscle activation patterns. Hypothesis 3 is therefore accepted.

The conclusions of this study show that the players in the cohort investigated present with abnormal posture. This abnormal posture is accompanied by the significant percentage (85%) of the cohort of rugby players who displayed non-ideal or unsatisfactory external rotator ROM. The literature indicates an association between forward shoulders and pectoralis muscles' resting muscle length. Adaptive shortening of the pectoralis muscles can be caused by a training-induced increase in muscle tone as well as a reduction in suppleness due to insufficient stretching of the shoulder muscles. Training programmes that do not place enough emphasis on well balanced antagonist/agonist muscle strength ratios and flexibility exercises could result in scenarios such as the one described above. This could explain the high frequency of forward shoulders within this cohort. Regarding the high frequency of players who manifested diminished external rotators' ROM, it has been shown previously that age and previous injury influenced glenohumeral ROM. Due to the fact that such a significant percentage of players present with non-ideal or unsatisfactory external rotator ROM, combined with the fact that the mean age of the players in this cohort is 20.8 years, it appears that a significant percentage of players with limited ROM are relatively young. It therefore seems unlikely that age plays a role in limited ROM within this cohort of players. Considering that only 27.5% of the players reported previous shoulder injury, it also appears unlikely that previous injury had a bearing on the high percentage of players with limited ROM. A possible explanation for this phenomenon could once again lie in the training approaches that these players were exposed to. The probability exist that flexibility exercises, or the lack thereof, combined with the continued micro-trauma of soft tissue structures around the shoulder, could explain this occurrence.

Shoulder biomechanics indicate that having an impaired range of motion around the shoulder joint could predispose an individual to future injury. The theory is that the areas that are affected by decreased ROM are less mobile than other areas. Therefore the supporting structures around the joints are dynamically loaded, and are consequently more susceptible to intrinsic injury. If

this were indeed the case, this could partially explain the fact that impaired shoulder external rotator ROM proved to be a significant predictor of consequent shoulder injury. In fact, with everything taken into consideration, this variable proved to be the biggest predictor of future injury with an odds ratio of 16.15.

Apart from the fact that diminished ROM could increase a player's risk of sustaining an injury due to increased tension on soft tissue structures, the possibility exists that a lack of ROM could contribute to the occurrence of injury through other related mechanisms. In Chapter 4 the relationship between thoracic posture, isokinetic shoulder strength and scapulae muscle activation patterns as well as ROM among the group of players were investigated. During that particular section of the study it came to the fore that non-ideal or unsatisfactory external shoulder joint rotation flexibility may contribute towards the altering of the infraspinates and lower trapezius muscle firing order. This opens up the possibility that a lack of ROM could indirectly contribute towards the occurrence of shoulder injury by influencing and therefore impairing the function or coordination of these two scapular stabilizers. The scapula plays a critical role during normal shoulder movement. The scapula, however, cannot function optimally without the coordinated support of the scapula stabilizers. Essentially these scapular stabilizers act as force couples around the scapula, which in turn help the scapula to act as the platform for normal shoulder movement. If these muscles do not function effectively in a coordinated manner, shoulder biomechanics and shoulder movement will be impaired. It therefore does seem that if the altered infraspinates and lower trapezius muscle firing order were in fact predictors of shoulder injury, this would have been indicated in the logistic regression model. However, it was not. This leads us to believe that ROM's predictive value may lie in the fact that the increased tension on soft tissue structures could predispose players to injury.

Another factor that was highlighted as an apparent weakness during the profiling of the players was the weakness of the dominant shoulders in terms of external rotation strength. As was the case with diminished ROM, this characteristic can also be predictive of the occurrence of future shoulder injury. Despite the fact that the mean external/internal rotation (ER/IR) ratio for the group was lower than the literature suggests it should be for optimal shoulder function, this fact did not prove to be predictive of the occurrence of shoulder injury. However, the non-dominant/dominant concentric external rotation ratio did in fact increase the chance of injury by 1.42 times for every 10% increase in this ratio. The weaker the dominant shoulder becomes relative to the non-dominant shoulder in terms of concentric external strength, the higher the risk of sustaining a shoulder injury. Regardless of which ratio is studied, a weakness of the dominant external shoulder rotators appears to be related to the occurrence of injury.

The only correlation found between posture and isokinetic strength was for forward shoulders and concentric ER/IR for the non-dominant shoulder. This is a contradictory finding as one would expect that players with abnormally forward shoulders would display an antagonist/agonist isokinetic strength ratio that tended to be lower than the norm due to the correlation between forward shoulders and strong and tight pectoralis major muscles. Despite the fact that this correlation is somewhat confusing it was found among the players' non-dominant shoulders, whereas the weaknesses displayed in Chapters 3 and 5 were found among the players' dominant shoulders. It therefore does not appear to be totally contradictory to previous findings. When the players were profiled, postural abnormalities that became evident among the group were an abnormally forward head position as well as an abnormally forward shoulder position. In theory these abnormalities could have contributed towards future injuries, but that did not prove to be the case. However, despite the fact that the majority of the group did not present with uneven shoulders before the commencement of the season, uneven shoulders did display predictive value for future shoulder injury.

To determine the possible reason for this phenomenon one can look at the correlations that forward shoulders displayed with the other variables that were measured during the study. It appears that uneven shoulders might have a negative influence on the time it takes for serratus anterior to fire. This delay could have a detrimental effect on the functioning of serratus anterior, which includes stabilizing the scapula during shoulder movement as well as acting as a force couple during shoulder movement. Having said that, the serratus anterior firing order did not display correlations with future injury, so it is unlikely that uneven shoulders caused injury through that mechanism.

As for all the postural abnormalities and their different correlations, it appears that abnormally forward shoulders, uneven shoulders and a rounded back could contribute towards the delay of the muscle onset times of serratus anterior and infraspinates. Therefore, despite the fact that these postural abnormalities somehow influenced some of the scapular stabilisers' muscle onset times, the delay apparently did not have an influence on the occurrence of future injury.

The last variable that proved to be predictive of future shoulder injury was increased age. It is generally accepted that posture improves as an individual develops from adolescence into adulthood. It therefore appears to be unlikely that poor posture played an increased role in the occurrence of shoulder injury as the players became older, because the chances are good that their posture would have improved as they got older. Also, the mean age of the participants in this study was 20.8 years. Due to the fact that the majority of the participants in this study had

therefore not reached their peak in strength development yet, it is unlikely that a decrease in strength would have an impact on the occurrence of shoulder injury as the players became older. It is probable that the players became stronger as they became older and had a smaller chance of getting injured due to a lack of strength. Another possibility that exists is that the older players at some previous stage in their career had had a shoulder injury. Such previous injuries were not evident at the time of testing, but we know that most injuries are repeated injuries.

It has been shown that injury among rugby players alters the firing order of the scapular stabilizers, but no link has been made between the age of rugby players and their ability to maintain correct scapular stabilizing and firing orders during certain movements. Also, because the firing orders and muscle onset times of the scapular stabilizers did not show correlations with shoulder injury, it is unlikely that they played a role in the ability of increased age to predict injury.

One aspect that did prove to be predictive of shoulder injury and which could be connected to age was a lack of shoulder ROM. It has been shown previously that rugby players lose ROM around the shoulder joint as they get older. If this was also the case in our study, it would explain why a loss of shoulder ROM as well as an increase in age would both predict the occurrence of future shoulder injury. Therefore a significant link between these two variables can be argued.

As a final conclusion, impaired ROM regarding shoulder external rotators appears to be the biggest predictor of shoulder injury. This abnormality also appears to be associated with impaired scapular stabilizer firing order. However, due to the fact that scapular stabilizer firing order did not appear to predict future shoulder injury, ROM's influence on shoulder injury could probably be attributed to increased tension on soft tissue structures that predispose players to injury. Despite the fact that forward shoulders and a rounded back impair the timely firing of serratus anterior and infraspinates muscles around the scapula, none of these factors appears to predict shoulder injury. It may be that uncoordinated muscle function around the scapula does not play as big a role in shoulder function in a contact sport as is the case with an overhead sport such as swimming and baseball pitching. Also, it might not be detrimental for rugby players to present with forward shoulders and a rounded back. If anything, it was shown that a rounded back may tend to be a protective factor against future shoulder injury. It has been postulated before that a "tucked-up" posture benefits participants in contact sports. Further food for thought is that our study also showed that forward shoulders positively influenced one isokinetic strength ratio. This was the only variable that appeared to have an influence of isokinetic strength. The fact that an apparent weakness of external rotator strength of the dominant shoulder also

predicted injury is significant in the sense that right-handed players prefer to make contact with their dominant shoulders. This weakness was found also only among the dominant shoulders. By implication this could mean that repetitive trauma to the shoulder may negatively influence a shoulders' external rotator strength, or that external rotator weakness might make a player more susceptible to injury. Because these relative weaknesses were found only among the dominant shoulders, and because the only apparent difference between the shoulders appears to be the amount of trauma they endure, we postulate that the contact component of rugby negatively influences the relative strength of the dominant shoulder external rotators. The only variable that could be associated with age is diminished ROM. This could probably be attributed to aging glenohumeral soft tissue and the continued micro-trauma that is caused by rugby over an extended period. This probable association between age and diminished ROM could well explain why both these factors appear to be strong predictors of shoulder injury.

Due to the fact that this was an availability study, the findings from this study can be reported and accepted for the cohort that participated in it but not extrapolated or generalized to the general rugby playing population of South Africa. The findings do, however, present an indication of the current situation among South African rugby players.

### **6.3 Limitations and recommendations**

This study is subject to some specific limitations that have to be considered when interpreting the results. Specific recommendations are made for future research in the area of shoulder biomechanics related to shoulder injuries in semi-professional rugby union players.

- After years of research in the area of posture, there is still uncertainty with regards to what is defined as normal posture. Various criteria have been used to define correct posture, but researchers are still divided regarding the definition of optimal posture.
- The New York Posture test was used for analyzing posture in this population of 21 years-old on average. This test was developed for adolescents, however, and has not been validated for adult populations. A recommendation would be to find a more objective measure of posture through photography, or to validate the New York Posture test in adults and in a sporting population.
- Range of motion measurements regarding shoulder internal and external rotator flexibility was done by means of the “hand-behind-the-back” and the “hand-behind-the-neck” method. According to this technique participants are classified in terms of the difference between their left and right shoulder’s ROM and not according to absolute

values expressed in degrees of rotation. Despite the fact that this is an accepted method of classifying participants regarding ROM, a unilateral approach where absolute values are measured by means of a goniometer might be more accurate.

- Despite the improvements in technology, EMG as a measurement of muscle activation is, still a robust measure instrument for muscle activation and very dependent on various factors of repeatability in the technology. Large variations in measurement were found in this study. Future researchers should perhaps make use of intramuscular or fine wire electrodes to gain more accurate data. However, in this population it would not be practical to simulate rugby functional activities with fine-wire electrodes.
- The nature of rugby exposes players to significant forces due to the collisions that take place and various forms of body contact. The nature of these forces inevitably causes acute damage to the body as well as injuries, and injuries cannot be prevented. By measuring the mechanism of injury throughout the year, it could be possible to distinguish between injuries that were in part caused by intrinsic risk factors and those that were caused by the physical nature of rugby.
- Further studies in this field need to concentrate on more objective methods to obtain posture and ROM data especially. With regards to surface EMG, more functional rugby-specific movements should be measured to determine the relevant muscle activation patterns.

#### **6.4 Future research**

Two variables that came to the fore during this study with regards to the possible prediction of future shoulder injuries were limited ROM, especially with regards to the shoulder external rotators, and the relative weakness of the group's shoulder external rotator muscles. Based on these findings, future research could focus on the following questions:

- What is the mechanism that leads to limited shoulder external rotator ROM's apparent predictive value towards future shoulder injury?
- Why is there an apparent weakness of relative shoulder external rotator strength among South African rugby players and how could that weakness possibly contribute to future shoulder injury?

# ANNEXURE A

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## **Guidelines for authors**

### ***South African Journal of Sports Medicine***

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All manuscripts should be submitted online: [www.sajsm.org.za](http://www.sajsm.org.za). If this is not feasible, the manuscript may be submitted, via e-mail, as a Microsoft Word attachment, to Mike Lambert, Editor-in-Chief, at [Mike.Lambert@uct.ac.za](mailto:Mike.Lambert@uct.ac.za).

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Authorship should be based only on substantial contribution to: (i) conception, design, analysis and interpretation of data; (ii) drafting the article or revising it critically for important intellectual content; (iii) final approval of the version to be published. All three of these conditions must be met by the authors (Uniform requirements for manuscripts submitted to biomedical journals; [www.icmje.org/index.html](http://www.icmje.org/index.html)).

#### **CONFLICT OF INTEREST**

Authors must declare all sources of support for the research and any association with the product or research topic that may constitute conflict of interest.

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Identifying information about the patient or research subject should not be published in written descriptions or photographs unless the information is essential for scientific purposes and the patient/research subject (or parent or guardian) gives informed written consent for publication. Informed consent for this purpose requires that the patient/research subject be shown the manuscript to be published ([www.icmje.org](http://www.icmje.org)).

## ETHNIC CLASSIFICATION

Work that is based on, or contains reference to ethnic classification must indicate the rationale for this. For clarification authors are encouraged to refer to *Ncayiyana DJ: Racial profiling in medical research: what are we measuring? S Afr Med J 2007;97:1225-1226.*

## TYPES OF MANUSCRIPTS

**Original research articles** of 3 000 words or less (*excluding references and tables*), with up to 6 tables or figures, should normally report observations or research of relevance to sports medicine and exercise science in South Africa. References should be limited to 20.

**Short reports, Commentaries, or Case studies** should be 1 000 words or less, with 1 table or illustration and no more than 6 references.

**Review articles** are rarely accepted unless invited.

**Letters to the editor** should be no longer than 400 words with only one illustration or table.

**Obituaries** should not exceed 400 words and may be accompanied by a photograph.

## MANUSCRIPT PREPARATION

1. The page set-up should be as follows: 2.54 cm margins, 1.5 line spacing, Times Roman 12 Font.
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3. The **Title Page** should have: (a) the title of the article, which should be concise but informative (*85 characters or less, including spaces*); (b) first name, middle initial, and last name of each author, with highest academic degree; (c) institutional affiliation, name of department(s) and/or institution(s) to which the work should be attributed; (d) name and address of author responsible for correspondence about the manuscript; (e) a short running header of no more than 40 characters (including spaces) placed near the bottom of the title page and identified.
4. Research articles should have a structured **Abstract** not exceeding 250 words (50 for short reports) comprising information under the subheadings: Objectives, Methods, Results, and Conclusions.
5. The **Introduction** section should provide a clear background of the study. The justification, practical importance of the study, and specific purpose or research objective should also be clearly stated.
6. The **Methods** section should identify the methods, apparatus (manufacturer's name and address in parentheses), and procedures in sufficient detail to allow other researchers to reproduce the results. Give references to established methods, including statistical methods (see #7). When reporting experiments on human subjects, indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human

experimentation (institutional or regional) and whether the subjects gave their written informed consent.

7. Describe the **Statistical methods** with sufficient detail to enable a knowledgeable reader with access to the original data to verify the reported results. All data should be presented with appropriate indicators of measurement error or uncertainty (such as standard deviations or confidence intervals). Avoid sole reliance on statistical hypothesis testing, such as the use of  $p$  values, which fails to convey important quantitative information. Precise  $p$  values must be shown as indirect indications such as  $p > 0.05$  or  $p = \text{NS}$  are unacceptable and difficult for other researchers undertaking meta-analyses.

8. **Abbreviations** should be spelt out when first used in the text and thereafter used consistently. Scientific measurements should be expressed in SI units.

9. Present your **Results** in a logical sequence in the text, tables, and figures. Do not repeat the presentation of data in the text, tables or figures. Tables and figures should appear on separate pages. Do not discuss data in this section. Data should be presented so that the number of digits and decimals are scientifically relevant.

10. In the **Discussion** section emphasise the new and important aspects of the study and the conclusions that follow from them. Do not repeat in detail data or other material given in the Introduction or the Results section. Include in the Discussion section the implications of the findings and their limitations, including implications for future research. Relate the observations to other relevant studies. Link the conclusions with the goals of the study but avoid unqualified statements and conclusions not completely supported by your data. Wherever possible comment on the practical applications of the study.

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References should be inserted in the text as superior numbers, with the first reference being #1 and the next reference #2 etc. The references should be listed at the end of the article in numerical order (i.e. in order of appearance). Authors are responsible for verification of references from the original sources. References should be set out in the Vancouver style and approved abbreviations of journal titles used; consult the List of Journals in *Index Medicus* for these details. Names and initials of all authors should be given unless there are more than six, in which case the first three names should be given followed by *et al.* First and last page numbers should be given.

**Journal references** should appear thus:

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2. Lane KN, Wenger HA. Effect of selected recovery conditions on performance of repeated bouts of intermittent cycling separated by 24 hours. *J Strength Cond Res* 2004;18(4):855-860.
3. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med* 1970;2(2):92-98.

**Book references** should be set out as follows:

1. Jeffcoate N. Principles of gynaecology. 4th ed. London: Butterworth; 1975. p. 96-101.
2. Weinstein L, Swartz MN. Pathogenic properties of invading microorganisms. In: Sodeman WA jun, Sodeman WA, eds. Pathologic physiology: mechanisms of disease. Philadelphia: WB Saunders; 1974. p. 457-472.

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# ANNEXURE B

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## **Guidelines for authors**

### ***Journal of Biomechanics***

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3. A separate title page should include the title, authors' names and affiliations, and a complete address for the corresponding author including telephone and fax numbers as well as

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**C. Thesis:**

van Werff, K., 1977. Kinematic and dynamic analysis of mechanisms. A finite element approach. PhD. Thesis, Delft University Press, Delft.

**D. Proceedings:**

van Soest, A. J., van den Bogert, A. J., 1991. Criteria for the comparison of direct dynamics software systems to be used in the field of biomechanics. In *Proceedings of the 3rd International Symposium on Computer Simulation in Biomechanics*. University of Western Australia, Perth.

## **E. Footnotes:**

As distinct from literature references, should be avoided. Where they are essential, superscript Arabic numbers should be employed.

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# ANNEXURE C

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## **Guidelines for authors**

### ***International Journal of Rehabilitation Research***

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Online submission and review system

NOTE: These instructions comply with The International Committee of Medical Journal Editors. For further details, authors should consult the article, “Uniform Requirements for Manuscripts Submitted to Biomedical Journals” at [www.icmje.org](http://www.icmje.org).

#### **Aims and scope**

The Journal is a quarterly, peer-reviewed, interdisciplinary forum for the publication of research into functioning, disability and contextual factors experienced by persons of all ages in both developed and developing societies. The wealth of information offered makes the journal a valuable resource for researchers, practitioners, and administrators in such fields as rehabilitation medicine, outcome measurement nursing, social and vocational rehabilitation/case management, return to work, special education, social policy, social work and social welfare, sociology, psychology, psychiatry assistive technology and environmental factors/disability. Areas of interest include functioning and disablement throughout the life cycle; rehabilitation programmes for persons with physical, sensory, mental and developmental disabilities; measurement of functioning and disability; special education and vocational rehabilitation; equipment access and transportation; information technology; independent living; consumer, legal, economic and sociopolitical aspects of functioning, disability and contextual factors.

#### **Points to consider before submission**

Please think carefully about the following points and make the appropriate declarations.

#### **Redundant or duplicate publication**

We ask you to confirm that your paper has not been published in its current form or a substantially similar form (in print or electronically, including on a web site), that it has not been

accepted for publication elsewhere, and that it is not under consideration by another publication. The International Committee of Medical Journal Editors has provided details of what is and what is not duplicate or redundant publication ([www.icmje.org](http://www.icmje.org)). If you are in doubt (particularly in the case of material that you have posted on a web site), we ask you to proceed with your submission but to include a copy of the relevant previously published work or work under consideration by other journals. In your covering letter to the editors, draw attention to any published work that concerns the same patients or subjects as the present paper.

### **Conflicts of interest**

Authors must state all possible conflicts of interest in the manuscript, including financial, consultant, institutional and other relationships that might lead to bias or a conflict of interest. If there is no conflict of interest, this should also be explicitly stated as none declared. All sources of funding should be acknowledged in the manuscript. All relevant conflicts of interest and sources of funding should be included on the title page of the manuscript with the heading “Conflicts of Interest and Source of Funding:”. For example:

Conflicts of Interest and Source of Funding: A has received honoraria from Company Z. B is currently receiving a grant (#12345) from Organization Y, and is on the speaker’s bureau for Organization X – the CME organizers for Company A. For the remaining authors none were declared.

In addition, each author must complete and submit the journal’s copyright transfer agreement, which includes a section on the disclosure of potential conflicts of interest based on the recommendations of the International Committee of Medical Journal Editors, “Uniform Requirements for Manuscripts Submitted to Biomedical Journals” ([www.icmje.org/update.html](http://www.icmje.org/update.html)). The form is readily available on the manuscript submission page [www.editorialmanager.com/ijrr](http://www.editorialmanager.com/ijrr) and can be completed and submitted electronically. Please note that authors may sign the copyright transfer agreement form electronically. For additional information about electronically signing this form, go to <http://links.lww.com/ZUAT/A106>.

### **Permission to reproduce previously published material**

We ask you to send us copies of permission to reproduce material (such as illustrations) from the copyright holder. We cannot send your paper to press without these permissions!

## **Patient consent forms**

The protection of a patient's right to privacy is essential. We ask you to send copies of patient or guardian consent forms on which patients or other subjects of your experiments clearly grant permission for the publication of photographs or other material that might identify them. If the consent form for your research did not specifically include this, please obtain it or remove the identifying material. A sample patient consent form is available above if required.

## **Ethics committee approval**

You must state clearly in your submission in the Methods section that you conducted studies on human participants must with the approval of an appropriate named ethics committee. Please also look at the latest version of the Declaration of Helsinki. Similarly, you must confirm that experiments involving animals adhered to ethical standards and must state the care of animal and licensing guidelines under which the study was performed.

## **Authorship**

We ask that all authors sign the submission letter. We have (rarely) had problems when someone named as an author was not aware of the submission of a paper and, on occasion, did not support the findings published. All authors must acknowledge that they have read and approved the paper, that they have met the criteria for authorship as established by the International Committee of Medical Journal Editors, and that they believe that the paper represents honest work, and are able to verify the validity of the results reported.

## **Compliance with NIH and Other Research Funding Agency Accessibility Requirements**

A number of research funding agencies now require or request authors to submit the post-print (the article after peer review and acceptance but not the final published article) to a repository that is accessible online by all without charge. As a service to our authors, LWW will identify to the National Library of Medicine (NLM) articles that require deposit and will transmit the post-print of an article based on research funded in whole or in part by the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or other funding agencies to PubMed Central. The Copyright Transfer Agreement provides the mechanism. Papers are accepted for publication on the understanding that exclusive copyright in the paper is assigned to the Publisher. Authors are asked to submit a signed copyright assignment form with

their paper. They may use material from their paper in other works published by them after seeking formal permission.

### **Submissions**

Authors are required to submit their manuscripts through the web-based tracking system at <http://ijrr.edmgr.com>. Signed author forms may be included in the submission as a 'supporting document' or mailed to the journal office. The site contains instructions and advice on how to use the system. Authors should NOT in addition then post a hard copy submission to the editorial office, unless you are supplying artwork, letters or files that cannot be submitted electronically, or have been instructed to do so by the editorial office. For those authors who have no option but to submit by mail first contact the editor, Dr Črt Marinček, at Email: [marincek.crt@ir-rs.si](mailto:marincek.crt@ir-rs.si).

Double spacing should be used throughout the manuscript, which should include the following sections, each starting on a separate page: Title Page, abstract and keywords, text, acknowledgements, references, individual tables and captions. Margins should be not less than 3 cm. Pages should be numbered consecutively, beginning with the Title Page, and the page number should be placed in the top right hand corner of each page. Abbreviations should be defined on their first appearance in the text; those not accepted by international bodies should be avoided.

Manuscript must be in English and should meet the following specifications:

- Original Article: A total word count of 3,000, including an abstract of no more than 250 words. Up to 60 references are allowed.
- Review: A total word count of 3,000, including an abstract of no more than 250 words. Up to 100 references are allowed.
- Brief Report: A total word count of 1,300, including an abstract of no more than 150 words. Up to 30 references are allowed.

Total word limits include abstract, figure and table legends, but not the title page and the references.

## **Presentation of papers**

### **Title page**

The Title Page should carry the full title of the paper and a short title to be used as a 'running head' (and which should be so identified). The first name, middle initial and last name of each author should appear. If the work is to be attributed to a department or institution, its full name should be included. Any disclaimers should appear on the Title Page, as should the name and address of the author responsible for correspondence concerning the manuscript and the name and address of the author to whom requests for reprints should be made. Finally, the Title Page should include a statement of conflicts of interest and source of funding, and when none state "none declared".

### **Abstracts**

The second page should carry a structured abstract of no more than 250 words. Abstracts will be translated into French, German and Spanish. Translations are welcome and may help to secure early publication of accepted original and review articles. The abstract should state the Objective(s) of the study or investigation, basic Methods (selection of study subjects or laboratory animals; observational and analytical methods), main Results (giving specific data and their statistical significance, if possible), and the principal Conclusions. It should emphasise new and important aspects of the study or observations.

### **Keywords**

The abstract should be followed by a list of 3–10 keywords or short phrases which will assist the cross-indexing of the article and which may be published. When possible, the terms used should be from the Medical Subject Headings list of the National Library of Medicine (<http://www.nlm.nih.gov/mesh/meshhome.html>).

### **Text**

Full papers of an experimental or observational nature may be divided into sections headed Introduction, Methods (including ethical and statistical information), Results and Discussion (including a conclusion), although reviews may require a different format.

### **Acknowledgements**

Acknowledgements should be made only to those who have made a substantial contribution to

the study. Authors are responsible for obtaining written permission from people acknowledged by name in case readers infer their endorsement of data and conclusions.

## References

The Harvard System is used. References in the text should be quoted in the following manner: (Jones, 1988) or (Brusilow and Horwich, 1989) or if there are more than two authors, (Silengo *et al.*, 1980). Multiple papers referred to together in the text should be given in chronological order.

The references should be listed alphabetically at the end of the paper. If references to the same author have the same year, they should be differentiated using 1980a and 1980b etc. Journal names should be abbreviated as in *MEDLINE* (NLM Catalog, <http://www.ncbi.nlm.nih.gov/nlmcatalog>).

The layout should be as follows:

For journals:

Meng K, Zdrahal-Urbaneck J, Frank S, Holderied A, Vogel H (2006). Patients' expectations, motivation and multi-dimensional subjective and objective socio-medical success in medical rehabilitation measures. *Int J Rehabil Res* **29**, 65-69.

For books:

Hodges JR (1999). *Cognitive assessment for clinicians*. Oxford: Oxford Medical Publications.

For chapters in books:

McDonnel J, Hardman M, McDonnel A (2003). Understanding people with disability. In *An introduction to persons with moderate and severe disabilities: educational and social issues*. Boston: Allyn & Bacon; pp. 1-22.

Personal communications and unpublished work should not feature in the reference list but should appear in parentheses in the text. Unpublished work accepted for publication but not yet released should be included in the reference list with the words 'in press' in parentheses beside the name of the journal concerned. References must be verified by the author(s) against the original documents.

## Tables

Each table should be typed on a separate sheet in double spacing. Tables should not be submitted as photographs. Each table should be assigned an Arabic numeral, e.g. (Table 3) and a brief title. Vertical rules should not be used. Place explanatory matter in footnotes, not in the heading. Explain in footnotes all non-standard abbreviations that are used in each table. Identify statistical measures of variations, such as standard deviation and standard error of the mean.

Be sure that each table is cited in the text. If you use data from another published or unpublished source, obtain permission and acknowledge the source fully.

## Illustrations

**Figures:** Digital art should be created/scanned and saved and submitted as either a TIFF (tagged image file format), an EPS (encapsulated postscript) file. If prepared in PowerPoint or Excel, line art should be imported into Photoshop then saved as TIFF format; or line art can be printed on a photoquality printer and then rescanned at 1200dpi. **Electronic photographs—radiographs, CT scans, and so on—and scanned images must have a resolution of at least 300 dpi.** If fonts are used in the artwork, they must be converted to paths or outlines or they must be embedded in the files. **Colour images must be created/scanned and saved and submitted as CMYK files. If you do not have the capability to create CMYK files, please disregard this step. Indicate in your cover letter that you are unable to produce CMYK files.** Cite figures consecutively in the text, and number them in the order in which they are discussed.

### ***Digital Art Checklist:***

1. Create and submit artwork in approximately the actual size it will appear in the journal
2. Crop out any extra white or black space surrounding the image
3. Text within figures should be in an acceptable font (Helvetica is preferred) and sized consistently throughout the artwork using 8-12 pt. type
4. Text within figures should be embedded in the file or converted to an outline or path
5. For black and white images: create & save in greyscale format
6. For colour files: create and save in CMYK format (not RGB)
7. For line art: save and submit at a resolution of at least 1200 dpi
8. For images/photographs: save and submit at a resolution of at least 300 dpi
9. For combination halftones: save and submit at a resolution of at least 600 dpi

10. For all artwork: save and submit TIFF or EPS files. Do not select "Save as Compressed TIFF" when saving files.
11. Save each figure as a separate file and save them separate from the accompanying text file(s). For multipanel or composite figures only: send as one file with each part labeled the way it is to appear in print
12. Name figures in the format: corresponding author's last name\_figure1.tif, etc.

***Detailed Figure Instructions:*** For a step by step guide for submitting Digital Art to please visit [www.LWWonline.com](http://www.LWWonline.com). Click "For Authors" then click "Artwork" in the menu to the right. Visit the "5 Steps for Creating Digital Artwork" for specific guidelines.

### **Legends for illustrations**

Captions should be typed in double spacing, beginning on a separate page. Each one should have an Arabic numeral corresponding to the illustration to which it refers. Internal scales should be explained and staining methods for photomicrographs should be identified.

### **Units of measurement**

Measurements of length, height, weight, and volume should be reported in metric units (metre, kilogram, or litre) or their decimal multiples. Temperatures should be given in degrees Celsius. Blood pressures should be given in millimeters of mercury.

All haematologic and clinical chemistry measurements should be reported in the metric system in terms of the International System of Units (SI). Editors may request that alternative or non-SI units be added by the authors before publication.

### **Abbreviations and symbols**

Use only standard abbreviations. Avoid abbreviations in the title and abstract. The full term for which an abbreviation stands should precede its first use in the text unless it is a standard unit of measurement.

### **Offprints**

Offprints may be purchased using the appropriate form that will be made available with proofs. Orders should be sent when the proofs are returned; orders received after this time cannot be fulfilled.

# ANNEXURE D

## PATIENT INFORMATION AND INFORMED CONSENT

---

### PART 3

#### Consent

Title of the project

Thoracic posture, electromyography and isokinetic strength of the shoulder in relation to shoulder injuries in semi professional rugby players .....

.....

I, the undersigned ..... (full names)

Read/listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project 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 .....

For non-therapeutic experimenting with subjects under the age the age of 21 years the written approval of a parent or guardian is required.

I, ..... (full names)

Parent or guardian of the subject named above, hereby give my permission that he/she may participate in this project and I also indemnify the University and any employee or student of the University, against any liability which may arise during the course of the project.

Signature: ..... Date: .....

Relationship: .....

For experimenting with married persons the following indemnity from the spouse is required.

I, ..... (full names),

The spouse of the subject in this application, hereby undertake not to submit any claims against the University regarding treatment in case of death or injuries of this person due to the project as described in this application, due to negligence of the University, its students or another subject, or in any other way.

Signature: ..... Date: .....

Relationship: .....



# ANNEXURE E

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## Measurement Form

---

<b>NAME:</b>	<b>NR:</b>	
<b>TEL. NUMBER:</b>		
<b>TEAM:</b>		
<b>DATE OF BIRTH:</b>		
<b>AGE:</b>	<b>MASS:</b>	<b>STATURE:</b>
<b>DOMINANT ARM:</b>		

PRIOR INJURIES: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

### UPPER EXTREMITIES (SPECIAL TESTS)

Ideal < 1cm Non-ideal 1-3cm Unsatisfactory >3cm	RIGHT Player's value	LEFT Player's value
Hand behind neck ROM		
Hand behind back ROM		

## EMG TESTING

	MVC Left	LEFT Mean value	LEFT Peak value	MVC Right	RIGHT Mean value	RIGHT Peak value
Lower trapezius						
Upper trapezius						
Serratus Anterior						
Infraspinates						

	LEFT Time of onset	LEFT Time of offset	LEFT Firing order	RIGHT Time of onset	RIGHT Time of offset	RIGHT Firing order
Lower trapezius						
Upper trapezius						
Serratus Anterior						
Infraspinates						

## ISOKINETIC TESTING

<b>Internal rotation</b>	<b>LEFT</b>	<b>RIGHT</b>
Concentric strength		
Eccentric strength		
Eccentric/Concentric strength ratio		

<b>External rotation</b>	<b>LEFT</b>	<b>RIGHT</b>
Concentric strength		
Eccentric strength		
Eccentric/Concentric strength ratio		

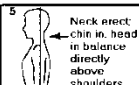

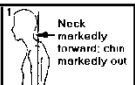

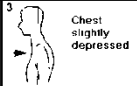
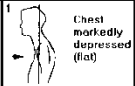
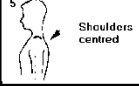
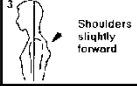

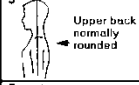
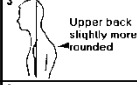
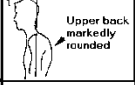
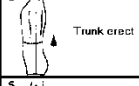
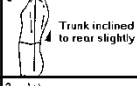
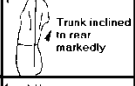
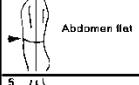
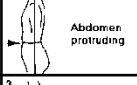
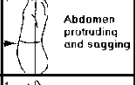
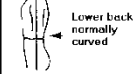
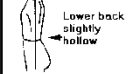
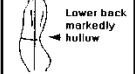
	LEFT	RIGHT
External rotation/Internal rotation ratio (Concentric)		
External rotation/Internal rotation ratio (Eccentric)		

LEFT versus RIGHT ISOKINETIC RATIOS

LEFT/RIGHT shoulder (concentric internal rotation) ratio:	
LEFT/RIGHT shoulder (concentric external rotation) ratio:	
LEFT/RIGHT shoulder (eccentric internal rotation) ratio:	
LEFT/RIGHT shoulder (eccentric external rotation) ratio:	

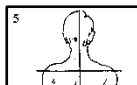
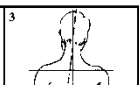

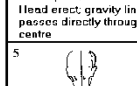
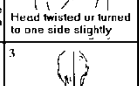
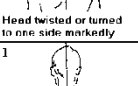
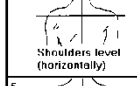
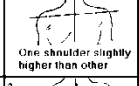
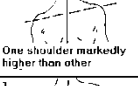



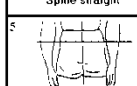
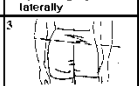

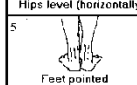


POSTURE RATING CHART  
SIDE VIEW POINTS

SCORE

5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____

POSTURE RATING CHART  
BACK VIEW POINTS

SCORE

5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____
5 	3 	1 	_____

Total:

New York Posture Test