



# **The effect of exercise intervention on shoulder girdle biomechanics and isokinetic shoulder muscle strength in university level cricket players: a bilateral comparison**

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# AUTHORS' CONTRIBUTIONS

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The principal author of this dissertation is Mister GJR Groenewald. The contributions of the authors are summarized below:

Co-author	Contribution
Dr EJ Bruwer	Supervisor
Professor DDJ Malan	Co-Supervisor.
	Co-authors assisted in: writing the manuscripts, determining the study design, performing the tests, extracting the data, doing technical editing, interpreting the results.

The following is a statement by the co-authors confirming their individual role in this study and granting permission for the manuscript to form part of this dissertation.

I hereby declare that my role in the preparation of the above-mentioned manuscript is as indicated above, and that I give my consent for it to be published as part of the MSc dissertation of Ruann Groenewald.

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# ABSTRACT

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## **The effect of exercise intervention on shoulder girdle biomechanics and isokinetic shoulder muscle strength in university-level cricket players: a bilateral comparison**

Literature indicates that adaptations such as scapula protraction, altered glenohumeral range of motion (ROM) and strength adaptations are commonly detected in the dominant shoulder of overhead athletes. Previous research has linked these adaptations to shoulder instabilities and a higher risk of injuries, for instance shoulder impingement syndrome, rotator cuff tears and labral tears. This study was aimed at detecting asymmetry in the shoulder rotation ROM and isokinetic shoulder rotation muscle strength characteristics of North-West University (NWU) cricket players (Potchefstroom campus), as well as the relationship of scapula protraction with the detected asymmetry. It also sought to determine the effect of a controlled stability exercise intervention on the bilateral biomechanical and isokinetic shoulder rotation muscle strength deficits in cricket players at the NWU (Potchefstroom Campus).

Forty-five cricket players voluntarily completed baseline testing and 30 cricketers completed the intervention phase and follow-up testing (randomly divided into an intervention group, n=15 and a control group, n=15). Scapula protraction, shoulder rotation ROM and isokinetic shoulder rotation muscle strength testing were performed on both groups at baseline, as well as after the six-week exercise intervention. The experimental group underwent two-weekly supervised exercise sessions that focused on correcting postural and biomechanical adaptations usually observed in overhead sports participants in addition to their normal conditioning regime. The reference group, which followed only normal training, was educated on these adaptations and corrective exercises. Some of the players in the reference group also performed the corrective exercises on their own during the intervention period.

Baseline testing of the entire group (n=45) indicated that on average, the dominant shoulder of the cricketers was significantly more protracted ( $p \leq 0.001$ ), with significantly less internal rotation (IR) ROM ( $p \leq 0.001$ ) and more external rotation (ER) ROM ( $p \leq 0.001$ ) than the non-dominant side. Both the IR and the ER average concentric peak torque were significantly higher in the dominant shoulder ( $p \leq 0.001$  and  $p = 0.002$  respectively). Associations with scapula

protraction were only significant on the dominant side, with shoulder ER ROM indicating a significantly negative association ( $r=-0.3$ ,  $p=0.05$ ), and shoulder IR average peak torque a significantly positive association ( $r=0.3$ ,  $p=0.05$ ). Although improvements in especially scapula protraction and shoulder IR ROM were observed after the six-week intervention period in both the experimental group ( $p=0.067$  and  $p\leq 0.001$ ) and the reference group ( $p=0.006$  and  $p\leq 0.001$ ), the IR ROM of only the experimental group no longer differed significantly from the norm. The exercise intervention indicated no effect on the concentric muscle strength characteristics.

This study indicated that asymmetry does exist in the shoulders of cricket players, cricket being a unilateral overhead sport. The dominant shoulder was more protracted, with less IR and more ER rotation ROM, as well as significantly higher IR and ER rotational muscle strength than the non-dominant shoulder. Exercises performed in season, which were aimed at correcting these adaptations, only indicated a significant improvement in IR ROM under supervision.

Future research should investigate the effect of corrective exercises in different periods of the cricket-playing season and ensure that the participants in the control group are not educated on these exercises and are not performing them during the intervention period. Ethically speaking, it might be a challenge to divide a cricket squad; therefore, future studies on this matter should use a different squad with more or less the same training and competition schedules as the control group of that study.

Keywords: *Isokinetic testing, intervention, shoulder dominance, overhead athletes, shoulder injuries*

# OPSOMMING

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## **Die effek van oefening-intervensie op skouergordelbiomeganika en isokinetiese skouerspierkrag by universiteitsvlakkrieketspelers: 'n bilaterale vergelyking**

Die literatuur dui aan dataanpassingssoos skapula-protraksie, gewysigde bewegingsomvang (BO) van die gleno-humeralegewrig en krageienskappe algemeen in die dominante skouer van oorhoofseatlete voorkom. Vroeëre navorsing het hierdie aanpassings gekoppel aan skouer-onstabiliteite en 'n groter risiko om beserings op te doen, byvoorbeeld vasknypingsindroom, rotatorkraagskeure en labrumskeure. Hierdie studie is daarop gemik om asimmetrie in die skouerrotasie-BO en isokinetiese skouerrotasiespierkrag-eienskappe van krieketspelers van die Noordwes Universiteit (NWU -Potchefstroom-kampus) vas te stel, asook om die verband te bepaal tussen skapulaprotraksie en die bespeurde asimmetrie. Daar is ook gepoog om die effek van 'n gekontroleerde stabiliteitsoefening-intervensie op bilaterale biomeganiese en isokinetiese skouerrotasiespierkrag-tekortkominge by krieketspelers van die NWU (Potchefstroomkampus) te bepaal.

Vyf-en-veertig krieketspelers het vrywilligbasislyn-toetsing voltooi en 30 krieketspelers het die intervensiefase en opvolgtoetsing voltooi (lukraak verdeel in 'n intervensiegroep,  $n=15$  en 'n kontrolegroep,  $n=15$ ). Skapula-protraksie, skouerrotasie-BO en isokinetiese skouerrotasiespierkragtoetsing is op beide groepeop basislyn gedoen, asook ná die oefeningintervensie, wat ses weke geduur het. Die eksperimentele groep het tweeweklikse oefensessies onder toesig bygewoon wat gerig was op die regstelling van postuur- en biomeganiese aanpassings wat gewoonlik by oorhoofsesportdeelnemers voorkom, bykomend tot hul normale kondisioneringsprogram. Die kontrolegroep, wat slegs hul normale kondisionering gevolg het, is in hierdie aanpassings en korrektiewe oefeninge onderrig. Sommige van die spelers in die kontrolegroep het ook op hul eie die korrekte oefeninge tydens die intervensietydperk gedoen.

Basislyn-toetsing van die hele groep ( $n=45$ ) het aangedui dat die dominante skouer betekenisvol meer protraksie toon ( $p<0.001$ ), met betekenisvol kleiner interne rotasie (IR) ( $p<0.001$ ) en groter eksterne rotasie (ER) BO ( $p\leq 0.001$ ) as die nie-dominante kant. Beide die interne en die eksterne rotasie-gemiddelde konsentriese piekwingkrag was betekenisvol hoër in die dominante skouer ( $p\leq 0.001$  and  $p=0.002$  onderskeidelik). Assosiasies met skapula-protraksie was slegs aan die dominante kant betekenisvol, met skouer-ER BO wat 'n betekenisvol negatiewe assosiasie ( $r=-$

0.3,  $p = 0.05$ ) aangedui het, en skouer-IR gemiddelde piekwingkrag wat 'n betekenisvol positiewe assosiasie ( $r=0.3$ ,  $p=0.05$ ) getoon het. Alhoewel verbetering in veral skapula-protrasie en skouer-IR BO na die intervensie-tydperk van sesweke in sowel die eksperimentele groep ( $p=0.067$  en  $p \leq 0.001$ ) as die kontrolegroep ( $p=0.006$  en  $p \leq 0.001$ ) waargeneem is, het die IR BO van slegs die eksperimentele groep nie meer betekenisvol van die norm verskil nie. Die oefening-intervensie het geen effek op die konsentriese spierkrag-eienskappe getoon nie.

Hierdie studie het aangedui dat asimmetriewel in die skouers van krieketspelers voorkom – krieket is 'n eensydig oorhoofsesport. Die dominante skouer toon groter protrasie, met minder IR BO en meer ERBO, asook betekenisvol meer IR- en ER-spierkrag as die nie-dominante skouer. 'n Betekenisvolle verbetering in IR is slegs waargeneem na oefeninge wat tydens die seisoen onder toesig gedoen is om hierdie aanpassings reg te stel.

Toekomstige navorsing behoort ondersoek in te stel na die effek van korrektiewe oefening tydens verskillende periodes van die krieket-seisoen en ook seker te maak dat die deelnemers wat in die kontrolegroep is, nie hierdie oefeninge aanleer entydens die intervensie-tydperk doen nie. Gesien vanuit 'n etieseperspektief kan dit dalk 'n uitdaging wees om 'n krieketgroep te verdeel; gevolglik behoort toekomstige studies wat oor hierdie aangeleentheid gedoen word, van 'n ander groep met min of meer dieselfde opleiding- en kompetisieskedules as die eksperimentele groep van daardie studie gebruik te maak.

*Sluitelwoorde: Isokinetiese toetsing, intervensie, skouer-dominansie, oorhoofse atlete, skouerbeterings*

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## LIST OF ABBREVIATIONS

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<b>BMI:</b>	body mass index
<b>cm:</b>	centimetre
<b>ER:</b>	external rotation
<b>GIRD:</b>	glenohumeral internal rotation deficit
<b>IR:</b>	internal rotation
<b>kg:</b>	kilogram
<b>m:</b>	meter
<b>n:</b>	Number of participants
<b>Nm:</b>	Newton meter
<b>NWU:</b>	North-West University
<b>pt/bw:</b>	peak torque to body weight
<b>ROM:</b>	range of motion
<b>SD:</b>	standard deviation
<b>°:</b>	degrees

# CHAPTER 1

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## INTRODUCTION

## 1.1 PROBLEM STATEMENT

Overhead athletes perform unilateral overhead movements such as bowling and throwing. Both actions produce high loads of force at the shoulder girdle during overhead motions (Stuelcken *et al.*, 2008:579; Elliot *et al.*, 2003:85). Essential components of the overhead motion include glenohumeral abduction-adduction, as well as internal rotation (IR) and external rotation (ER) movements (Cools *et al.*, 2007:26). Unbalanced force couples and attenuation changes may develop in the shoulder girdle of overhead athletes in response to repetitive forces observed during overhead motions (Baltaci & Tunay, 2004:232). Musculoskeletal profiles documenting muscular strength have identified unilateral dominance in selected muscles in the upper extremities of overhead athletes (Ellenbecker & Roetert, 2003:68). Isokinetic evaluation has proved to be a good method for muscle strength assessment and the literature has set normative criteria for rotational shoulder movements, indicating a significant difference between the dominant and non-dominant limb, which is characteristic of overhead sport (Silva *et al.*, 2006:517). Thomas *et al.* (2011:711) advocate that the throwing arm has a decreased glenohumeral IR and an increased ER range of motion (ROM) as a result of posterior capsule thickness. The external rotators of the dominant side are often weak in relation to those of the non-dominant side (Malliou *et al.*, 2004:766). Downer and Sauers (2005:23) state that, for optimal sports performance in professional baseball players – and overhead sport– a delicate balance between shoulder mobility and stability should be attained. Without stability, the shoulder's proprioception is dysfunctional and the performance of shoulder repositioning will be influenced (Lee *et al.*, 2003:846).

Static and dynamic structures of the shoulder must maintain functional stability and work in synchrony for controlled overhead motion in the shoulder girdle (Bolton *et al.*, 2011:13). Overhead actions of the glenohumeral joint require muscle balance in the scapular stabilisers for the rhythm to remain systematic, for instance during scapulohumeral movement. During the first 30° of humeral abduction, the scapula sets owing to elevation. The clavicle rotates minimally during this stage. In the second phase of 60° abduction the scapula rotates 20° upwards and the humerus elevates 40° with minimal protraction of the scapula; thus a 2:1 ratio. In the third phase of the final 90° of motion the 2:1 ratio of the scapulohumeral movement continues. In this stage the clavicle rotates posteriorly 30°-50° and elevates up to 15°. Lastly, the humerus also rotates

laterally 90° so that the greater tuberosity of the humerus avoids the acromion process (Magee, 2008:251). The supraspinatus initiates humerus elevation and provides stability to the glenohumeral joint by compressing the humeral head into the glenoid fossa as part of a force-couple mechanism (Malcarney & Murrell, 2003:995; David *et al.*, 2000:169). The infraspinatus and teres minor serve as external rotators and posterior stabilisers of the shoulder, as described by Malcarney and Murrell (2003:995). The subscapularis is the only component of the anterior rotator cuff and functions as an internal rotator of the glenohumeral joint (Malcarney & Murrell, 2003:994). The major upward rotators of the scapula are the upper and lower trapezius muscle group and the serratus anterior (Cools *et al.*, 2004:64). When the stabilisers are overused, fatigue sets in, rhythm within the shoulder girdle is uncontrolled and strength is lost (Morella *et al.*, 2010:1257).

Strength and biomechanical adaptations in overhead athletes, such as forward head posture, rounded or forward shoulders, anterior humeral head translation, scapular protraction, tightness in the posterior capsule and alterations in rotational ROM have previously been linked to shoulder instability (Thigpen *et al.*, 2010:707; Kennedy *et al.*, 2009:159; Downar & Sauers, 2005:23). Functional shoulder instability has been defined as the clinical situation in which the humeral head moves excessively relative to the confines of the glenoid fossa, or passes over the rim as in a subluxation or dislocation (Cools *et al.*, 2004:64). When shoulder adaptations influence the shoulder stability, the functional ability of the shoulder will be influenced. Superior humeral head migration is theorised to result from the inability of the rotator cuff to maintain alignment of the humeral head with the centre of the glenoid cavity, thus allowing it to translate superiorly, reducing the subacromial space (Chopp *et al.*, 2011:44). Thigpen *et al.* (2010:707) revealed that individuals without shoulder pain with forward head posture and rounded shoulder posture have greater scapular anterior protraction and IR throughout and greater scapular upward rotation at the upper ranges of elevation, with lower levels of serratus anterior muscle activity during overhead activities. Greater scapular IR with lower levels of serratus anterior muscle activity during overhead activities. This provides support for the clinical theory that postural adaptations can alter scapular kinematics and muscle activity during overhead tasks.

Muscular imbalances in the rotator cuff and scapular musculature, coupled with inadequate muscular endurance and improper stroke biomechanics, can lead to overuse injury in the glenohumeral joint of overhead sport players (Ellenbecker & Roetert, 2003:63). Kennedy *et al.* (2009:159) found that overhead athletes show many biomechanical adaptations that can be secondary to injuries. These include ROM and strength deficits that can lead to scapular dyskinesis, glenohumeral instability and deficits in proprioception control. The forward shoulder posture or scapular protraction is a cause of stronger internal rotator and adductor muscle groups, and strengthening posterior shoulder muscles, including the external rotator and abductor groups, can reduce forward shoulder posture in overhead athletes (Kluemper *et al.*, 2006:58). The latissimus dorsi is then in a lengthened position and causes the pectoralis major to lose its function during IR (Smith *et al.*, 2006:342). The posterior rotator cuff and the posterior deltoid muscles are all shortened during scapular protraction, which places a disadvantaged position for the length-tension curves (Smith *et al.*, 2006:342). Understanding the characteristics of these muscles in overhead sport athletes can be useful for conditioning/pre-habilitation exercises. Literature also shows that a decrease in the glenohumeral ER ROM is the result of the demands of throwing (Dwelly *et al.*, 2009:614-615). Kluemper *et al.* (2006:67) proved that stretching and strengthening all the muscles involved can decrease injury risk and improve the posture of overhead athletes. Implementation of a posterior capsule stretch should be an integral part of flexibility programmes for the overhead athlete and should be integrated for both strength training and rehabilitation programmes (Lorenz, 2005:62). This imbalance between the internal and external rotators may result in injury in the shoulder girdle (Ellenbecker & Mattalino, 1997:326). Isokinetic testing is an accurate quantitative measurement of muscle performance, which tests at fixed angular velocity of joint motions (Lertwanich *et al.*, 2006:948). The strength of various muscle groups can be measured by using modern dynamometric methods such as isokinetics (David *et al.*, 2000:169). For this reason, isokinetic machine testing is advocated for testing athletes' muscle strength for accurate measures. Kibler *et al.* (2007:748) mentioned that rehabilitation programmes that focus on activation of the muscles involved and endurance of these muscles in their activation phase should be considered for rehabilitation or for conditioning purposes. Miller *et al.* (2011:18) point out that pre-habilitation is a more reliable way of managing an overhead athlete's career and lowers the risk of shoulder injuries.

The stability of the shoulder girdle influences the biomechanical functioning, muscle function and performance of the shoulder, especially in overhead athletes. Research on stabilising intervention programmes for performance enhancement and injury prevention is limited, especially in cricket players, hence the research questions to be answered in this study are: Firstly, does asymmetry exist in the shoulder rotational ROM and isokinetic muscle strength characteristics of university-level cricket players? Secondly, what is the relationship of shoulder rotational ROM and isokinetic muscle strength characteristics on the one hand, and scapula protraction in university-level cricket players on the other? Thirdly, what is the effect of a controlled shoulder stability exercise intervention on the bilateral biomechanical and isokinetic shoulder rotational muscle strength deficits in university-level cricket players?

The results of this study will contribute to scientific knowledge regarding scapular protraction, ROM and strength adaptations in overhead athletes. Better understanding of the above could furthermore contribute to injury and pathology prediction and inclusion of preventative exercise modalities in conditioning regimes. The practical significance of shoulder stability exercises could be communicated to biokineticists, sport scientists and coaches working with overhead athletes.

## **1.2 OBJECTIVES**

The objectives of this study are to:

- 1) detect asymmetry in the shoulder rotation ROM and isokinetic rotation muscle strength characteristics of university-level cricket players;
- 2) determine the relationship of shoulder rotation ROM and isokinetic rotation muscle strength characteristics with scapula protraction in university-level cricket players;
- 3) determine the effect of a supervised stability exercise intervention on the bilateral biomechanical adaptations and isokinetic rotational muscle strength deficits in university-level cricket players.

### **1.3 HYPOTHESES**

The study is based on the following hypotheses:

- 1) Significant asymmetry in shoulder rotation ROM, isokinetic rotation muscle strength and scapula protraction will exist between the dominant and non-dominant sides of university-level cricket players.
- 2) Scapula protraction will show significantly negative associations with shoulder rotational ROM, as well as with isokinetic rotation muscle strength characteristics of university-level cricket players.
- 3) A controlled stability exercise intervention will significantly improve the bilateral shoulder biomechanical adaptations and isokinetic rotation muscle strength deficits in university-level cricket players.

## 1.4 STRUCTURE OF DISSERTATION

Chapter 1: Introduction

Chapter 2: Posture, biomechanics and muscle strength of the overhead athletes: a literature review

Chapter 3: The relationship between bilateral scapular position, shoulder range of motion and selected muscle shoulder strength characteristics in cricketers

(This article will be submitted to: *South African Journal of Sports Medicine*)

Chapter 4: The effect of an exercise intervention on bilateral biomechanical and strength deficits in isokinetic shoulder strength of cricket players

(This article will be submitted to: *Preventative Medicine*)

Chapter 5: Summary, conclusion, limitations and recommendations

Each chapter in the dissertation will be followed by references, with Chapter 1 and Chapter 2 written in accordance with the NWU guidelines and Chapter 3 and Chapter 4 in accordance with those required by the peer-reviewed journals to which they will be submitted. These requirements are listed in Appendix A and Appendix B.

## REFERENCES

- Baltaci, G. & Tunay, V.B. 2004. Isokinetic performance at diagonal pattern and shoulder mobility in elite overhead athletes. *Scandinavian journal of medicine & science in sport*, 14:231-238.
- Bolton, G., Moss, S.J., Sparks, M. & Venter, P.C. 2013. Thoracic posture, shoulder muscle activation patterns and isokinetic strength of semi-professional rugby union players. *South African journal of sport medicine*, 25(1):12-17.
- Chopp, J.N., Fischer, S.L. & Dickerson, C.R. 2011. The specificity of fatiguing protocols affects scapular orientation: implications for subacromial impingement. *Clinical biomechanics*, 26:40-45.
- Cools, A.M., Witvrouw, E.E., Declercq, G.A., Vanderstraeten, G.G. & Cambier, D.C. 2004. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction retraction movement in overhead athletes with impingement symptoms. *British journal of sport medicine*, 38:64-68.
- Cools, A.M., Declercq, G.A., Cambier, D.C., Mahieu, N.N. & Witvrouw, E.E. 2007. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scandinavian journal of medicine & science in sport*, 17:25–33.
- David, G., Dvir, Z., Simmons, N., Magarey, M., Jones, M., Turker, K. & Sharpe, M. 2000. The relationship between strength and width of the supraspinatus: an isokinetic and ultra sonographic study. *Isokinetics and exercise science*, 8:169-174.
- Downar, J.M. & Sauer, E.L. 2005. Clinical measures of shoulder mobility in the professional baseball player. *Journal of athletic training*, 40(1):23-29.
- Dwelly, P.M., Tripp, B.L., Tripp, P.A., Eberman, L.E. & Gorin, S. 2009. Glenohumeral rotational range of motion in collegiate overhead-throwing athletes during an athletic season. *Journal of athletic training*, 44(6):611-616.
- Ellenbecker, T.S. & Mattalino, A.J. 1997. Concentric isokinetic shoulder internal and external rotation strength in professional baseball pitchers. *Journal of orthopaedic & sports physical therapy*, 25(5):323-329
- Ellenbecker, T. & Roetert, E.P. 2003. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of science and medicine in sport* 6(1):63-70.

- Elliott, B., Fleisig, G., Nicholls, R. & Escamilla, R. 2003. Technique effects on upper limb loading in the tennis serve. *Journal of science and medicine in sport*, 6(1):76-87.
- Forte, F.C., de Castro, M.P., de Toledo, J.M., Ribeiro, D.C. & Loss, J.F. 2009. Scapular kinematics and scapulohumeral rhythm during resisted shoulder abduction – Implications for clinical practice. *Physical therapy in sport*, 10:105-111.
- Kennedy, D.J., Visco, C.J. & Press, J. 2009. Current concepts for shoulder training in the overhead athlete. *Journal of sport medicine*, 3(8):154-160.
- Kibler, W.B., Chandler, T.J., Shapiro, R. & Conuel, M. 2007. Muscle activation in coupled scapulohumeral motions in the high performance tennis serve. *British journal of sports medicine*, 41:745-749.
- Kluemper, M., Uhl, T. & Hazelrigg, H. 2006. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *Journal of sport rehabilitation*, 15:58-70.
- Lee, H.M., Liau, J.J., Cheng, C.K., Tan, C.M. & Shih, J.T. 2003. Evaluation of shoulder proprioception following muscle fatigue. *Clinical Biomechanics*, 18:843-847
- Lertwanich, P., Lamsam, C. & Kulthanan, T. 2006. Difference in isokinetic strength of the muscles around dominant and non-dominant shoulders. *Journal of medicine association Thailand*, 89(7):948-952.
- Lorenz, D.S. 2005. The importance of the posterior capsule of the shoulder in overhead athletes. *Strength and conditioning journal*, 27(4):60-62.
- Magee, D.J. 2008. Orthopaedic physical assessment. 5<sup>th</sup>ed. Philadelphia: Saunders.
- Malcarney, H.L. & Murrell, G.A.C. 2003. The rotator cuff biological adaptations to its environment. *Journal of sport medicine*, 33(13):993-1002.
- Malliou, P.C., Giannakopoulos, K., Beneka, A.G., Gioftsidou, A. & Godolias, G. 2004. Effective ways of restoring muscular imbalances of the rotator cuff muscle group: a comparative study of various training methods. *British journal of sports medicine*, 38:766-772.
- Merolla, G., de Santis, E., Sperling, J.W., Campi, F., Palandini, P. & Porcellini, G. 2010. Infraspinatus strength assessment before and after scapular muscles rehabilitation in professional volleyball players with scapular dyskinesis. *Journal of shoulder and elbow surgery*, 19, 1256-1264.

- Miller, C.J., Collins, M. & Schwellnus, M. 2011. Intrinsic and extrinsic factors associated with change in range of motion (ROM) after a single stretch session and repeated loading following an endurance run. *University of Cape Town*, 1-151.
- Silva, R.T., Gracitelli, G.C., Saccol, M.F., de Souza Laurino, C.F., Silva, A.C. & Braga-Silva, J.L. 2006. Shoulder strength profile in elite junior tennis players: horizontal adduction and abduction isokinetic evaluation. *Journal of sport medicine*, 40:513-517.
- Smith, J., Dietrich, C.T., Kotajarvi, B.R. & Kaufman, K.R. 2006. The effect of scapular protraction on isometric shoulder rotation strength in normal subjects. *Journal of shoulder and elbow surgery*, 15(3):339-343.
- Stuelcken, M.C., Karen A., Ginn, K.A. & Sinclair, P.J. 2008. Shoulder strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain. *Journal of science and medicine in sport*, 11:575-580.
- Thigpen, C.A., Padua, D.A., Michener, L.A., Guskiewicz, K., Giuliani, C., Keener, J.D. & Stergiou, N. 2010. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *Journal of electromyography and kinesiology*, 20:701-709.
- Thomas, S.J., Swanik, C., Higginson, J.S., Kaminski, T.W., Swanik, K.A., Bartolozzi, A.R., Abboud, J.A. & Nazarian, L.N. 2011. A bilateral comparison of posterior capsule thickness and its correlation with glenohumeral range of motion and scapular upward rotation in collegiate baseball players. *Journal of shoulder and elbow surgery*, 20:708-716.

## CHAPTER 2

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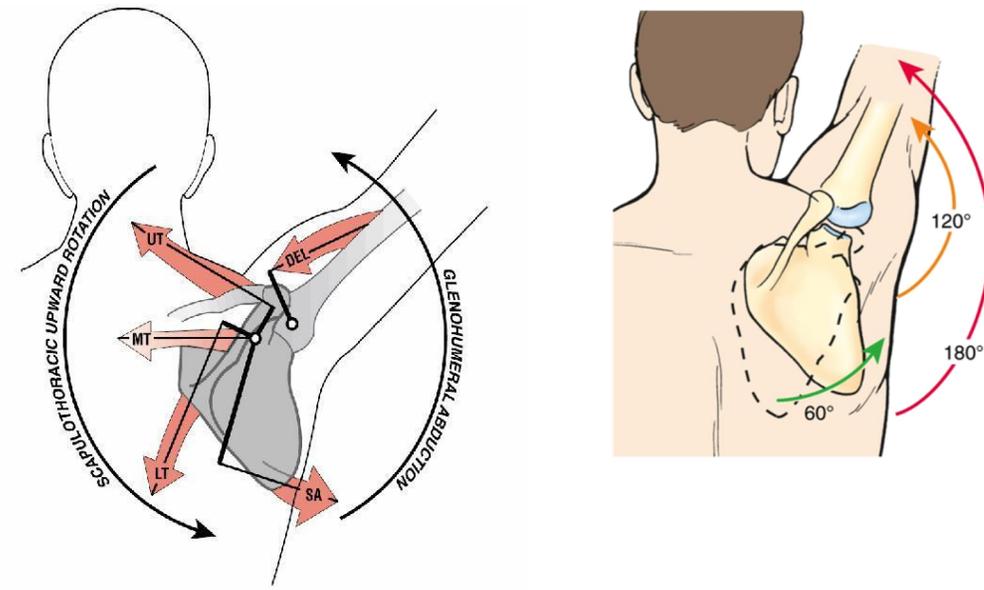
# **POSTURE, BIOMECHANICS AND MUSCLE STRENGTH OF OVERHEAD ATHLETES: A LITERATURE REVIEW**

## **2.1 INTRODUCTION**

The repetitive nature of overhead sports such as baseball, cricket, tennis, volleyball, swimming and javelin holds a considerable risk for overuse injuries in the shoulder joint. Overhead athletes must perform two distinct unilateral overhead movements, namely bowling and throwing, and both actions produce high loads at the shoulder (Stuelcken *et al.*, 2008:579). The shoulder allows a large range of motion (ROM) in all directions, therefore stability and support are mostly due to 18 muscles acting as stabilisers and mobilisers (Shultz *et al.*, 2010:226-227). Stability is provided predominantly by the ligamentous, capsular and muscular structures and by the relative position of the glenoid and the arm through all motions (Cools *et al.*, 2005:107; Shultz *et al.*, 2008:226).

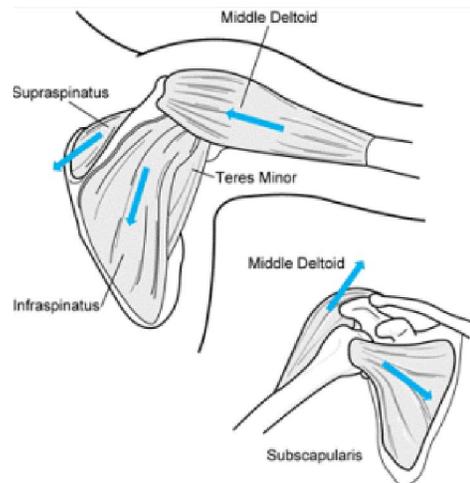
## **2.2 SHOULDER MOVEMENT IN OVERHEAD SPORT**

The scapula plays a vital role in normal upper extremity function. The scapular muscles are subjected to extremely high loads in maintaining and transferring lower extremity and trunk energy into the throwing arm. During overhead activity protraction and retraction scapular movements occur; however, glenohumeral abduction–adduction and internal rotation (IR) and external rotation (ER) movements are also essential movement components (Cools *et al.*, 2007:26). Synchronised scapulohumeral movement involves abduction of the humerus at the shoulder girdle during the first 30° of humeral abduction, while the scapula sets and the clavicle rotates minimally during this stage. In the second phase of 60° elevation the scapula rotates 20° and the humerus elevates 40° with minimal protraction of the scapula; thus a 2:1 ratio. In the third phase or the final 90° of motion the 2:1 ratio of the scapulohumeral movement continues. In this stage the clavicle rotates posteriorly 30°-50° and elevates up to 15°. Lastly, the humerus also rotates 90° laterally so that the greater tuberosity of the humerus avoids the acromion process (Magee 2008:251).



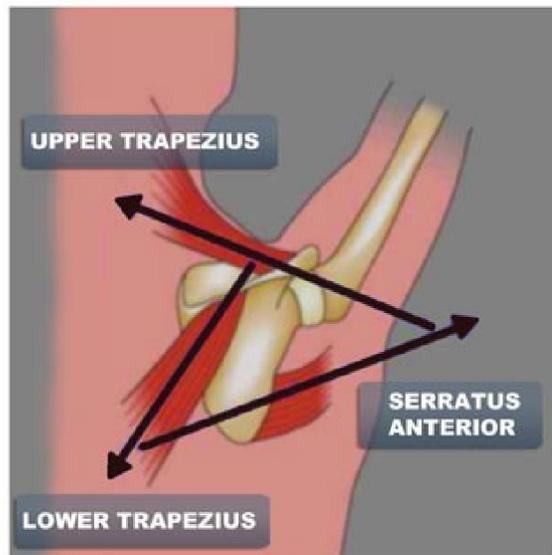
**Figure 2.1 (a and b): Scapulohumeral rhythm**

The muscles of the rotator cuff fulfill a crucial role in providing dynamic stability at the shoulder joint (Stuelcken, 2008:575-576). The rotator cuff consists of the supraspinatus, infraspinatus, teres minor and subscapularis muscle. The rotator cuff muscles depress the humerus head into the glenoid fossa so that the shoulder joint can be fully abducted during overhead activities (Shultz *et al.*, 2010:227). In the overhead athlete, an adequate ratio of concentric agonist muscle strength to eccentric antagonist muscle strength is crucial for dynamic stability and optimal function. Force couples are two equal forces acting in opposite directions to produce rotatory motion (Houghlum, 2010:600). The shoulder complex has four force couples acting with arm movement. In the glenohumeral joint, the infraspinatus and teres minor form a force couple with the subscapularis to produce downward force of the humerus into the glenoid. This allows greater motion during overhead activities.



**Figure 2.2: Force couple in shoulder**

Another force couple is formed between all the muscles of the rotator cuff and the deltoid muscle. The rotator cuff muscles depress the humeral head during elevation of the humerus. In the scapular force couples the upper and lower trapezius work together to rotate the scapula upward (Houglum, 2010:600).



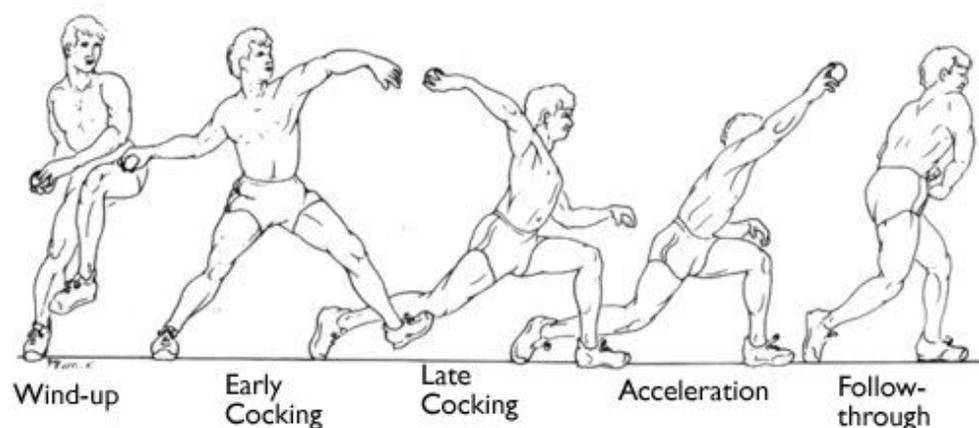
**Figure 2.3: Force couple in shoulder**

The serratus anterior is activated, which, together with the upper trapezius, acts to maintain the scapula against the thorax and rotate it superiorly, preserving scapulohumeral rhythm. These actions contribute to joint stability during the entire ROM, providing mechanical advantages for

the rotator cuff muscles (Moraes *et al.*, 2008:51-52). In contrast the pectoralis minor, levator scapulae and rhomboids work together to rotate the scapula downward (Shultz *et al.*, 2010: 227).

These force couples could be important to preserve adequate osteokinematics of the glenohumeral joint. The scapula acts as a stable basis of support for muscle attachment, allowing the humeral head to initiate the upper limb elevation. During upper limb elevation, the stabilising action of the scapular muscles is essential for adequate performance of the rotator cuff (Moraes *et al.*, 2008:51). In an unstable shoulder or one in which rotator cuff dynamic control is absent, the humeral head can translate when the rotator cuff is stressed. Where the instability is more functional than structural, provocation of symptoms and compensation by other muscle groups are often noted, without the sensation of humeral head translation (Magarey & Jones, 2003:199).

The overhead throwing action, which is a distinct part of the game of cricket, can be divided into several phases, namely the wind-up, stride, arm cocking, arm acceleration, arm deceleration and follow-through phases. Below, the phases are explained as described by Copeland (1993:222) and Escamilla (2009:571-576).



**Figure 2.4: Throwing motion**

### *The wind-up phase*

The wind-up phase is the initial movement where the weight is transferred to the back foot, the trunk laterally flexed and arm extended. The rotator cuff muscles, which have a dual function as glenohumeral joint compressors and rotators, are least active during this phase. The shoulder forces and torques generated in this phase are low (Escamilla & Andrews, 2009:572; Houglum, 2010:590).

### *The cocking phase*

This action can be divided into two phases, the early and late cocking phase. In the early cocking phase, the humerus is abducted to 90° and horizontally extended 30° (at the shoulder girdle). The supraspinatus, infraspinatus, teres minor and subscapularis achieve high to very high activity to resist glenohumeral distraction and enhance glenohumeral stability. The infraspinatus and teres minor muscle provide ER while the periformis and latissimus dorsi provide IR and also contribute to glenohumeral stability by drawing the humeral head towards the glenoid fossa. The subscapularis produces its peak activity in the late cocking phase when contracting eccentrically to decelerate the shoulder ER and protect the anterior structures of the shoulder, which are under extreme tension at this point. The late cocking phase involves ER of the shoulder and elbow flexion in the already abducted and extended arm. Supraspinatus activity is at its highest in the late cocking phase, as it contributes to stability in the shoulder girdle by drawing the humeral head towards the glenoid fossa, preventing translation, which could compromise the volume of the subacromial space. Very high shoulder muscle activity is needed during this phase (Escamilla & Andrews, 2009:573; Houglum, 2010:590).

### *The acceleration phase*

The activity of the serratus anterior is at its highest during the late cocking phase, along with the pectoralis major and latissimus dorsi. The pectoralis major and latissimus dorsi are the two muscles that introduce velocity to the ball during the acceleration phase of the throwing action in overhead sports. This phase of throwing is explosive and drives the humerus into rapid IR by means of a concentric contraction. The subscapularis appears to act as a stabilising muscle to position the head of the humerus in the glenoid. The acceleration phase also includes elbow

extension, forearm pronation and wrist flexion (Escamilla & Andrews, 2009:575; Houglum, 2010:590-591).

### *The follow-through phase*

This phase begins at ball release and ends at maximum shoulder IR. Large loads are generated at the shoulders to slow down the forward acceleration of the arm. The posterior fibres of deltoid along with the supraspinatus, teres minor and infraspinatus all contract eccentrically in this phase of throwing, not only to decelerate horizontal adduction and IR of the arm, but also to help resist shoulder distraction and anterior subluxation forces. The trapezius and the rhomboids play a large role in decelerating scapular protraction and the biceps long head works in decelerating elbow extension and forearm pronation (Copeland 1993:222; Escamilla& Andrews, 2009:576).

In overhead sport such as cricket, baseball, tennis and swimming the athlete must achieve a delicate balance between shoulder mobility and stability to attain optimal sport performance. Repetitive overhead throwing may result in an altered mobility-stability relationship in the shoulder due to sport-specific demands (Downar & Sauers, 2005:23). Scapular kinematics and muscle activity place increased stress on the shoulder, leading to shoulder adaptations such as forward head/rounded shoulder posture (Thigpen *et al.*, 2010:706).

### **Postural, biomechanical and muscle strength adaptations due to long-term participation in overhead sport**

In overhead athletes, many biomechanical adaptations, such as a forward head posture, rounded or forward shoulders, anterior humeral head translation, scapular protraction, tightness in the posterior capsule, and alterations in shoulder rotation ROM, have previously been linked to shoulder instability (Kennedy *et al.*, 2009:159). Functional shoulder instability has been defined as the clinical situation in which the pathology does not allow the humeral head to move excessively relative to the confines of the glenoid fossa, or to pass over the rim as in a subluxation or dislocation (Cools *et al.*, 2004:64). Superior humeral head migration is the result from the inability of the rotator cuff to maintain the alignment of the humeral head with the glenoid cavity centre, thus allowing it to translate superiorly, reducing the subacromial space (Chopp *et al.*, 2011:44).

### 2.2.1 Postural adaptations

The upper-body posture of an overhead athlete is characterised by a protracted and anteriorly tipped scapula position with increased rounded shoulders and a forward-head position (Thigpen *et al.*, 2010:706). The cause of a forward-shoulder posture is multifactorial. A factor that can contribute to forward-shoulder posture is tightness of the pectoralis minor muscle. When an athlete has a forward-head posture with thoracic kyphosis, the shoulder has excessive anterior orientation of the humeral head relative to the vertical plumb line of the body. This causes the scapula not to function normally in its scapular plane and the humerus is medially rotated. Muscle imbalance develops, with shortening of the anterior muscles and lengthening and weakness of the posterior muscles. Maintaining a posture with the shoulders and head forward for along time causes secondary weakness of the scapular retractors and shoulder lateral rotators and tightness of the scapular protractors and shoulder medial rotators (Weon *et al.*, 2010:368; Houglum, 2010:600). Thigpen *et al.* (2010:707) found that the lower trapezius muscles are deactivated during glenohumeral ER and abduction in individuals presenting with a forward-head-rounded-shoulder posture, and the upper trapezius muscle then becomes over-activated. An added result of this posture is less serratus anterior activity with notably greater scapular IR during the ascending phase of overhead tasks (Thigpen *et al.*, 2010:707).

### 2.2.2 Range of motion adaptations

It is well recognised that overhead athletes normally develop ROM adaptations to their sports, implying increased external shoulder rotation and loss of internal shoulder rotation with posterior capsular tightness presenting as a glenohumeral IR deficit compared to the non-dominant arm (Houglum, 2010:601). Increases in glenohumeral ER are associated with the repetitive stretching of the anterior capsule and acquired tight posterior capsule. Increased protraction or decreased upward rotation have also been identified in the scapular motion of athletes and may be defined as scapular dyskinesis, which is an observable alteration in the position of the scapula and the patterns of scapular motion in relation to those of the thoracic cage (Houglum, 2010:601; Thomas *et al.*, 2009:230).

### 2.2.3 Muscle strength adaptations

Scapular stabilisers have been shown to have an abnormal activation pattern during overhead motion. The serratus anterior and lower trapezius both show delayed onset. Lower ER:IR strength ratios have been reported in the asymptomatic throwing shoulder than in the non-throwing shoulder. This difference in ER:IR strength ratios results from the presence of greater dominant limb internal rotators without a similar dominance effect in the external rotators (Hurd *et al.*, 2011:293). When force couples do not work cooperatively or display differences in strength ratios, injury may be the result (Stuelcken *et al.*, 2008:579). It has been hypothesised that the combination of abduction and ER of the upper arm overloads the static and dynamic stabilisers of the shoulder joint (Houglum, 2010:592). Balanced force production between protractors and retractors is a necessity, but not the sole condition for muscle balance. In addition, balanced muscle activity among the three trapezius muscles are necessary for scapular stability. Moreover, balanced timing of muscle recruitment among the scapular muscles is a crucial component of dynamic stability of the scapula throughout arm movement (Cools *et al.*, 2003:543). If the anterior wall muscles of the shoulder (muscles that form support for the anterior capsule: the subscapularis, pectoralis major, latissimus dorsi and teres major) are weak, fatigued, or injured, the anterior capsule becomes stretched, and can lead to the humeral head to subluxes anteriorly (Jobe & Pink, 1993:427-428). The shoulder rotators become fatigued in the same way during concentric and eccentric muscle actions (Dale *et al.*, 2007:79). The scapula is stabilised by the serratus anterior and trapezius muscles against the posterior chest wall. If the trapezius or serratus anterior muscles are weak and imbalanced, scapular winging may be present (Shultz *et al.*, 2010:240). These imbalances result in scapular instability, increasing the risk of shoulder problems (Cools *et al.*, 2005:104).

Ellenbecker and Roetert (2003:67) identified significantly greater dominant arm glenohumeral IR strength, with no bilateral difference in ER strength. The recommended ER/IR ratio typically ranges between 66-75%, such that the external rotators are at least two thirds the strength of the internal rotators, to provide muscular balance (Ellenbecker & Roetert, 2003:68).

## **2.3 INJURIES OCCURRING DURING PARTICIPATION IN OVERHEAD SPORT**

Overhead throwing performance requires muscular strength and endurance, flexibility and neuromuscular control. If any one of these factors is compromised, active repositioning in shoulder ER is significantly altered when the muscle mechanoreceptors are dysfunctional because of muscular fatigue (Lee *et al.*, 2003:846). Understanding the pathology in the young overhead athlete has led to the concept of an instability continuum: imbalanced muscle ratios lead to instability of the shoulder, which in turn leads to subluxation. Impingement follows and can eventually lead to rotator cuff tears (Shultz *et al.*, 2010:234).

### **2.3.1 Shoulder impingement**

The shoulder is significantly stressed, especially during distinct phases of the throwing motion in overhead athletes. During the throwing motion, enormous stress is put on the dynamic as well as the static stabilisers of the shoulder. These repetitive forces cause adaptive soft tissue changes, which lead to shoulder pathologies (Kirchhoff & Imhoff, 2010:1056). Athletes participating in sport requiring abduction and ER, such as tennis, volleyball, javelin throwing and swimming, are at risk. It has been suggested that internal shoulder impingement is most likely caused by fatigue of the muscles of the shoulder girdle resulting from lack of conditioning. As the shoulder girdle muscles become fatigued, the humerus drifts out of the scapular plane, which can lead to stressing of the anterior aspect of the capsule in overhead actions. Loss of integrity of the anterior capsule may compromise the posterior rollback of the humeral head, leading to an anterior translation (Braun *et al.*, 1995:974). Impingement is caused by encroachment in the subacromial space in which the supraspinatus passes underneath the sub-acromial arch caused by repetitive overhead motions (Shultz *et al.*, 2010:234). Repetitive actions place the shoulder in vulnerable positions, possibly leading to impingement syndrome. Shoulder impingement syndrome has been classified as primary or secondary. Primary impingement refers to mechanical encroachment into the subacromial space by the humeral head. The subscapularis tendon impinges between the anterior humeral head and the anterosuperior labrum during forward flexion of the arm (Kirchhoff & Imhoff, 2010:1051). Secondary impingement results from encroachment due to glenohumeral instability (Shultz *et al.*, 2010:234). Insufficient elevation of the scapula narrows the subacromial arch and decreases the rotator cuff clearance

under the acromion (Seroyer *et al.*, 2009:112). The symptoms of secondary impingement syndrome are thought to be a result of anterior shoulder instability that leads to subluxation, posterior capsule tightness and scapulothoracic muscle weakness. Functional instability in the shoulder may be one of the causes leading to a vicious circle involving microtrauma and secondary impingement, and may eventually lead to chronic shoulder pain. Weakness in one or more scapular rotators may cause muscular imbalance in the force couples around the scapula, leading to abnormal kinematics and an altered throwing technique (Webster *et al.*, 2009:8). Scapulothoracic dysfunction is often seen in patients with shoulder problems. Alterations of shoulder kinematics include weakness of rotator cuff muscles, changes in scapulothoracic rhythm, glenohumeral instability and capsular tightness (Michener *et al.*, 2003:372). 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. Malposition of the scapula for any given arm configuration may also influence the instantaneous centre of shoulder rotation, which can significantly alter moments of force generation around the shoulder (McQuade *et al.*, 1998:79).

Posterior impingement in the throwing shoulder is caused by over-rotation into hyper-ER during the throwing motion. Micro-instability develops, with corresponding posterior capsular hypertrophy, leading to increased ER and reduced IR (Kirchhoff & Imhoff, 2010:1050). Overhead athletes are inclined to sustain posterior impingement through a tight posterior capsule that may lead to increased protraction and inferior positioning of the scapula during throwing. It appears that the humeral head is pinching the supraspinatus and infraspinatus into the posterosuperior labrum. Patients demonstrate instability with impingement secondary to the microtrauma that comes from overuse (Jobe & Pink, 1993:431; Shultz *et al.*, 2010:234).

### 2.3.2 Rotator cuff injuries

The rotator cuff muscles are among the most commonly injured muscles in the shoulder girdle. An overhead athlete can be significantly disabled by a rotator cuff injury and these muscles are prone to overuse (Shultz *et al.*, 2010:232). The four muscles of the rotator cuff are positioned so that they surround the anterior, superior and posterior aspects of the glenohumeral joint of the shoulder girdle. The muscles are separate in their respective fossa of the scapula. However, their tendons unite with one another and the capsule of the glenohumeral joint as they approach their insertion sites on the humerus, forming a cuff around the humeral head (Blevins, 1997:206). An acute rotator cuff injury results from decreased ROM and loss of strength. Repetitive forceful contraction of the muscles during the deceleration phase of throwing can eccentrically injure the supraspinatus and infraspinatus (Shultz *et al.*, 2010:232). Fatigue of the shoulder muscles may result in changed throwing mechanics, increasing demands on the cuff. This can eventually result in a vicious cycle of cuff pathology: as stresses on the cuff increase to the point where it is unable to keep the head centred in the glenoid, increased anterior and superior translation occurs, resulting in impingement (Blevins, 1997:208).

### 2.3.3 Shoulder dislocation and subluxations

The shoulder structures must maintain a delicate balance between adequate laxity to achieve extreme ROM and sufficient stability to inhibit subluxation and instability (Seroyer *et al.*, 2009:108). The throwing motion moves the arm through a rapid glenohumeral motion, coupled with large compressive and distractive forces imparted to the joint that place the shoulder at risk of injury (Seroyer *et al.*, 2009:118). Subluxation occurs from chronic shoulder instability. In overhead athletes, the imbalanced force couples are a major contributor to instability in the shoulder girdle (Shultz *et al.*, 2010:237). Patients have an increased scapular protraction, and simultaneous humeral head migration away from the centre of the joint as the arm moves. This position allows the humeral head to translate inferiorly out of the glenoid socket creating the instability (Kibler *et al.*, 2013:4). Anterior instability is the root problem in the painful shoulder in an overhead athlete. Pseudolaxity is consistent with the circle concept of the periarticular labral fibres acting together as a unit, such that a disruption of one area of the labrum may manifest as apparent laxity elsewhere along the labral ring (Parten & Burkhart, 2002:12). Glenohumeral dislocations occur most often anteriorly and inferiorly. The dislocation causes an

avulsion of the anterior-inferior labrum and ligamentous restraints and deformation of the anterior capsule. In some instances, subscapularis tearing occurs. Extension of the abducted, externally rotated arm is the most frequent mechanism for anterior dislocations. Anterior instability commonly produces posterior shoulder pain. Posterior dislocations caused by trauma are less common and usually occur from a fall onto the flexed, adducted, and internally rotated arm (Owens & Itamura, 2000:254).

#### 2.3.4 Labrum tears

The glenoid labrum is composed of fibrocartilagenous tissue. The labrum serves as an anchor point for the capsuloligamentous structures and adds stability to the shoulder by deepening the glenoid fossa (Dutchshen *et al.*, 2007:96). Labral tears are usually associated with glenohumeral instability and can result from dislocation or chronic instability. Repetitive overhead arm motion as performed by throwers and swimmers can also disrupt the labrum, particularly in the superior region (Chang *et al.*, 2008:73). The disruption of the labrum is referred to as a superior labrum from anterior to posterior (SLAP) lesion. This condition causes inability to throw with pre-injury velocity, and lack of control is caused by a combination of pain and subjective unease in the shoulder, which is extremely disabling and potentially career-ending to the overhead athlete (Burkhart& Morgan, 2000:213).

## 2.4 SHOULDER MUSCLE STRENGTH TESTING AND RATIOS

Muscle strength is commonly assessed and reassessed for diagnostic purposes and for assessing the outcome of therapeutic interventions and rehabilitation. Three methods applied for performing muscle strength assessment are manual muscle testing, hand-held dynamometry and isokinetic dynamometry (Land & Gordon, 2011:231). Isokinetic dynamometers enable measurement of muscle torque production during the performance of a constant-velocity movement (Land & Gordon, 2011:231-232). Isokinetic testing of the shoulder has become popular for several reasons: firstly, it is capable of performing eccentric and concentric work and of collecting data regarding power (peak torque), work and endurance of the shoulder. Secondly, it is a safe and reliable instrument to use on athletes. Lastly, it allows the opportunity for documenting progression (Davies, 1992:391). Isokinetic testing is an accurate quantitative measurement of muscle performance that tests at fixed angular velocity. The most frequently

used isokinetic variable is peak torque (PT, unit Nm) which correlates well with the strength of the muscle (Lertwanich *et al.*, 2006:948).

Data interpretation is done by applying three parameters: 1) Bilateral comparison, 2) unilateral comparison (agonist and antagonist) and 3) torque to body weight ratios (Davies, 1992:392). Evaluating the relative strength and/or unilateral muscle strength ratio (i.e., concentric external rotators/internal rotators ratio) will help to direct the emphasis in the rehabilitation exercise program (Ellenbecker & Davies, 2000:338).

#### 2.4.1 Muscle strength

A proper balance between agonist and antagonist muscle groups is thought to provide dynamic stabilisation to the shoulder joint. Previous studies have proposed that an adequate ER:IR strength ratio can be a useful tool for identifying shoulder imbalance in athletes (Gabriel & Wong, 2008:575). It is recommended to create a posterior-dominant shoulder in athletes with anterior-inferior glenohumeral joint instability to produce an ER:IR ratio of two thirds of external rotators' strength compared to that of the internal rotators (Ellenbecker & Davies, 2000:342). When normal individuals are evaluated, imbalances in unilateral strength of less than 10% can be regarded as normal, a difference of 10-20% as possibly abnormal, and those greater than 20% as probably abnormal. When one extremity is clearly expected to be weaker, on the basis of previous injury or disuse, differences of 10-20% can be considered probably abnormal and those of more than 20% almost certainly abnormal. The commonly used criterion of 80-90% of the measured capability in the uninvolved extremity can be used as a minimum standard for the involved extremity before the patient returns to sport or strenuous work after injury (Lertwanich *et al.*, 2006:948-949).

One rather consistent finding during the examination of the overhead athlete is increased dominant arm ERROM (defined or referred to as ER gain) as well as reduced dominant arm glenohumeral joint IRROM (Ellenbecker *et al.*, 2002:2054). The ER strength of a pitcher's throwing shoulder shows no significant weakness or equal strength compared to the non-throwing shoulder. Contrary to this, the IR strength of the throwing shoulder is significantly stronger than that of the non-throwing shoulder. Muscular imbalances in the rotator cuff and

scapular musculature, coupled with inadequate muscular endurance and improper biomechanics can lead to over-use injury in the glenohumeral joint of professional athletes (Donatelli *et al.*, 2000:549).

The scapular muscles play a vital role during the overhead throwing motion. These muscles work in a synchronised fashion and act as force couples around the scapula, providing both movement and stabilisation. Wilk *et al.*(1999:82) documented the isometric scapular muscle strength values of professional baseball players. The results indicated significantly different strength increases of the protractor and elevator muscles of the scapula in pitchers and catchers when compared with position baseball players. All players (except infielders) exhibited significantly stronger depressor muscles of the scapula on the throwing side compared to the non-throwing side (Wilk, 2002:138). Balance of agonist-antagonist muscular strength in the shoulder muscles surrounding the glenohumeral joint is a vital resource in the rehabilitation and prevention of shoulder injuries (Ellenbecker & Davies, 2000:338).

## **2.5 SOLVING ADAPTATIONS IN OVERHEAD ATHLETES**

It is clear from literature that prolonged participation in overhead sports is likely to cause postural, biomechanical and muscle strength adaptations. Various authors and researchers found that adaptations need to be addressed to prevent related injuries (Kennedy *et al.*, 2009:159; Reinold *et al.*, 2009:114). Overhead sports showed a lower rate of return to sport after injury than other sport (van der Hoeven & Kibler, 2006:438). The main reason is that the overhead action is an abnormal, complex motion at the physiological limits of the shoulder (Van der Hoeven & Kibler, 2006:439-440). It appears that the recruitment order of the scapula-stabilising muscles (serratus anterior, upper, middle and lower trapezius) may be important for overhead athletes to maintain healthy shoulder function as well as to analyse muscular imbalance of the rotator cuff (Moraes *et al.*, 2008:48). The isokinetic shoulder-muscle strength and ratios indicated a possible deficiency with regard to external rotators' strength in the dominant shoulder, possibly manifested in an unsatisfactory antagonist/agonist shoulder rotation ratio. The thoracic posture of the participants presents an inappropriate ROM. Identifying these musculoskeletal weaknesses may make it possible to rectify them pro-actively with pre-habilitation (Bolton *et al.*, 2013:17).

Intervention at an early stage of adaptations can alter the natural course of the disorder and may prevent the development of serious intra-articular injury (van der Hoeven & Kibler, 2006:440). The scapula plays a vital role in athletes' shoulder function. A thorough rehabilitation programme for shoulder injuries should include the prescription of flexibility or ROM exercises, scapula-stabilisation exercises, rotator-cuff exercises, and sport-specific training including plyometrics (Brumitt, 2006:18). The physician must evaluate the thrower to establish a differential diagnosis, and then the physical therapist or athletic trainer must evaluate the thrower to establish a list of physical limitations or problems that may be contributing to or resulting from the disorder. The rehabilitation specialist must evaluate ROM, muscle strength, laxity and proprioception. In addition, the rehabilitation specialist should address the athlete's throwing programme, exercise schedule and throwing mechanics. Once these areas have been assessed, a comprehensive rehabilitation programme can be established (Wilk, 2002:146). A coordinated approach among trainers, therapists, and physicians is required for the comprehensive evaluation, diagnosis, and treatment of shoulder pain in the throwing athlete (Seroyer *et al.*, 2009:118).

Intervention studies focusing on correcting adaptations commonly seen in overhead athletes are scarce. Exercise interventions should aim at strengthening scapular stabilizers and stretching the anterior musculature (Lynch *et al.*, 2010:380). A six-week intervention study by Kluemper *et al.* (2006:66), including stretching of the anterior shoulder muscles and strengthening of the posterior shoulder muscles, resulted in decreased rounded shoulder posture, as well as improved posture, in an overhead sports population of swimmers. Few studies have investigated an intervention specific to the correction of forward head posture, although it has been indicated as an important factor in the development of several pathologies, such as shoulder injuries. Many of these studies suggest that forward head posture and rounded shoulder posture can improve, but have not examined whether changes occur in shoulder girdle muscle performance or clinical outcomes. Implementation of a posterior capsule stretch should form an integral part of flexibility programmes for the overhead athlete and should be integrated for both strength training and rehabilitation programmes (Lorenz, 2005:62). Lynch *et al.* (2010:376, 381) hypothesised that "the isometric strength of the scapular stabilizer muscles would improve following intervention". Lynch *et al.* (2010:381) stated that the exercise intervention used in their study improved posture in the course of the season in elite swimmers. The results of the

last-mentioned study suggest that preventive interventions aimed at improving postural deviations appear to improve posture and decrease the impact of shoulder pain (Lynch *et al.*, 2010:381).

Differences in internal shoulder rotation and external shoulder rotation strength ratios appear to be related to injury in most sports that demand overhead throwing, such as baseball, volleyball, cricket, tennis, and handball (Dale *et al.*, 2007:79; Ellenbecker & Roetert, 2003:69). Isokinetic testing is an accurate quantitative measurement of muscle performance that tests at fixed angular velocity of joint motions (Lertwanich *et al.*, 2006:948). Literature shows that biomechanical deficits do indeed respond to correct therapy and can result in decreased shoulder pain in the overhead athlete, which simultaneously prevents injuries (Kennedy *et al.*, 2009:154). Kibler *et al.* (2007:748) mentioned that intervention programmes that focus on activation of the muscles involved and endurance of these muscles in their activation phase should be considered for rehabilitation purposes. Further research can be performed by the clinician with a view to design appropriate rehabilitation and injury prevention programmes (Reinold *et al.*, 2009:114). Klumper *et al.* (2006:69) also stated the need for further study for an intervention programme in a season. Furthermore, during the evaluation process, the clinician can gain understanding of what is considered the 'normal' or acceptable physiologic characteristics of the overhead throwing population (Wilk, 2002:137).

## **2.6 CONCLUSION**

The glenohumeral joint allows a large ROM in all directions, therefore stability and support are due to stabiliser and mobiliser muscles (Shultz *et al.*, 2010:226-227). Static and dynamic structures of the shoulder must maintain stability and work in synchrony for controlled overhead motion in the shoulder girdle (Bolton *et al.*, 2013:16). Adequate force-couple strength is crucial for dynamic stability and optimal functioning.

Postural, biomechanical and strength adaptations, such as a forward-head posture, forward shoulders, humeral head translation, scapular protraction and alterations in rotational ROM have previously been linked to shoulder instability. Overhead throwing performance requires muscular strength and flexibility. Kinematic changes and postural adaptations in the overhead sporting population create glenohumeral instabilities, which have been linked to many injuries,

including shoulder impingement, rotator cuff tears and labral tears. These injuries can be acute or chronic. If these factors are compromised, functional instability occurs, performance diminishes and shoulder injuries are more likely to occur.

Identification of musculoskeletal weaknesses may make it possible to rectify them with pre-habilitation. Intervention at an early stage may prevent the development of serious injury. A six-week intervention study by Kluemper *et al.* (2006:66), which included stretching of the anterior shoulder muscles and strengthening of the posterior shoulder muscles, resulted in decreased rounded shoulder posture and decreased micro-tears in the rotator cuff muscles in an overhead swimming population.

Research on postural, biomechanical and muscle strength adaptations due to prolonged participation in cricket – an overhead sporting activity – is limited.

A limited amount of research has been performed on shoulder-stabilising intervention programmes in the interest of enhancing performance and preventing injury. This knowledge may assist in preventing injuries during training and game play by individualising each player's conditioning programme in the interest of promoting optimal functioning.

## REFERENCES

- Alderink, G. & Kuck, D. 1986. Isokinetic shoulder strength of high school and college-aged pitchers. *Journal of orthopedics sports physiotherapy*, 7:163–172.
- Blevins, F.T. 1997. Rotator cuff pathology in athletes. *Sports medicine*, 24(3):205-220.
- Bolton, G., Moss, S.J., Sparks, M. & Venter, P.C. 2013. Thoracic posture, shoulder muscle activation patterns and isokinetic strength of semi-professional rugby union players. *South African journal of sports medicine*, 25(1):12-17.
- Braun, S., Kokmeyer, D. & Millett, P.J. 2009. Shoulder injuries in the throwing athlete. *The Journal of bone and joint surgery*, 91:966-978.
- Brumitt, J. 2006. Scapular-stabilization exercises: early-intervention prescription. *Athletic therapy today*, 11(5):15-18.
- Burkhart, S.S. & Morgan, C. 2000. Slap lesions in the overhead athlete. *Operative techniques in sports medicine*, 8(3):213-220.
- Chang, D., Mohana-Borges, A., Borso, M. & Chung, C.B. 2008. SLAP lesions: anatomy, clinical presentation, MR imaging diagnosis and characterization. *European journal of radiology*, 68:72-87.
- Chopp, J.N., Fischer, S.L. & Dickerson, C.R. 2011. The specificity of fatiguing protocols affects scapular orientation: implications for subacromial impingement. *Clinical biomechanics*, 26:40-45.
- Cole, A.K., McGrath, M.L., Harrington, S.E., Padua, D.A., Rucinski, T.J. & Prentice, W.E. 2013. Scapular bracing and alteration of posture and muscle activity in overhead athletes with poor posture. *Journal of athletic training*, 48(1):12-24.

Cools, A.M., Witvrouw, E.E., Declercq, G.A., Danneels, L.A. & Cambier, D.C. 2003. Scapular muscle recruitment pattern: trapezius muscle latency in overhead athletes with and without impingement symptoms. *American journal of sports medicine*, 31(4):542–549.

Cools, A.M., Witvrouw, E.E., Declercq, G.A., Vanderstraeten, G.G. & Cambier, D.C. 2004. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *Journal of sport medicine*, 38:64-68.

Cools, A.M., Witvrouw, E.E., Mahieu, N.N. & Danneels, L.A. 2005. Isokinetic scapular muscle performance in overhead athletes with and without impingement symptoms. *Journal of athletic training*, 40(2):104-110.

Cools, A.M., Declercq, G.A., Cambier, D.C., Mahieu, N.N. & Witvrouw, E.E. 2007. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scandinavian Journal of medicine & science in sport*, 17:25–33.

Copeland, S. 1993. Throwing injuries of the shoulder. *British journal of sports medicine*, 27(4):221-227.

Dale, R.B., Kovalski, J.E., Ogletree, T., Heitman, R.J. & Norrell, P.M. 2007. The effects of repetitive overhead throwing on shoulder rotator isokinetic work-fatigue. *North American journal of sports physical therapy*, 2(2):74-80.

Donatelli, R., Ellenbecker, T.S., Ekedahl, S.R., Wilkes, J.S., Kocher, K. & Adam, J. 2000. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of orthopaedic & sports physical therapy*, 30(9):544-551.

David, G., Dvir, Z., Simmons, N., Magarey, M., Jones, M., Turker, K. & Sharpe, M. 2000. The relation between strength and width of the supraspinatus: an isokinetic and ultrasonographic study. *Isokinetics and exercise science*, 8:169-174.

Davies, G.J. 1992. A compendium of isokinetics in clinical usage and rehabilitation techniques. 4<sup>th</sup> ed. Wisconsin.

Downar, J.M. & Sauers, E.L. 2005. Clinical measures of shoulder mobility in the professional baseball player. *Journal of athletic training*, 40(1):23-29.

Dutchshen, N.T., Reinold, M.M. & Gill, T.J. 2007. Superior labrum anterior posterior lesions in the overhead athlete: current options for treatment. *Operative techniques in sport medicine*, 15:96-104.

Ellenbecker, T. & Davies, G. 2000. The application of isokinetics in testing and rehabilitation of the shoulder complex. *Journal of athletic training*, 35(3):338–350.

Ellenbecker, T.S. & Cools, A. 2010. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Journal of sports medicine*, 44:319–327.

Ellenbecker, T. & Roetert, E.P. 2003. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of science and medicine in sport*, 6(1):63-70.

Ellenbecker, T.S., Roetert, E.P. & Bailie, D.S. 2002. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Medicine & science in sport & exercise*, 34:2052–2056.

Erol, Ö., Özçakar, L. & Çeliker, R. 2008. Shoulder rotator strength in patients with stage I-II subacromial impingement: relationship to pain, disability, and quality of life. *Journal of shoulder and elbow surgery*, 17(6):893-897.

Escamilla, R.F. & Andrews, J.R. 2009. Shoulder muscle recruitment patterns and related biomechanics during upper extremity sports. *Sports medicine*, 39(7):569-590.

Gabriel, N.G. & Wong, E. 2008. Isokinetic work profile of shoulder flexors and extensors in sport climbers and nonclimbers. *Journal of orthopaedic & sports physical therapy*, 38:572–577.

Hadzic, V., Ursej, E., Kalc, M. & Dervisevic, E. 2012. Reproducibility of shoulder short range of motion in isokinetic and isometric strength testing. *Department of Sports Medicine*, 10:83-89.

Houglum, P.A. 2010. Therapeutic exercise for musculoskeletal injuries. 3<sup>rd</sup> ed.

Hurd, W.J., Kaplan, K.M., E. Attrache, N.S., Jobe, F.W., Morrey, B.F. & Kaufman, K.R. 2011. A profile of glenohumeral internal and external rotation motion in the uninjured high school baseball pitcher, part II: strength. *Journal of athletic training*, 46(3):289-295.

Jobe, F.W. & Pink, M. 1993. Classification and treatment of shoulder dysfunction in the overhead athlete. *Journal of orthopaedic & sports physical therapy*, 18(2):427-432.

Kennedy, D.J., Visco, C.J. & Press, J. 2009. Current concepts for shoulder training in the overhead athlete. *Journal of sport medicine*, 3(8):154-160.

Kibler, W.B., Chandler, T.J., Shapiro, R. & Conuel, M. 2007. Muscle activation in coupled scapulohumeral motions in the high performance tennis serve. *British journal of sports medicine*, 41:745-749.

Kibler, W.B., Ludewig, P.M., McClure, P.W., Michener, L.A., Bak, K. & Sciascia, A.D. 2013. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the ‘scapular summit’. *British journal of sports medicine*, 00:1-12.

Kirchhoff, C. & Imhoff, A.B. 2010. Posterosuperior and anterosuperior impingement of the shoulder in overhead athletes-evolving concepts. *International orthopaedics*, 34:1049–1058.

Kluemper, M., Uhl, T. & Hazelrigg, H. 2006. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *Journal of sport rehabilitation*, 15:58-70.

Land, H. & Gordon, S. 2011. What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinetics and exercise science*, 19:231-241.

Lee, H.M., Liao, J.J., Cheng, C.K., Tan, C.M. & Shih, J.T. 2003. Evaluation of shoulder proprioception following muscle fatigue. *Clinical biomechanics*, 18:843-847.

Lertwanich, P., Lamsam, C. & Kulthanan, T. 2006. Difference in isokinetic strength of the muscles around dominant and non-dominant shoulders. *Journal of medicine association Thailand*, 7(89):948-952.

Lorenz, D.S. 2005. The importance of the posterior capsule of the shoulder in overhead athletes. *Strength and conditioning journal*, 4(27):60-62.

Lynch, S.S., Thigpen, C.A., Mihalik, J.P., Prentice, W.E. & Padua, D. 2010. The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers. *Sports medicine*, 44:376–381.

Magarey, M.E. & Jones, M.A. 2003. Dynamic evaluation and early management of altered motor control around the shoulder complex. *Manual therapy*, 8:195-206.

Magee, D.J. 2008. Orthopaedic physical assessment. 5<sup>th</sup> ed. Philadelphia: Saunders.

McQuade, K.J., Dawson, J. & Smidt, G.L. 1998. Scapulothoracic muscle fatigue associated with alterations in scapulohumeral rhythm kinematics during maximum resistive shoulder elevation. *Journal of orthopaedic & sports physical therapy*, 28:74–80.

Michener, L.A., McClure, P.W. & Karduna, A.R. 2003. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clinical biomechanics*, 18:369–379.

Moraes, G.F.S., Faria, C.D.C.M. & Teixeira-Salmela, L.F. 2008. Scapular muscle recruitment patterns and isokinetic strength ratios of the shoulder rotator muscles in individuals with and without impingement syndrome. *Journal of shoulder and elbow surgery*, 17(1):48-53.

Owens, S. & Itamura, J.M. 2000. Differential diagnosis of shoulder injuries in sports. *Operative techniques in sports medicine*, 8(4):253-257.

Parten, P.M. & Burkhart, S.S. 2002. The relationship of superior labral anteroposterior (SLAP) lesions and pseudolaxity to shoulder injuries in the overhead athlete. *Operative techniques in sports medicine*, 10(1):10-17.

Reinold, M.M., Escamilla, R. & Wilk, K.E. 2009. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *Journal of orthopaedic & sports physical therapy*, 39(2):105-117.

Seroyer, S.T., Nho, S.J., Bach, B.R., Bush-Joseph, C.A., Nicholson, G.P. & Romeo, A.A. 2009. Shoulder pain in the overhead throwing athlete. *American orthopaedic society for sports medicine*, 1(2):108-120.

Shultz, S.J., Houglum, P.A. & Perrin, D.H. 2010. Examination of musculoskeletal injuries. 3<sup>rd</sup>ed. USA: Human Kinetics.

Stuelcken, M.C., Karen A., Ginn, K.A. & Sinclair, P.J. 2008. Shoulder strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain. *Journal of science and medicine in sport*, 11:575-580.

Thomas, S.J., Swanik, K.A., Swanik, C. & Huxel, K.C. 2009. Glenohumeral rotation and scapular position adaptations after a single high school female sports season. *Journal of athletic training*, 44(3):230-237.

Thigpen, C.A., Padua, D.A., Michener, L.A., Guskiewicz, K., Giuliani, C., Keener, J.D. & Stergiou, N. 2010. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *Journal of electromyography and kinesiology*, 20:701-709.

Van der Hoeven, H. & Kibler, W.B. 2006. Shoulder injuries in tennis players. *British journal of sports medicine*, 40:435-440.

Webster, M.J., Morris, M.E. & Galna, B. 2009. Shoulder pain in water polo: a systematic review of the literature. *Journal of science and medicine in sport*, 12:3-11.

Weon, J., Oh, J., Cynn, H., Kim, Y., Kwon, O. & Yi, C. 2010. Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. *Journal of bodywork & movement therapies*, 14:367-374.

Wilk, K.E., Suarez, K. & Reed, J. 1999. Scapular muscular strength values in professional baseball players [abstract]. *Physical therapy*, 79:81-82.

Wilk, K.E., Meister, K. & Andrews, J.R. 2002. Current concepts in the rehabilitation of the overhead throwing athlete. *The American journal of sports medicine*, 30(1):136-151.

## CHAPTER 3

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# THE RELATIONSHIP BETWEEN BILATERAL SCAPULAR POSITION, SHOULDER RANGE OF MOTION AND SELECTED MUSCLE STRENGTH CHARACTERISTICS IN CRICKETERS

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## ABSTRACT

**Background:** Participation in overhead sports causes adaptations in upper body posture, which may alter shoulder girdle biomechanics and strength.

**Objectives:** To identify possible asymmetries in glenohumeral range of motion (ROM) and isokinetic rotation muscle strength of university level cricket players and the relation with scapula protraction.

**Method:** A cross-section of university male cricket players (n=45) voluntarily participated in this study. Scapula protraction was measured by means of the wall-to-acromion test and shoulder internal rotation (IR) and external rotation (ER) ROM with a goniometer. The Biodex<sup>®</sup> (System 4) was used to test the isokinetic concentric internal and external shoulder rotation muscle peak torque.

**Results:** The dominant shoulder of the cricketers was 1.10 cm more protracted ( $p \leq 0.001$ ) compared to the non-dominant shoulder (IR) ROM ( $13.38^\circ$ ,  $p \leq 0.001$ ) and more ER ROM ( $10.16^\circ$ ,  $p \leq 0.001$ ) than the non-dominant side. IR and ER average concentric peak torques were significantly higher in the dominant shoulder ( $p \leq 0.001$  and  $p = 0.002$ , respectively). Significant associations with scapula protraction were only observed on the dominant side, with shoulder ER ROM indicating a significantly negative association ( $r = -0.3$ ,  $p = 0.05$ ), and shoulder IR average peak torque a significantly positive association ( $r = 0.3$ ,  $p = 0.05$ ).

**Conclusion:** The cricket players in this study presented with asymmetry in scapula protraction shoulder ROM and shoulder muscle peak torque. Associations in the dominant shoulder indicated that the stronger the shoulder internal rotators, the more protracted the scapula and the less the ER ROM.

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### 3.1 INTRODUCTION

Cricket players perform unilateral overhead skills such as bowling and throwing, and both actions produce high loads at the shoulder girdle.<sup>[1,2]</sup> Overhead sports such as cricket, tennis, swimming and baseball have identified certain adaptive aspects in the dominant arm.<sup>[3]</sup> Kennedy<sup>[4]</sup> found that overhead athletes show a more protracted scapula on the dominant side than on the non-dominant side of baseball players. According to Thomas,<sup>[5]</sup> the throwing arm in baseball players has a decreased glenohumeral internal rotation (IR) range of motion (ROM) and an increased external rotation (ER) ROM. The external rotators of the dominant side are often weak in relation to those of the non-dominant side.<sup>[6]</sup> The forward shoulder posture or scapular protraction has been identified as a result of stronger internal rotators and weaker external rotators in professional swimmers.<sup>[7,8]</sup> Strength and biomechanical adaptations in overhead athletes, such as forward head posture, rounded or forward shoulders, anterior humeral head translation, scapular protraction, tightness in the posterior capsule as well as alterations in rotational ROM and rotational muscle strength have previously been linked to shoulder injuries.<sup>[4,9,10]</sup>

Overhead-throwing performance requires muscular strength and endurance, flexibility and neuromuscular control. If any one of these factors is compromised, functional instability occurs, performance diminishes and shoulder injuries are more likely to occur.<sup>[11]</sup> It is therefore important to determine the bilateral adaptations to ensure that the correct injury prevention strategies are implemented. Therefore the objectives of this study were firstly to determine the bilateral differences in scapula protraction, shoulder rotational ROM and isokinetic shoulder rotational muscle strength characteristics of cricket players. Secondly, the relationship between scapula protraction and shoulder rotational ROM, as well as isokinetic rotational muscle strength characteristics in cricket players, were determined. The results of this study may contribute to scientific knowledge of postural and shoulder strength adaptations in cricket players. Identifying areas of asymmetry in the shoulder girdle of overhead athletes would ensure exercise modalities are added to conditioning programmes to prevent injuries previously linked to adaptive changes.

## **3.2 METHOD**

### **3.2.1 Study design and participants**

This study formed part of the *Overhead Sport Injury Prevention Project* conducted at the North-West University (NWU - Potchefstroom campus). Ethical approval was obtained from the ethics committee of NWU (NWU-00026-12-S1). Male cricket players from the NWU cricket squad were recruited in October 2012 and attended one educational session on upper body postural, biomechanical and strength adaptations due to prolonged participation in overhead sports and the role of these in shoulder instabilities and injury. Coaches and players were thoroughly informed regarding the testing procedures to be used in this project. A detailed informed consent form was completed by each cricket player who volunteered to participate in the study (n=49). Only players  $\geq 17$  and  $\leq 25$  years, who did not suffer from any current orthopaedic condition or injury or who was not rehabilitating from any orthopaedic injury at commencement of the study were eligible for inclusion. Two of the original 49 players were excluded because of asymptomatic shoulder pathology detected by ultrasound imaging prior to baseline testing and another two were excluded as they were part of the coaching staff and could therefore not be included as competing players. Therefore, the final sample of this observational sub-study of the Overhead Sports Injury Prevention Project (for data collection in 2013) comprised 45 male cricket players.

### **3.2.2 Measurements and equipment**

The test protocol comprised a demographic and injury history questionnaire (used for the exclusion criteria), anthropometric assessment, scapula protraction measurement, shoulder rotation ROM and isokinetic shoulder rotational muscle strength testing. (The measurement procedures, as well as equipment used, are thoroughly explained below).

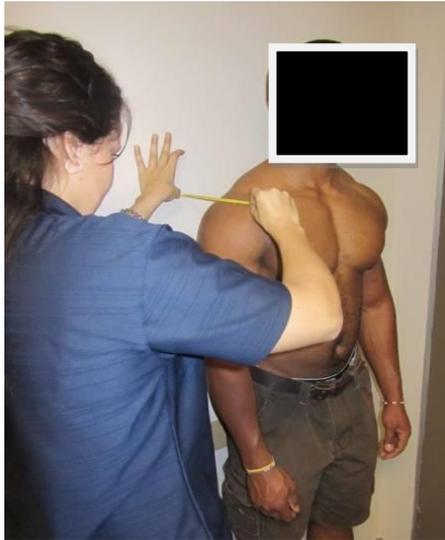
#### **Anthropometric measurement**

Stature was measured with a stadiometer to the nearest 0.1 cm, with shoes removed and head held in the Frankfort plane, while body mass was determined using an electronic scale to the nearest 0.1 kg, with minimal clothing.<sup>[12]</sup>

#### **Scapula protraction (wall-to-acromion measurement)**

Scapula protraction was measured with the athlete standing with his back against the wall (posterior part of calcaneus touching the wall) and the upper body relaxed. A horizontal

measurement was then taken from the wall to the anterior acromion process to the nearest 0.1 cm.



**Figure 3.1: Wall-to-acromion measurement**

### **Range of motion**

The shoulder IR and ER ROM were measured using a goniometer. IR was measured to the nearest degree ( $^{\circ}$ ) with the athlete lying supine, the humerus abducted to  $90^{\circ}$ , and the elbow flexed to  $90^{\circ}$ . The participant was instructed to rotate the humerus internally and the measurement was taken at the point where the biokineticist observed scapular protraction to occur. ER was also measured in the supine position to the nearest degree ( $^{\circ}$ ), with the humerus abducted to  $90^{\circ}$  and the elbow flexed to  $90^{\circ}$ . The participant was instructed to rotate the humerus externally while keeping the lower back against the plinth.<sup>[19]</sup>

### **Isokinetic shoulder rotational muscle strength testing**

Isokinetic testing of the glenohumeral rotator muscles was conducted using a Biodex<sup>®</sup> System 4 (Biodex Corporation, Shirley, NY). Participants were seated during the test with appropriate stabilisation provided by an abdominal belt, crisscrossed chest straps, and a footrest in accordance with the Biodex Isokinetic Dynamometer manual. The chair of the Biodex<sup>®</sup> and the dynamometer attachment were individually adjusted to each participant to ensure proper fit and alignment and these settings were recorded from the numerical scale on the Biodex<sup>®</sup> apparatus and shoulder attachment. The humerus was placed in the glenohumeral neutral position ( $45^{\circ}$

flexion in the scapular plane) and the elbow joint was in 90° of flexion. The Biodex System 4 Isokinetic Dynamometer comes factory-calibrated and the maintenance calibration, as described in the manual (Biodex advantage software V.4X operation manual:29), was regularly performed in the practice setup. Gravity compensation or limb weight calibration was performed prior to each test. The participants were already warmed up when arriving at the isokinetic testing station, as electromyography recordings during standardised functional shoulder movements (not part of this study's variables) were performed prior to the isokinetic testing. Each participant was allowed a few familiarisation repetitions prior to the start of the isokinetic recordings. The concentric torque levels (Nm) of the shoulder complex were determined at speeds of 60°/sec and 180°/sec for IR and ER. Five repetitions were done of 60°/sec and 180°/sec with 30seconds of rest between each set of isokinetic measurements. The isokinetic variables were concentric IR and ER (Nm) for both the 60°/sec and 180°/sec.

### **3.2.3 Data collection procedure**

The participating cricket players completed an informed consent form and demographic information sheet, followed by a brief injury history questionnaire to ensure injured athletes were excluded. Ultrasound imaging was performed on both shoulders by a qualified radiographer prior to baseline testing to ensure asymptomatic shoulder pathology was detected and players in whom this was found were excluded. Baseline testing then commenced on all uninjured cricketers, starting with anthropometric measurements (body mass and stature) followed by shoulder rotational ROM (dominant and non-dominant IR and ER) and the wall-to-acromion measurement for scapula protraction. Lastly, shoulder rotation muscle strength characteristics were measured by means of the Biodex<sup>®</sup> isokinetic apparatus (tested concentric at 60°/second, as well as 180°/second).

### **3.2.4 Statistical analyses**

Statistical analyses were performed with the Statistica 12 computer software program (Statsoft Inc., 2014). Departure from normality was evaluated using the Shapiro-Wilk test and quantile-quantile plots, justifying the use of parametric statistical analysis methods. Dependent *t*-tests were used to determine the differences between the dominant and non-dominant sides for all parameters. One-sample *t*-tests were used to compare the shoulder rotational ROM values, as

well as the shoulder rotational strength ratios to normative data, for both the dominant and the non-dominant side. The relationships between scapula protraction and shoulder rotational ROM and isokinetic rotation muscle strength characteristics were described by means of Pearson correlation matrixes. Strong correlation was indicated by  $r \geq 0.5$ , medium strength correlation by  $r \geq 0.3$  or  $r < 0.5$  and low-strength correlation by  $r < 0.3$ . Statistical significance for all analyses was set at  $p \leq 0.05$ .<sup>[19]</sup>

### 3.3 RESULTS

Participant characteristics (Table 3.1) indicate that 31% of the cricketers were batsmen and 69% bowlers (medium/fast and spinners combined). The players' averages with regard to age, stature and body mass are listed in Table 3.1.

**Table 3.1 Descriptive characteristics of the study population (N=45)**

Variable	Mean ( $\pm$ SD)
Age (years)	20.6 ( $\pm$ 1.54)
Stature (m)	1.81 ( $\pm$ 0.07)
Body Mass (kg)	80.76 ( $\pm$ 10.80)
BMI (kg.m <sup>2</sup> )	24.68 ( $\pm$ 2.31)
Variable	n (%)
Batsmen	14 (31.11)
Bowlers (medium/fast)	18 (40)
Bowlers (spinners)	13 (28.89)

SD, Standard deviation; m, metre; kg, kilogram; BMI, body mass index;  $\pm$ SD, standard deviation; n. number of participants.

Table 3.2 indicates the bilateral differences observed for the selected parameters. The dominant shoulder was on average significantly more protracted, with significantly less IR ROM and significantly more ER ROM compared to the non-dominant shoulder. The isokinetic shoulder strength tests indicated that the average concentric peak torque (tested at 60°/sec) of both the internal and external rotators on the dominant side was statistically significantly stronger than that of the non-dominant side.

**Table3.2: Dependent T-tests indicating bilateral differences in scapula position, shoulder rotational range of motion and isokinetic concentric rotational muscle strength measures (n=45)**

Variable	Dominant Mean (±SD)	Non-dominant mean(±SD)	Difference Dominant versus non-dominant	Asymmetry significance (p-value)
Scapular protraction (cm)	13.76 (±2.04)	12.65 (±2.41)	1.10	≤0.001*
Shoulder IR ROM (°)	47.63 (±13.65)	61.01 (±13.67)	13.38	≤ 0.001*
Shoulder ER ROM (°)	110.87 (±9.95)	100.71 (±10.02)	10.16	≤ 0.001*
Shoulder IR average peak torque (Nm)	47.64 (±12.80)	41.46 (±11.29)	6.18	≤ 0.001*
Shoulder ER average peak torque (Nm)	33.35 (±7.13)	31.03 (±6.24)	2.32	0.002 <sup>#</sup>

\* Statistical significance (p≤0.001); # statistical significance (p≤0.05); ±SD, standard deviation; cm, centimetre; Nm, Newton meter; °, degrees; n, number of participants;

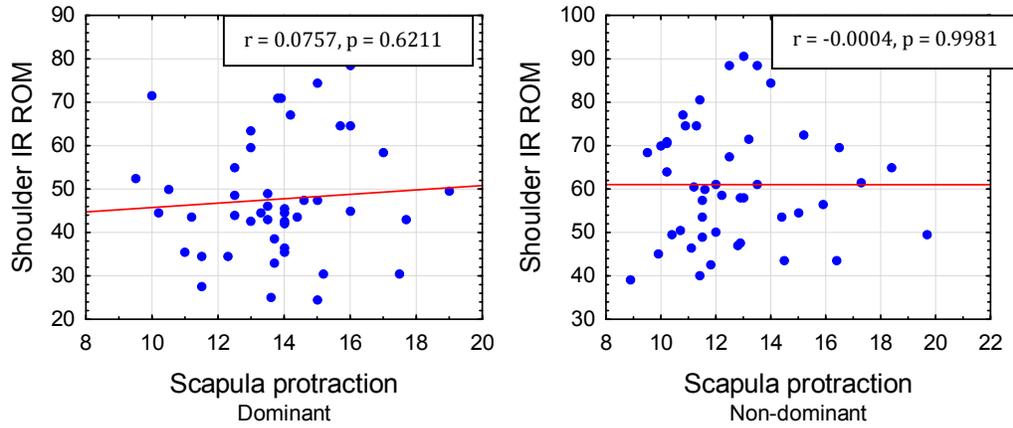
Table 3.3 shows the comparison of the shoulder rotation ROM, as well as the shoulder rotation strength ratios to normative values. In summary, Table 3.3 indicates that both the dominant and non-dominant shoulders of the cricketers presented with limited IR ROM and excessive ER ROM (if compared with the normative values). The IR, as well as the ER muscle strength peak torque tested weak in relation to the body weight on both the dominant and non-dominant sides, with the ER strength indicated as closer to the norm than the IR strength. The agonist-antagonist ratio was indicated as significantly higher than the norm in both shoulders. This finding agrees with the peak torque to body weight, which also indicated the IR peak torque as a bigger problem in this group of cricketers than the ER peak torque. The muscle endurance ratios tested at 180°/second indicated the same trends as the muscle strength ratios (tested at 60°/second). This was also true for IR and ER muscle endurance. The ER:IR ratio in the dominant and non-dominant shoulder was found to be more than the normative value. This trend was more pronounced in the dominant and non-dominant shoulders for both muscle strength and muscle endurance.

**Table 3.3: One-sample *t*-tests comparing bilateral shoulder rotational ROM and strength characteristics with normative data (n=45)**

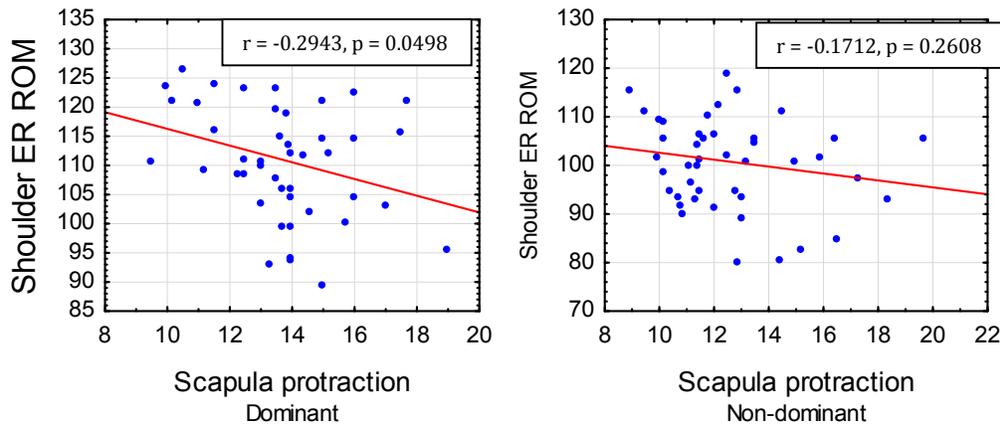
Variable	Norm	Dominant mean (± SD)	p-value	Non-dominant mean (± SD)	p-value
Shoulder IR	70	47.63 (±13.65)	≤0.001*	61.01 (±13.67)	≤0.001*
Shoulder ER (°)	80	110.87 (±9.95)	≤0.001*	100.02 (±10.02)	≤0.001*
<b>60 degrees</b>					
Shoulder IR pt/bw (%)	77.70	66.71 (±16.59)	≤ 0.001*	57.00 (±15.03)	≤0.001*
Shoulder ER pt/bw (%)	50.80	45.25 (±10.52)	0.002 <sup>#</sup>	41.80 (±10.94)	0.002 <sup>#</sup>
IR:ER ratio	64.00	69.40 (±13.33)	0.017 <sup>#</sup>	74.96 (±13.59)	0.017 <sup>#</sup>
<b>180 degrees</b>					
Shoulder IR pt/bw (%)	68.70	57.24 (±12.65)	≤ 0.001*	48.02 (±13.46)	≤ 0.001*
Shoulder ER pt/bw (%)	44.80	38.40 (±8.55)	≤ 0.001*	34.62 (±8.85)	≤ 0.001*
IR:ER ratio	66	68.34 (±12.24)	0.016 <sup>#</sup>	75.12 (±19.09)	0.016 <sup>#</sup>

\* Statistical significance ( $p \leq 0.001$ ); # statistical significance ( $p \leq 0.05$ ); ±SD-standard deviation; IR-internal rotation; ER- external rotation; pt/bw-peak torque per bodyweight; °, degrees; %, percentage.

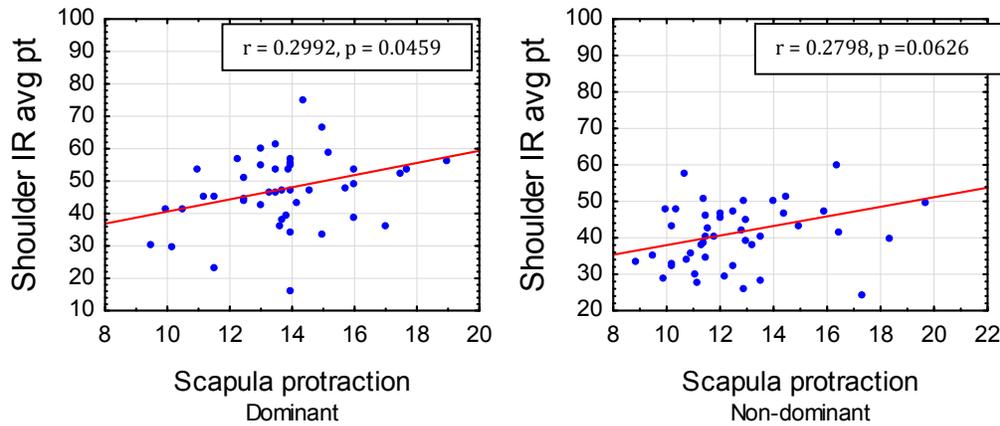
Figures 3.1-3.4 (a and b) below present the Pearson correlations, indicating the relation of scapula protraction with shoulder rotational ROM and rotational muscle strength in both the dominant and non-dominant shoulders. Scapula protraction only indicated a statistically significant negative correlation on the dominant side with shoulder ER ROM ( $r = -0.2943$ ,  $p = 0.0498$  - Fig. 2a), as well as a statistically significant positive correlation with shoulder IR average peak torque ( $r = 0.2992$ ,  $p = 0.0459$  - Fig. 3a). In other words, the stronger the average IR peak torque, the more protracted the scapula becomes, resulting in less glenohumeral ER ROM. Although statistically significant, both these correlations were only of moderate strength ( $r = 0.3$ ). The same trends were observed in the non-dominant shoulders; however, these were not statistically significant.



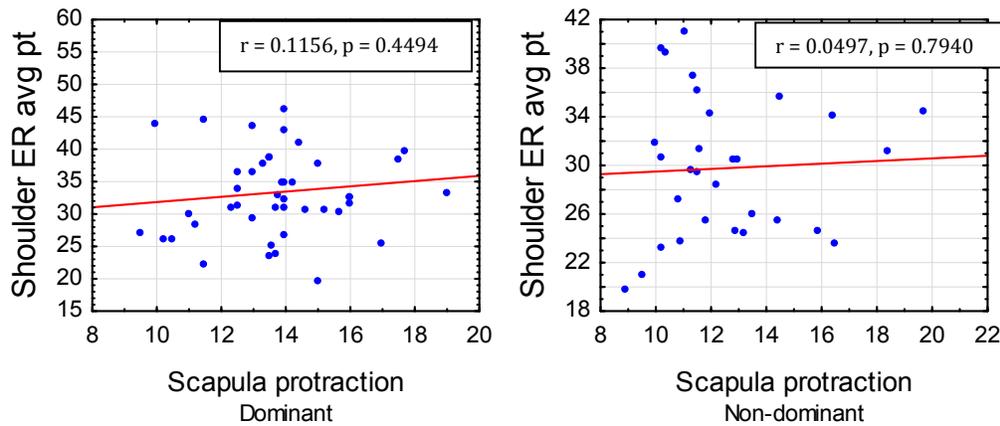
**Figure 3.2 (a and b):** Pearson correlation matrixes indicating the relationship between shoulder IR ROM and scapula protraction in both the dominant and non-dominant shoulders



**Figure 3.3 (a and b):** Pearson correlation matrixes indicating the relationship between shoulder ER ROM and scapula protraction in both the dominant and non-dominant shoulders



**Figure 3.4 (a and b):** Pearson correlation matrixes indicating the relationship between shoulder IR average peak torque and scapula protraction in both the dominant and non-dominant shoulder



**Figure 3.5 (a and b):** Pearson correlation matrixes indicating the relationship between shoulder ER average peak torque and scapula protraction in both the dominant and non-dominant shoulders

### 3.4 DISCUSSION

This study was aimed at determining whether semi-professional cricket players of the NWU (Potchefstroom campus) showed asymmetry in shoulder rotational ROM and isokinetic muscle strength characteristics. It also sought to determine the relationship of shoulder rotational ROM and isokinetic muscle strength characteristics with scapula protraction in university-level cricket players.

The findings of this study indicated that asymmetry in shoulder rotational ROM and isokinetic muscle strength characteristics does exist in semi-professional cricket players. The dominant

shoulder was indicated to be statistically significantly more protracted, with limited IR ROM and excessive ER ROM compared to the non-dominant sides. An overhead athlete is characterised by a protracted and anteriorly tipped scapula position.<sup>[1]</sup>Overhead athletes normally develop ROM adaptations due to their sports and show increased ER and loss of IR, presenting as a glenohumeral IR deficit compared to the non-dominant arm.<sup>[13]</sup>The cause of a forward shoulder posture is multifactorial. One factor that can contribute to forward shoulder posture is tightness of the pectoralis minor muscle. Clinically, the loss in IR ROM could indicate thickening of the posterior capsule due to the repetitive impingement of the capsule between the greater tubercle of the humerus and posterior edge of the glenoid rim during the late cocking phase of the overhead motion – thus the lower IR may be expected. Posterior impingement in the throwing shoulder is caused by over-rotation into a hyper-ER during the throwing motion. Micro-instability with corresponding posterior capsular hypertrophy develops, leading to increased ER and reduced IR.<sup>[14]</sup>Burkhart<sup>[15]</sup> suggested that the hypertrophied posterior capsule will result in the commonly seen loss of IR in overhead throwing athletes. Both the dominant and non-dominant shoulders indicated limited IR ROM and excessive ER ROM when compared with shoulder rotational ROM normative data.

Both the IR and ER average peak torque, was significantly stronger on the dominant shoulder. However, both the dominant and non-dominant shoulders' IR and ER peak torque tested weak in relation to the body weight. Hurd's<sup>[13]</sup> study found similar bilateral strength differences, including less ER strength and greater IR strength of the throwing shoulder compared to the non-throwing shoulder of baseball players. Lower ER:IR strength ratios have been reported in the asymptomatic throwing shoulder than in the non-throwing shoulder. These strength differences result from the presence of greater dominant-limb internal rotators without a similar dominance effect in the external rotators. Ellenbecker and Roetert<sup>3]</sup> also identified significantly greater dominant arm glenohumeral IR strength in junior elite tennis players.

There was a statistically significant negative correlation between scapula protraction and ER ROM in the current study. This is consistent with the study of Thomas,<sup>[5]</sup> which indicated that the more the scapula is protracted, the more the ER ROM increased and the IR ROM decreased in the shoulders of baseball players. Stuelcken<sup>[1]</sup> presented ROM differences in dominant and non-dominant shoulder profiles in elite female cricket players, which confirmed the findings of

this study. Common injuries among overhead players that may be explained by these adaptations include subacromial impingement syndrome, rotator cuff tears and superior SLAP lesions.<sup>[16,17]</sup> Although the results of this study also demonstrated a negative correlation between scapula protraction and glenohumeral IR ROM, the finding was not statistically significant.

Both the IR and ER average peak torque were significantly stronger on the dominant shoulder. However, both the dominant and non-dominant shoulder IR and ER peak torque tested weak in relation to the participants' body weight. The cricket players had greater ER strength in the dominant arm and exhibited a dominance effect in IR strength. However, statistical significance was found when the IR pt/bw as well as ER pt/bw were compared with the normative value for both muscle strength speeds (60°/second and 180°/second). The only statistical significance that was found in this study was in ER pt/bw in the 60°/second strength test. Stuelcken<sup>[1]</sup> only used female cricket players for the study, which could have had an impact on the strength characteristics of the shoulder. For all measurements of IR strength, the dominant shoulder was stronger than the non-dominant shoulder. These findings are consistent with the research of Sacco<sup>[18]</sup>, in which the dominant shoulder indicated that the internal rotator strength was greater than the external strength of the shoulder girdle in both male and female tennis players (a unilateral overhead sport). Stuelcken<sup>[1]</sup> studied tennis players (both male and female participants) and the principles of overhead athletes' shoulder anatomy and adaptations were similar to those of the current study.

### **3.5 CONCLUSION**

In conclusion, cricket players who participated regularly in the sport presented scapula protraction, which was more evident on the dominant side. The dominant shoulder of the cricketers was more protracted, with less IR ROM and more ER ROM than the non-dominant side. Scapula protraction showed statistically significantly negative associations with shoulder rotational ROM characteristics of NWU cricket players. Statistically significant associations with scapula protraction were only observed on the dominant side, with shoulder ER ROM indicating a significantly negative association, and shoulder IR average peak torque indicating a significantly positive association. The stronger the shoulder internal rotators, the more protracted the scapula and the less the external rotation ROM. All of these characteristics found are associated with overhead athletes' scapular posture. The dominant throwing arm showed

adaptations in the posture and strength aspects in contrast with the non-dominant throwing arm. Both IR and ER average concentric peak torque proved to be statistically significantly higher in the dominant shoulder.

The cricket players in this study presented with asymmetry in scapula protraction, shoulder rotational ROM and shoulder rotational muscle strength.

### **Limitations of the study**

There were limitations to this study. Research into specific sporting codes always limits the population's size, which in turn affects the significance of associations studied. Recruiting players from different squads could be a possible solution. However, researchers must ensure that conditioning regimes and training schedules are more or less similar, as this might influence study outcomes. A limited number of cricket players were available to participate in the study, as only players of the NWU squad were included. The reason for only including players from one squad was to ensure that conditioning regimes and the competition schedule were the same in both the experimental and control groups. The small sample size might, however, have affected detection of significant associations.

## REFERENCES

1. Stuelcken MC, Ginn KA, Sinclair PJ. Shoulder strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain. *Journal of Science and Medicine in Sport* 2008;11:575-580.
2. Elliott B, Fleisig G, Nicholls R, Escamilla R. Technique effects on upper limb loading in the tennis serve. *Journal of Science and Medicine in Sport* 2003;6(1):76-87.
3. Ellenbecker T, Roetert EP. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of Science and Medicine in Sport* 2003;6(1):63-70.
4. Kennedy DJ, Visco CJ, Press J. Current concepts for shoulder training in the overhead athlete. *Journal of Sport Medicine* 2009;3(8):154-160.
5. Thomas ST, Swanik C, Higginson JS, Kaminski TW, Swanik KA, Bartolozzi AR, Abboud JA, Nazarian LN. A bilateral comparison of posterior capsule thickness and its correlation with glenohumeral range of motion and scapular upward rotation in collegiate baseball players. *J Shoulder Elbow Surg* 2011;20:708-716. [DOI: 10.1016/j.jse.2010.08.031]
6. Malliou PC, Giannakopoulos K, Beneka AG, Gioftsidou A, Godolias G. Effective ways of restoring muscular imbalances of the rotator cuff muscle group: a comparative study of various training methods. *Br J Sport Med* 2004;38:766-772. [DOI:10.1136/bjism.2003.009548]
7. Kluemper M, Uhl T, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *J Sport Rehabil* 2006;15:58-70.
8. Smith J, Dietrich CT, Kotajarvi BR, Kaufman KR. The effect of scapular protraction on isometric shoulder rotation strength in normal subjects. *J Shoulder Elbow Surg* 2006;15(3):339-34. [DOI:10.1016/j.jse.2005.08.023]
9. Thigpen CA, Padua DA, Michener LA, Guskiewicz K, Giuliani C, Keener JD, Stergiou N. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *Journal of Electromyography and Kinesiology* 2010;20:701-709. [DOI:10.1016/j.jelekin.2009.12.003]

10. Downar JM, Sauers EL. Clinical measures of shoulder mobility in the professional baseball player. *Journal of Athletic Training* 2005;40(1):23-29.
11. Lee HM, Liao JJ, Ceng CK, Tan CM, Shih JT. Evaluation of shoulder proprioception following muscle fatigue. *Clinical Biomechanics* 2003;18:843-847. [DOI:10.1016/S0268-0033(03)00151-7]
12. De Ridder JH. *Grondaspekte van Kinantropometrie*. 3<sup>rd</sup>ed. South Africa, 2006.
13. Hurd WJ, Kaplan KM, ElAttrache NS, Jobe FW, Morrey BF, Kaufman KR. A profile of glenohumeral internal and external rotation motion in the uninjured high school baseball pitcher, part II: strength. *Journal of Athletic Training* 2011;46(3):289-295.
14. Shultz JS, Houglum AP, Perrin DH. *Examination of musculoskeletal injuries*. 3<sup>rd</sup>ed. USA: Human Kinetics, 2010.
15. Burkhart SS, Kibler W. The disabled throwing shoulder: spectrum of pathology. Part 3: The SICK scapula. Scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* 2003;19(6):641-661.
16. Dale RB, Kovalski JE, Ogletree T, Heitman RJ, Norrell PM. The effects of repetitive overhead throwing on shoulder rotator isokinetic work-fatigue. *North American Journal of Sports Physical Therapy* 2007; 2(2):74-80.
17. Chang D, Mohana-Borges A, Borso M, Chung CB. SLAP lesions: Anatomy, clinical presentation, MR imaging diagnosis and characterization. *European Journal of Radiology* 2008;68:72-87. [DOI:10.1016/j.ejrad.2008.02026]
18. Saccol MF, Gracitelli GC, da Silva RT, de Souza Laurino CF, Fleury AM, dos Santos Andrade M, da Silva AC. Shoulder functional ratio in elite junior tennis players. *Physical Therapy in Sport* 2010;11:8-11. [DOI:10.1016/j.ptsp.2009.11.002]
19. Ellis SM, Steyn HS. Practical significance (effect sizes) versus or in combination with statistical significance (p-values), *Management Dynamics* 2003;12(4): 51-53.

## CHAPTER 4

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# THE EFFECT OF AN EXERCISE INTERVENTION ON BILATERAL BIOMECHANICAL AND STRENGTH DEFICITS IN ISOKINETIC STRENGTH OF CRICKET PLAYERS

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## ABSTRACT

**Background:** Participation in sporting activities involving the overhead throwing motion causes adaptations in upper body posture, as well as shoulder range of motion (ROM) and muscle strength.

**Objectives:** To identify the effect of a six-week exercise intervention on bilateral scapular position, glenohumeral rotation ROM, and isokinetic shoulder rotation muscle strength in cricket players at NWU.

**Method:** A randomised controlled trial was performed on North-West University (NWU) cricket players during the 2013 season. Players (n=30) were randomly divided into experimental (n=15) and control groups (n=15). Scapula protraction, shoulder rotation ROM and shoulder rotational concentric muscle strength were measured pre- and post-intervention. The experimental group were subjected to supervised exercise sessions twice a week for six weeks, while the control group was only educated on exercise intervention for upper body adaptations in overhead athletes. Both groups continued with their normal cricket conditioning regime during the intervention period.

**Results:** Improvements in scapula protraction and shoulder internal rotation (IR) ROM were observed after the six-week intervention period in both the experimental ( $p=0.067$  and  $p\leq 0.001$ ) and control ( $p=0.006$  and  $p\leq 0.001$ ) groups. Only the experimental group showed no significant post-intervention shoulder IR ROM difference from the norm (dominant,  $p=0.254$  and non-dominant,  $p=0.151$ ). The exercise intervention did not indicate any effect on the concentric muscle strength characteristics.

**Conclusion:** A six-week supervised exercise intervention aimed at correcting postural and biomechanical adaptations usually observed in overhead athletes only resulted in proper improvement of shoulder IR ROM.

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## 4.1 INTRODUCTION

Static and dynamic structures in the shoulder girdle must maintain functional stability and work in synchrony to perform controlled overhead motions (Bolton *et al.*, 2011). Numerous strength and biomechanical adaptations such as a forward-head posture, rounded shoulders, scapular protraction and alterations in rotational range of motion (ROM) have previously been identified in overhead athletes and have been linked to risk of shoulder injury (Thigpen *et al.*, 2010; Kennedy *et al.*, 2009). Muscular imbalances in the rotator cuff and scapular musculature, coupled with inadequate muscular endurance and improper stroke biomechanics, can lead to overuse injury in the glenohumeral joint of overhead sporting players (Bolton *et al.*, 2013; Ellenbecker & Roetert, 2003).

A thorough rehabilitation programme (injury prevention) for shoulder injuries should include the prescription of flexibility or ROM exercises, scapula-stabilisation exercises, rotator-cuff strengthening exercises, as well as sport-specific training (Brumitt, 2006). Lynch *et al.* (2010) found that preventive interventions aimed at improving postural deviations improved posture and decreased the impact of shoulder pain in swimmers. Kibler *et al.* (2007) pointed out that prehabilitation was a way of managing an overhead athlete's career while lowering the risk of sustaining shoulder injuries. Although literature consensus was that participation in overhead sport causes postural and biomechanical adaptations, our literature searches failed to provide studies investigating the effect of prehabilitative intervention strategies on these adaptations during the in-season period of overhead sports participation. Hence the aim of this study was to investigate the effect of a supervised shoulder stability exercise intervention on the bilateral shoulder biomechanical and isokinetic shoulder rotational muscle strength deficits in cricket players.

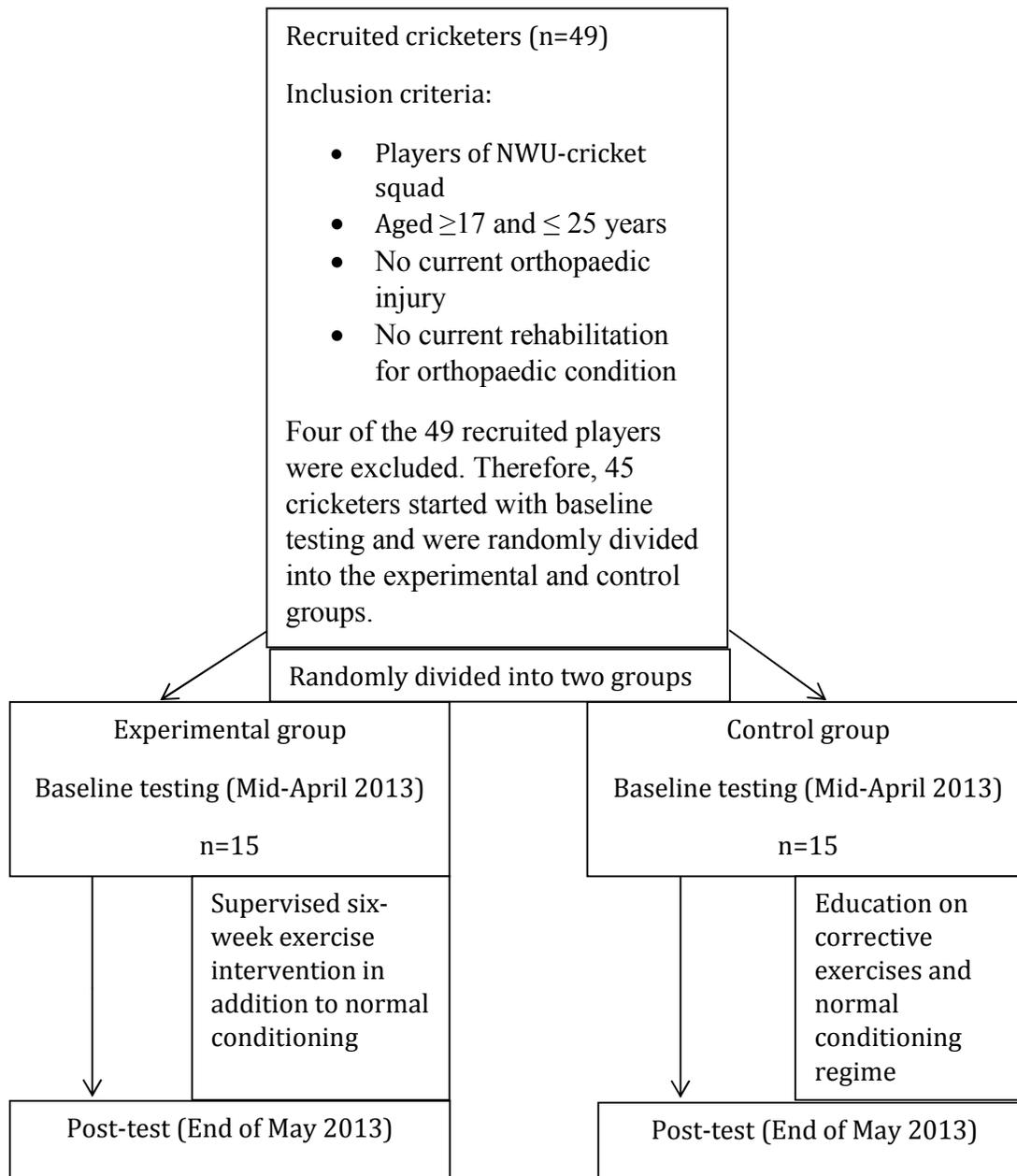
## 4.2 METHOD

### 4.2.1 STUDY DESIGN

#### EMPIRICAL RESEARCH

This study formed part of the Overhead Athlete Injury Prevention Project conducted at the NWU (Potchefstroom campus), which aimed to determine the effect of a supervised exercise intervention on the postural and biomechanical adaptations of overhead sports participants during the in-season. Ethical approval was obtained from the ethics committee of the NWU (NWU-00026-12-S1). Male cricket players from the respective cricket squads of the NWU were recruited in October 2012 to participate in the study voluntarily. At the beginning of 2013, all participants, including coaches, were invited to attend an educational session on postural, biomechanical and strength adaptations in overhead athletes, the role of shoulder instabilities in injury, as well as corrective exercises. Coaches and players were thoroughly informed regarding the testing procedures and the exercise intervention. All the cricket players who completed the intervention (n=30) participated voluntarily and signed a detailed informed consent form prior to baseline testing.

A schematic presentation of the study design, as well as the inclusion criteria, is provided in Figure 4.1 below. Four players did not meet the inclusion criteria and were thus excluded prior to baseline testing. Another 15 players dropped out during the course of the intervention period due to either injury or not continuing their studies (thus no longer being part of the university squad), or participants from the intervention group were not retested as they did not comply with attending the required two stability intervention sessions per week. Thirty players were retested (experimental group, n=15 and control group, n=15) and therefore only the baseline results of these players (n=30) were analysed for comparison purposes.



**Figure 4.1: Outline of the study design**

#### 4.2.2 MEASUREMENTS AND EQUIPMENT

The test protocol comprised a demographic and injury history questionnaire (used for the exclusion criteria), anthropometric assessment, scapula protraction, shoulder rotational ROM (internal and external) and isokinetic shoulder rotational muscle strength testing. (Measurement procedures, as well as equipment used, are thoroughly explained below.)

#### 4.2.3 ANTHROPOMETRIC MEASUREMENT

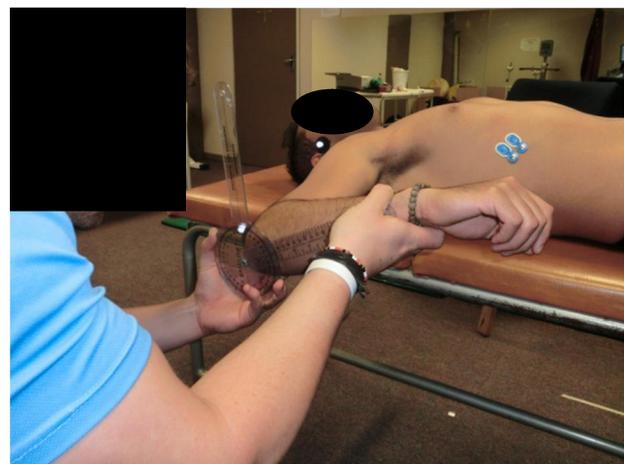
Stature was measured with a stadiometer to the nearest 0.1 cm, with shoes removed and head held in the Frankfort plane. Weight was determined using an electronic scale to the nearest 0.1 kg, with minimal clothing (de Ridder, 2011).

#### 4.2.4 SCAPULA PROTRACTION (WALL-TO-ACROMION)

Scapula protraction was measured with the participant standing with his back against the wall (posterior part of calcaneus touching the wall) and the upper body relaxed. A horizontal measurement was then taken from the wall to the anterior acromion process to the nearest 0.1 cm.

#### 4.2.5 SHOULDER ROTATION RANGE OF MOTION

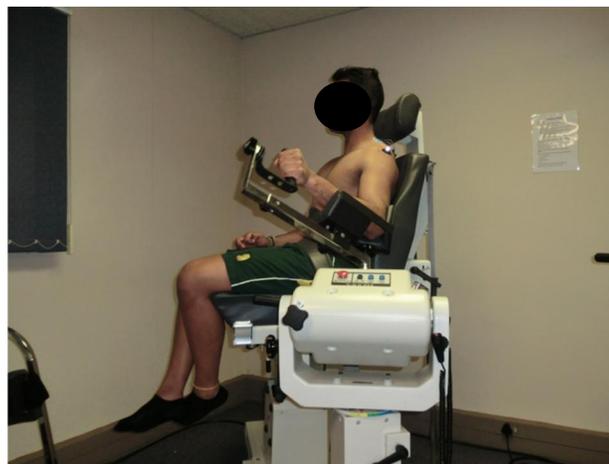
The shoulder IR and ERROM was measured using a goniometer (Shultz et al., 2010). IR was measured with the athlete lying supine, the humerus abducted to 90°, and the elbow flexed to 90°. The participant was instructed to rotate the humerus internally and the measurement was taken at the point where the biokineticist observed scapular protraction. ER was also measured in the supine position, with the humerus abducted to 90° and the elbow flexed to 90°. The athlete was instructed to rotate the humerus externally while keeping the lower back against the plinth.



**Figures 4.2 and 4.3: Measuring shoulder IR and ER**

#### 4.2.6 ISOKINETIC SHOULDER ROTATIONAL MUSCLE STRENGTH TESTING

Isokinetic testing of the shoulder rotator muscles was performed using a Biodex<sup>®</sup> System 4 (Biodex Corporation, Shirley, NY). Subjects were seated during the test, with appropriate stabilisation provided by a lap belt, crisscrossed chest straps, and footrest in accordance with the Biodex<sup>®</sup> Isokinetic Dynamometer manual. The chair of the Biodex<sup>®</sup> and the dynamometer attachment were individually adjusted to each subject to ensure proper fit and alignment and these settings were recorded from the numerical scale on the Biodex<sup>®</sup> apparatus and shoulder attachment. The humerus was placed in the glenohumeral neutral position (45° flexion in the scapular plane) and the elbow joint was in 90° of flexion. The Biodex System 4 Isokinetic Dynamometer comes factory-calibrated and maintenance calibration, as described in the manual (Biodex advantage software V.4X operation manual:29), was regularly performed in the practice setup. Gravity compensation or limb weight calibration was performed prior to each test. The participants were already warmed up when arriving at the isokinetic testing station, as electromyography recordings during standardised functional shoulder movements (not part of this study's variables) was performed prior to the isokinetic testing. Each participant was allowed a few familiarisation repetitions prior to the start of the isokinetic recordings. The concentric torque levels (Nm) of the shoulder complex were determined at speeds of 60°/sec and 180°/sec for IR and ER.



**Figure 4.4: Isokinetic testing of rotational muscle strength on the Biodex<sup>®</sup> machine**

#### 4.2.7 EXERCISE INTERVENTION

A six-week supervised exercise intervention programme followed after completion of the baseline tests. The intervention exercises included mobilisation and stabilisation of the pelvic area, lower back and shoulder girdle, and were based on correction of common postural and biomechanical characteristics, which overhead athletes tend to adapt during prolonged participation in overhead sporting activities (Magee, 2008; Jaggi & Lambert, 2010; Reinold *et al.*, 2009). Each session was 45 minutes in duration and the athletes were requested to participate in the intervention sessions twice a week, for six weeks (mid-April 2013 to the end of May 2013), under supervision of qualified biokineticists. A register was kept to log each session an athlete had attended. The exercise programme was adjusted every two weeks. Exercise apparatus included foam rollers, tennis balls, elastic bands (blue thera-band®TheHygenic Corporation, headquarters in Akron, Ohio) and bosu-balls (®Ashland, Ohio, USA). The complete exercise program is attached to this manuscript (Appendix F).

#### 4.2.8 STATISTICAL ANALYSES

Statistical analyses were performed with the Statistica 12 computer software program (Statsoft Inc., 2014). Departure from normality was evaluated using the Shapiro-Wilk test and quantile-quantile plots. Dependent *t*-tests ( $p \leq 0.05$ ) were used to compare the pre- and post-test values for all parameters in both the experimental and control groups, separately (dominant and non-dominant sides). One-sample *t*-tests were used to compare the shoulder rotational ROM values, as well as the shoulder rotational strength ratios, to normative data both before and after the intervention (Ellis and Steyn, 2003).

### 4.3 RESULTS

Participant characteristics (Table 4.1) indicate that both the experimental and control groups' characteristics were similar at baseline. The players' averages with regard to age, stature and body mass are listed in Table 4.1.

**Table 4.1 Basic descriptive characteristics of the study population (n=30)**

<b>Variable</b>	<b>Mean (<math>\pm</math>SD)</b>
<b>Experimental group (n=15)</b>	
Age (years)	20.5 ( $\pm$ 1.27)
Length (metre)	1.82 ( $\pm$ 0.08)
Weight (kg)	81.75 ( $\pm$ 9.03)
BMI (kg.m <sup>2</sup> )	24.71 ( $\pm$ 1.51)
<b>Control group (n=15)</b>	
Age (years)	20.7 ( $\pm$ 1.62)
Length (meter)	1.79 ( $\pm$ 0.06)
Weight (kg)	77.75 ( $\pm$ 10.39)
BMI (kg.m <sup>2</sup> )	24.26 ( $\pm$ 2.28)
$\pm$ SD, standard deviation; m, metre; kg, kilogram; BMI, body mass index; n, number of participants	

Tables 4.2 and 4.3 indicate the postural, shoulder ROM and shoulder rotation strength characteristics of cricketers before and after the intervention in both the experimental and control groups. Scapula protraction decreased and shoulder rotational ROM increased in both the dominant and non-dominant shoulders of the experimental group (borderline significant changes were noted on the dominant side). Although the reference group also indicated improvements in these characteristics, slight improvements were observed in the dominant shoulder (throwing arm) of the experimental group subsequent to the supervised exercise sessions when compared to the control group. No improvements were found after the intervention in the strength characteristics of either the experimental or reference group (Table 4.3).

**Table 4.2: Dependent *t*-tests indicating the pre- and post-test differences in scapula protraction and shoulder ROM for both the experimental and control groups separately**

Variable	Dominant Mean ( $\pm$ SD) Pre-intervention	Dominant Mean ( $\pm$ SD) Post-intervention	p-value	Non-dominant Mean ( $\pm$ SD) Pre-intervention	Non-dominant Mean ( $\pm$ SD) Post-intervention	p-value
<b>Experimental group (n=15)</b>						
Scapular Protraction (cm)	14.17 ( $\pm$ 2.73)	12.69 ( $\pm$ 1.32)	0.067	13.20 ( $\pm$ 3.10)	11.09 ( $\pm$ 1.43)	0.005#
Shoulder IR ROM ( $^{\circ}$ )	49.70 ( $\pm$ 12.88)	65.80 ( $\pm$ 13.67)	$\leq$ 0.001*	59.70 ( $\pm$ 9.86)	73.93 ( $\pm$ 10.02)	$\leq$ 0.001*
Shoulder ER ROM ( $^{\circ}$ )	110.93 ( $\pm$ 11.93)	112.57 ( $\pm$ 9.57)	0.528	100.37 ( $\pm$ 8.66)	109.47 ( $\pm$ 8.20)	0.003#
<b>Control group (n=15)</b>						
Scapular Protraction (cm)	13.45 ( $\pm$ 1.73)	12.05 ( $\pm$ 1.55)	0.006#	11.91 ( $\pm$ 1.96)	11.63 ( $\pm$ 2.10)	0.449
Shoulder IR ROM ( $^{\circ}$ )	42.67 ( $\pm$ 13.53)	56.40 ( $\pm$ 9.27)	$\leq$ 0.001*	58.07 ( $\pm$ 15.41)	69.97 ( $\pm$ 9.88)	$\leq$ 0.001*
Shoulder ER ROM ( $^{\circ}$ )	112.90 ( $\pm$ 8.31)	113.53 ( $\pm$ 11.66)	0.760	101.17 ( $\pm$ 10.12)	105.83 ( $\pm$ 12.26)	0.040#
<p>* Statistical significance (<math>p \leq 0.001</math>); # statistical significance (<math>p \leq 0.05</math>); <math>\pm</math>SD, standard deviation; cm, centimetre; IR-internal rotation; ER- external rotation; pt/bw-peak torque per bodyweight; p-value, statistical significance level; <math>^{\circ}</math>, degrees</p>						

**Table 4.3: Dependent *T*-tests indicating the pre- and post-test differences in shoulder rotational muscle strength characteristics for the experimental and control groups, separately**

Variable	Dominant Mean( $\pm$ SD)Pre-intervention	Dominant Mean( $\pm$ SD)Post-intervention	<i>p</i> -value	Non-dominant Mean( $\pm$ SD)Pre-intervention	Non-dominant Mean( $\pm$ SD)Post-intervention	<i>p</i> -value
<b>Experimental group (n=15)</b>						
<b>60 degrees/sec</b>						
Shoulder IR PT/BW(%)	64.99 ( $\pm$ 13.81)	62.95 ( $\pm$ 11.96)	0.560	53.69 ( $\pm$ 11.18)	55.83 ( $\pm$ 8.85)	0.388
Shoulder ER PT/BW(%)	46.17 ( $\pm$ 6.72)	45.71 ( $\pm$ 5.85)	0.802	39.53 ( $\pm$ 6.16)	40.38 ( $\pm$ 5.98)	0.535
<b>180 degrees/sec</b>						
Shoulder IR PT/BW(%)	56.12 ( $\pm$ 13.78)	55.54 ( $\pm$ 14.47)	0.896	45.67 ( $\pm$ 9.42)	49.54 ( $\pm$ 6.80)	0.152
Shoulder ER PT/BW(%)	38.43 ( $\pm$ 7.03)	39.01 ( $\pm$ 6.41)	0.812	32.78 ( $\pm$ 5.86)	34.17 ( $\pm$ 5.63)	0.396
<b>Control group (n=15)</b>						
<b>60 degrees/sec</b>						
Shoulder IR PT/BW(%)	68.29 ( $\pm$ 21.61)	67.90 ( $\pm$ 14.39)	0.907	61.57 ( $\pm$ 16.94)	58.09 ( $\pm$ 16.59)	0.195
Shoulder ER PT/BW(%)	45.48 ( $\pm$ 14.48)	44.53 ( $\pm$ 12.96)	0.350	45.05 ( $\pm$ 16.00)	41.95 ( $\pm$ 14.71)	0.045#
<b>180 degrees/sec</b>						
Shoulder IR PT/BW(%)	60.18 ( $\pm$ 13.74)	60.47 ( $\pm$ 11.13)	0.890	50.55 ( $\pm$ 17.82)	51.69 ( $\pm$ 12.36)	0.634
Shoulder ER PT/BW(%)	38.85 ( $\pm$ 11.58)	38.43 ( $\pm$ 12.77)	0.732	36.04 ( $\pm$ 12.50)	35.07 ( $\pm$ 9.47)	0.512
* Statistical significance ( $p \leq 0.001$ ); # statistical significance ( $p \leq 0.05$ ); $\pm$ SD, standard deviation; cm, centimetre; IR-internal rotation; ER-external rotation; pt/bw-peak torque per bodyweight; %, percentage						

Shoulder IR ROM in the experimental group was not statistically significantly different from the norm after the intervention period. Although the control group showed statistically significant improvement, the post-test IR value was still statistically significantly limited, compared to the normative value (Table 4.4).

**Table 4.4: One-sample T-tests comparing the pre- and post-test values in shoulder ROM for both the experimental and control groups against the norm**

Variable	Norm	Dominant Mean ( $\pm$ SD) Pre-intervention	Dominant Mean ( $\pm$ SD) Post-intervention	<i>p</i> -value pre-intervention	Non-dominant Mean ( $\pm$ SD) Pre-intervention	Non-dominant Mean ( $\pm$ SD) Post-intervention	<i>p</i> -value pre-intervention
				<i>p</i> -value post-intervention			<i>p</i> -value post-intervention
<b>Experimental group (n=15)</b>							
Shoulder IR (°)	70.00	49.70 ( $\pm$ 12.88)	65.80 ( $\pm$ 13.67)	$\leq 0.001^*$	59.70 ( $\pm$ 9.86)	73.93 ( $\pm$ 10.02)	$\leq 0.001^*$
				0.254			0.151
Shoulder ER (°)	80.00	110.93 ( $\pm$ 11.93)	112.57 ( $\pm$ 9.57)	$\leq 0.001^*$	100.37 ( $\pm$ 8.66)	109.47 ( $\pm$ 8.20)	$\leq 0.001^*$
				$\leq 0.001^*$			$\leq 0.001^*$
<b>Control group (n=15)</b>							
Shoulder IR (°)	70.00	42.67 ( $\pm$ 13.53)	56.40 ( $\pm$ 9.27)	$\leq 0.001^*$	58.07 ( $\pm$ 15.41)	69.97 ( $\pm$ 9.88)	0.010#
				$\leq 0.001^*$			0.990
Shoulder ER (°)	80.00	112.90 ( $\pm$ 8.31)	113.53 ( $\pm$ 11.66)	$\leq 0.001^*$	101.17 ( $\pm$ 10.12)	105.83 ( $\pm$ 12.26)	$\leq 0.001^*$
				$\leq 0.001^*$			$\leq 0.001^*$

**Table 4.5: One-sample *T*-tests comparing the pre- and post-test shoulder rotational muscle strength PT/BW values against the norm for the experimental and control groups.**

Variable	Norm	Dominant Mean ( $\pm$ SD) Pre-intervention	Dominant Mean ( $\pm$ SD) Post-intervention	<i>p</i> -value pre-intervention	Non-dominant Mean ( $\pm$ SD) Pre-intervention	Non-dominant Mean ( $\pm$ SD) Post-intervention	<i>p</i> -value pre-intervention
				<i>p</i> -value post-intervention			<i>p</i> -value post-intervention
<b>Experimental group (n=15)</b>							
<b>60 degrees/sec</b>							
Shoulder IR PT/BW (%)	77.70	64.99 ( $\pm$ 13.81)	62.95 ( $\pm$ 11.96)	0.003#	53.69 ( $\pm$ 11.18)	55.83 ( $\pm$ 8.85)	$\leq$ 0.001*
				$\leq$ 0.001*			$\leq$ 0.001*
Shoulder ER PT/BW (%)	50.80	46.17 ( $\pm$ 6.72)	45.71 ( $\pm$ 5.85)	0.019#	39.53 ( $\pm$ 6.16)	40.38 ( $\pm$ 5.98)	$\leq$ 0.001*
				0.005#			$\leq$ 0.001*
IR:ER Ratio	64.00	73.03 ( $\pm$ 13.52)	74.09 ( $\pm$ 11.35)	0.021#	75.52 ( $\pm$ 16.04)	73.33 ( $\pm$ 12.78)	0.015#
				0.004#			0.013#
<b>180 degrees/sec</b>							
Shoulder IR PT/BW (%)	68.70	56.12 ( $\pm$ 13.78)	55.54 ( $\pm$ 14.47)	0.003#	45.67 ( $\pm$ 9.42)	49.54 ( $\pm$ 6.80)	$\leq$ 0.001*
				0.003#			$\leq$ 0.001*
Shoulder ER PT/BW (%)	44.80	38.43 ( $\pm$ 7.03)	39.01 ( $\pm$ 6.41)	0.003#	32.78 ( $\pm$ 5.86)	34.17 ( $\pm$ 5.63)	$\leq$ 0.001*
				0.004#			$\leq$ 0.001*
IR:ER Ratio	66.00	70.43 ( $\pm$ 11.83)	72.65 ( $\pm$ 12.90)	0.169	73.55 ( $\pm$ 16.27)	69.49 ( $\pm$ 12.19)	0.094
				0.066			0.289

- Continued overleaf -

Table 4.5 (continued)

Control group (n=15)							
60 degrees/sec							
Shoulder IR PT/BW (%)	77.70	68.29 (±21.61)	67.90 (±14.39)	0.114	61.57 (±16.94)	58.09 (±16.59)	0.002#
				0.019#			≤0.001*
Shoulder ER PT/BW (%)	50.80	45.48 (±14.48)	44.53 (±12.96)	0.178	45.05 (±16.00)	41.95 (±14.71)	0.185
				0.082			0.035#
IR:ER Ratio	64	68.25 (±14.19)	65.53 (±8.75)	0.265	73.67 (±12.69)	73.22 (±13.86)	0.010#
				0.510			0.022#
180 degrees/sec							
Shoulder IR PT/BW (%)	68.70	60.18 (±13.74)	60.47 (±11.13)	0.031#	50.55 (±17.82)	51.69 (±12.36)	0.002#
				0.013#			≤0.001*
Shoulder ER PT/BW (%)	44.80	38.85 (±11.58)	38.43 (±12.77)	0.067	36.04 (±12.50)	35.07 (±9.47)	0.017#
				0.074			≤0.001*
IR:ER Ratio	66.00	64.85 (±11.10)	63.56 (±15.10)	0.695	76.95 (±27.49)	68.92 (±12.80)	0.145
				0.542			0.392
* Statistical significance (p≤0.001); # statistical significance (p≤0.05); ±SD, standard deviation; cm, centimetre; IR- internal rotation; ER-external rotation; pt/bw-peak torque per bodyweight							

Table 4.5 indicates that the shoulder rotational muscle PT characteristics, tested at both 60 and 180 degrees per second, indicate no significant changes following the intervention period, in both the experimental and reference groups. Almost every value that significantly differed from the normative value during pre-testing indicated the same trend during post-testing.

#### 4.4 DISCUSSION

This study was aimed at determining the effect of a supervised six-week exercise intervention programme on scapular position, glenohumeral rotational ROM and isokinetic muscle strength characteristics in cricket players at the NWU. Significant improvements in scapula protraction and shoulder ROM were observed after the six-week intervention period. Although these changes were also observed in the control group, who were educated on exercises for specific adaptations in overhead sports, the changes in the experimental group, who had undergone supervised exercise sessions, were more notable for IR ROM statistics. The exercise intervention, which focused on improving postural and biomechanical adaptations, usually observed in overhead sports participants, did not result in any significant changes in the shoulder rotation muscle strength.

Cricket players can be plagued by shoulder pain and dysfunction attributed to several factors, including strength imbalances and posture adaptations. The results obtained in this study indicate that the intervention significantly decreased scapula protraction, suggesting that the exercises targeted tissues that contributed to improved posture. The improvement in scapular posture following exercise intervention is supported by literature, which states that decreased scapula protraction was found following a six-week intervention that included stretching of the anterior shoulder muscles and strengthening of the posterior shoulder muscles (Kleumper *et al.*, 2006). In addition, Roddey *et al.* (2002) successfully improved scapula protraction that decreased the forward shoulder posture in a study following a two-week pectoralis stretching programme. Lynch *et al.* (2010) reported that an eight-week exercise intervention programme significantly decreased forward shoulder posture. The control group also indicated improvement in scapular posture during this period. However, if the differences in the pre- and post-test raw values were calculated, these improvements were on average greater in the experimental group that had undergone supervised exercise sessions. These improvements in the control group maybe due to the fact that they also attended educational sessions prior to the intervention and testing period. The control group still exercised with the experimental group during normal coaching sessions and thus could have heard what exercises had been done and had incorporated these into their exercise programmes at the gymnasium.

When ROM and strength characteristics were compared with normative data, it was only the shoulder IR ROM that indicated a trend to improve more closely to the normative value during the intervention period. The results from the present study are supported by other intervention programmes that found that IR ROM increased after intervention programmes (Manske *et al.*, 2013). Harshbarger *et al.* (2013) found significant improvements to glenohumeral IR ROM when participants were treated using combined joint mobilisation and stretching protocols over an intervention period. Tight capsular and muscular tissues of the shoulder affect normal shoulder ROM. Posterior shoulder tightness creates a need for some athletes to stretch the structures in the region of the shoulder. A tight posterior capsule is thought to cause antero-superior migration of the humeral head with forward elevation of the shoulder, possibly contributing to impingement. Tight posterior shoulder tissues may also contribute to a loss in shoulder rotation (Tyler *et al.*, 1999).

The isokinetic strength show any statistical significance when compared with the normative value. This maybe due to the intervention programme not focusing as much on muscle strength than on improvement of postural adaptations. The isokinetic strength of the cricket players did not improve after the intervention exercise programme and this finding is supported by the studies performed by Lynce *et al.*(2010) and de Mey *et al.*(2012). Lynce *et al.* (2010) found no differences in the scapular muscle strength after an eight-week intervention program presented to elite swimmers. Bilateral strength differences included less ER strength and greater IR strength of the throwing shoulder than those of the non-throwing shoulder. Lower ER:IR strength ratios have been reported in the asymptomatic throwing shoulder compared to the non-throwing shoulder. Differences in ER:IR strength ratios result from the presence of greater dominant-limb internal rotators without a similar dominance effect in the external rotators (Hurd *et al.*, 2011).

#### **4.5 CONCLUSION**

In this study, supervised shoulder stability exercises performed twice per week for six weeks during the in-season made a significant difference compared to non-supervised shoulder exercise for improvement of shoulder IR ROM in the dominant arm of cricketers, who practise an

overhead sport. However, the exercise intervention did not make a significant difference to the shoulder rotational concentric muscle strength.

Although the researchers in the current study acknowledge that randomised controlled trials are ideal for testing intervention, the implementation of such a study design creates many obstacles in testing exercise interventions in the sporting population. Firstly, it is ethically unfair to the control group not to be included in the training group exercise regimes that are established to improve ‘niggles’ in the shoulder joint in clinical practice. Moreover, in the current study many of the participants in the experimental group verbally communicated after a few weeks that their dominant shoulders felt more stable. This encouraged participants allocated to the control group to do some of the exercises (especially the self-release techniques) on their own. It is therefore seen as a limitation in the current study that players from the same cricket squad were used in both the experimental and control groups. Although it could be difficult to find two totally different squads that participate on the same level of competition and are exposed to more or less the same conditioning regimes, this would be recommended for future research to limit these obstacles experienced in the current study.

This study was unique in the sense that the exercise intervention was performed during the competitive period of the season. Future research could perform such interventions throughout the entire season (including pre- and off-season periods) to determine when such an intervention would have most effect and whether any effect observed might diminish after time.

## REFERENCE

Brumitt J, 2006. Scapular-stabilization exercises: early-intervention prescription. *Athletic Therapy Today* 11: 15-18.

Bolton G, Moss SJ, Sparks M, Venter PC, et al., 2013. Thoracic posture, shoulder muscle activation patterns and isokinetic strength of semi-professional rugby union players. *SAJSM* 25:12-17.

Dale RB, Kovalski JE, Ogletree T, Heitman RJ, Norrell PM, et al., 2007. The effects of repetitive overhead throwing on shoulder rotator Isokinetic work-fatigue. *North American Journal of Sports Physical Therapy* 2:74-80.

De Mey K, Danneels L, Cagnie B, Cools AM, et al., 2012. Scapular muscle rehabilitation exercises in overhead athletes with impingement symptoms: effect of a 6-week training program on muscle recruitment and functional outcome. *The American Journal of Sports Medicine* 8:1906-1915.

De Ridder JH, 2006. *Grondaspekte van Kinantropometrie*. 3<sup>rd</sup>ed., South Africa

Ellenbecker T, Roetert EP, 2003. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of Science and Medicine in Sport* 6:63-70.

Ellis SM, Steyn HS, 2003. Practical significance (effect sizes) versus or in combination with statistical significance (p-values). *Management Dynamics* 12: 51-53.

Harshbarger ND, Eppelheimer BL, Valovich McLeod TC, McCarty CW, et al., 2013. The effectiveness of shoulder stretching and joint mobilisations on posterior shoulder tightness. *Journal of Sport Rehabilitation* 22:313-319.

Hurd WJ, Kaplan KM, ElAttrache NS, Jobe FW, Morrey BF, Kaufman KR, et al., 2011. A profile of glenohumeral internal and external rotation motion in the uninjured high school baseball pitcher, part II: strength. *Journal of Athletic Training* 46:289-295.

Jaggi A, Lambert S, 2010. Rehabilitation for shoulder instability. *Br J Sports Med* 44:333-340.

Kennedy DJ, Visco CJ, Press J, et al., 2009. Current concepts for shoulder training in the overhead athlete. *Curr. Sports Med Rep* 3:154-160.

Kibler WB, Chandler TJ, Shapiro R, Conuel M, et al., 2007. Muscle activation in coupled scapulohumeral motions in the high performance tennis serve. *Br J Sports Med* 41:745-749.

Kluemper M, Uhl T, Hazelrigg H, et al., 2006. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *J Sport Rehabil* 15:58-70.

Lynch SS, Thigpen CA, Mihalik JP, Prentice WE, Padua D, et al., 2010. The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers. *Br J Sports Med* 44:376-381.

Magee DJ, 2008. *Orthopaedic physical assessment*, 5<sup>th</sup> ed., Philadelphia, Saunders.

Malcarney HL, Murrell GAC, 2003. The rotator cuff biological adaptations to its environment. *Sports Med* 33:993-1002.

Manske R, Wilk KE, Davies G, Ellenbecker T, Reinold M, et al., 2013. Glenohumeral motion deficits: friend or foe? *The International Journal of Sports Physical Therapy* 8:537-553.

Reinold MM, Escamilla R, Wilk KE, et al., 2009. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *JOSPT* 39:105-117.

Roddey TS, Olson SL, Grant SE, et al., 2002. The effect of pectoralis muscle stretching on the resting position of the scapula in persons with varying degrees of forward head/rounded shoulder posture. *Journal of Manipulative and Physiological Therapeutics* 10:124-8.

Saccol MF, Gracitelli GC, da Silva RT, de Souza Laurino CF, Fleury AM, dos Santos AndradeM, da Silva AC, et al., 2010. Shoulder functional ratio in elite junior tennis players. *Physical Therapy in Sport* 11:8-11.

Shultz JS, Houghlum AP, Perrin DH, et al., 2010. Examination of musculoskeletal injuries. 3<sup>rd</sup> ed., USA, Human Kinetics.

Stuelcken MC, Ginn KA, Sinclair PJ, et al., 2008. Shoulder strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain. *Journal of Science and Medicine in Sport* 11:575-580.

Thigpen CA, Padua DA, Michener LA, Guskiewicz K, Giuliani C, Keener JD, Stergiou N, et al., 2010. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *Journal of Electromyography and Kinesiology* 20:701-709.

Thomas JR, Nelson JK, Silverman SJ, et al., 2005. Research methods in physical activity, 5<sup>th</sup> ed., USA, Human Kinetics.

Tyler TF, Roy T, Nicholas SJ, Gleim GW, et al., 1999. Reliability and validity of a new method of measuring posterior shoulder tightness. *Journal of Orthopaedic & Sports Physical Therapy* 29:262-274.

## CHAPTER 5

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# **SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS**

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## 5.1 SUMMARY OF RESULTS

This study was aimed at detecting bilateral asymmetry in scapular position, glenohumeral rotational ROM and isokinetic rotation muscle strength of NWU cricket players, and to determine relationships between these characteristics. The effect of a supervised six-week exercise intervention, which mainly focused on correcting postural and biomechanical adaptations normally observed in overhead athletes, on the measured characteristics was also investigated.

In **Chapter 1** the problem statement, aim of the study and hypotheses were explained, and the structure of the dissertation was laid out.

**Chapter 2** provided a literature review that discussed normal movement patterns in the shoulder girdle, the need for balanced muscle activity (force couple activation) to create stability during overhead motions and the effect of participation in overhead sporting activities on upper body posture and biomechanics. Previous intervention studies to correct upper body adaptations in other overhead sporting activities such as tennis and swimming were also discussed.

Cricket players must perform two distinct unilateral overhead movements, namely bowling and throwing, and range of motion (ROM) in all directions and stability of the shoulder capsule are therefore very important. The scapula plays a vital role in ensuring that energy from the lower extremities and trunk is transferred to the throwing arm, while the muscles of the scapulothoracic and glenohumeral joints play a crucial role in providing dynamic and stabilising support of the shoulder joint during overhead activities. Postural, biomechanical and muscle strength adaptations can be detected in response to long-term participation in overhead sport. The upper body posture of an overhead athlete is characterised by a protracted and anteriorly tipped scapula position. Increased protraction has also been identified in the scapular motion of overhead athletes and may be defined as scapular dyskinesis. Overhead athletes normally develop ROM adaptations with posterior capsular tightness presenting as a glenohumeral IR ROM deficit compared to the non-dominant arm. Muscle imbalance with shortening of the anterior muscles and lengthening and weakness of the posterior muscles develops.

These adaptations in the shoulder joint lead to the injuries described below. The stresses of overhead throwing lead to soft tissue musculature adaptations, which also may contribute

partially to a decreased ROM. Bilateral strength differences occur, including less external rotation (ER) strength and greater internal rotation (IR) strength of the throwing shoulder than of the non-throwing shoulder. The anterior wall muscles of the shoulder become stretched, which may eventually lead to the subluxation of the humeral head anteriorly. Labral tears are usually associated with glenohumeral instability and can result from dislocation or chronic instability. These imbalances result in scapular instability, potentially increasing the risk of shoulder problems, and would be present as timing properties as well as in force output. Another injury risk can be internal impingement, which is most likely caused by fatigue of the muscles of the shoulder girdle. Rotator cuff injury results from decreased ROM and loss of strength. Repetitive forceful contraction of the muscles during the deceleration phase of throwing can eccentrically injure the rotator cuff. If the function of the rotator cuff muscles becomes impaired, superior translation of the humeral head will occur, resulting in impingement of the rotator cuff muscles.

Intervention studies, focusing on correction of adaptations commonly seen in overhead athletes, are limited. A six-week intervention study including stretching of the anterior shoulder muscles and strengthening of the posterior shoulder muscles resulted in decreased rounded shoulder posture of swimmers. Biomechanical deficits do respond to correct therapy and can result in decreased shoulder pain in the overhead athlete and prevent injuries.

Pre-habilitation is a more reliable way to manage and lower the risk of shoulder injuries during the overhead athlete's career. Future research can be used to design appropriate rehabilitation and injury prevention programmes for all overhead sports.

**Chapter 3** was aimed at determining bilateral differences in scapula protraction, glenohumeral rotational ROM and shoulder isokinetic rotational muscle strength characteristics in NWU cricket players. Relationships between scapula protraction and ROM and strength characteristics were also investigated. Asymmetry was present when the dominant and non-dominant sides were compared. The dominant shoulder was on average more protracted, with less GH IR ROM and significantly more ER ROM than the non-dominant shoulder. The isokinetic shoulder strength indicated that the concentric peak torque of both the internal and external rotators on the dominant side was significantly stronger than on the non-dominant side.

Both the dominant and non-dominant shoulders of the cricketers presented with limited IR ROM and excessive ER ROM compared with the normative values. The IR and the ER muscle strength peak torque tested weak on both the dominant and non-dominant sides, with the ER strength proving to be closer to the norm than the IR strength. Only the IR strength and ER ROM showed a relationship with scapula protraction, only on the dominant side.

**Chapter 4** investigated the effect of an exercise intervention on the upper body postural and biomechanical adaptations in NWU cricket players. The squad was randomly divided into experimental and control groups. Both groups received proper education on adaptations resulting from long-term participation in overhead sports and the exercises indicated in literature to improve such adaptations. The experimental group underwent supervised exercise sessions twice a week for six weeks; the intervention mainly focused on self-release techniques for the anterior glenohumeral muscles, as well as the posterior capsule, strengthening of the scapular and glenohumeral stabiliser muscles and lumbo-pelvic stabilisation. The control group did not participate in any supervised sessions and both groups continued with normal conditioning regimes during the intervention period. The values of the total shoulder rotational ROM increased, thus giving the cricket players a larger extent in the shoulder complex. IR ROM, as well as scapulaprotraction, improved significantly in both groups, Only the IR ROM on the dominant side of the intervention did not differ significantly from the norm after the supervised exercise intervention. The rotational muscle strength adaptations did not show any improvement.

## **5.2 CONCLUSION**

The conclusions of the study are derived from the stated hypotheses.

### **5.2.1 Hypothesis 1**

**Significant asymmetry in shoulder rotational ROM, isokinetic rotational muscle strength and scapula protraction will exist between the dominant and non-dominant sides of university-level cricket players.**

The results of the current research indicated that on average, the dominant shoulder of the cricketers was significantly more protracted, with significantly less IR ROM and significantly more ER ROM than the non-dominant side. Both IR and ER average concentric peak torque were significantly higher in die dominant shoulder.

**Hypotheses 1 is therefore accepted.**

### **5.2.2 Hypotheses 2**

**Scapula protraction will show statistically significantly negative association with shoulder rotational ROM, as well as isokinetic rotational muscle strength characteristics of university-level cricket players.**

Statistically significant ROM and muscle strength associations with scapula protraction were only observed in the dominant shoulders of the cricketers. Shoulder ER ROM indicated a statistically significantly negative association, and shoulder IR average peak torque a statistically significantly positive association. It seems that the stronger the shoulder IR muscle strength, the more protracted the scapula, which resulted in less ER ROM.

**Hypotheses 2 could therefore only be partially accepted.**

### **5.2.3 Hypothesis 3**

**A controlled stability exercise intervention will significantly improve the bilateral shoulder biomechanical and isokinetic rotational muscle strength deficits in university-level cricket players.**

The results of this study showed statistically significantly bilateral shoulder biomechanical improvement in scapula protraction and in IR and ER ROM in the experimental group. However, the exercise intervention did not indicate any effect on the concentric muscle strength characteristics. The intervention programme improved both the dominant and non-dominant side of the overhead athlete.

**Hypothesis 3 could therefore only be partially accepted.**

The conclusion of this study is thus that overhead athletes do present bilateral differences in scapular position, glenohumeral rotational ROM, and isokinetic shoulder rotational muscle strength adaptations commonly associated with prolonged participation in overhead sporting activities. The findings were that the dominant side presented stronger IR strength that contributed to the scapula being more protracted and ER ROM being limited. These postural and biomechanical adaptations observed in the cricket players were very similar to those of other studies on other overhead sporting codes. After completion of the six-week intervention programme both the experimental and control groups presented with decreased scapula protraction, as well as increased shoulder IR rotational ROM. Only the IR ROM on the dominant side of the intervention group did not significantly differ from the norm at pre- and post-test. The muscle strength of the players did not show any improvement in either of the two groups. This could be due to the intervention mainly focusing on self-release techniques for the anterior glenohumeral muscles, as well as the posterior capsule, strengthening of the scapular and glenohumeral stabiliser muscles, and lumbo-pelvic stabilisation. Further research needs to be done to prescribe resistance exercises in overhead athletes after postural adaptations have been addressed.

### **5.3 LIMITATIONS AND RECOMMENDATIONS**

Conclusive results were obtained from this study, with significant differences observed between the dominant and non-dominant shoulders of cricket players. This study had several limitations, which may have affected the results. The following limitations were identified and recommendations are made on how to improve future research:

- A limited number of cricket players were available to participate in the study, as only players of the NWU squad were included. The reason for only including players of one squad was to ensure that conditioning regimes, as well as the competition schedule, were the same in both the experimental and control groups. The small sample size might, however, have affected detection of significant associations.
- During the six-week intervention programme the experimental group felt a difference in their cricket abilities and revealed to the control group what they were doing. This could

have had an influence on the end result and could have influenced the clear impact of the intervention programme on the experimental group.

Future research needs to be initiated, testing continuously throughout the season (pre-, in- and recovery period). This could result in significant differences between the experimental and control groups and could also provide useful information to the coaches on the effect of conditioning and strengthening regimes used and the best time to include stability training.

After conclusion of this study, the following recommendations are made for future research:

- The shoulder complex during the overhead motion of throwing and bowling should be addressed as a whole. The flexion and extension of the shoulder complex can also be tested. This will ensure that the whole shoulder complex is tested rather than just a few components.
- Once postural adaptations have been addressed in the intervention programme, a follow-up intervention programme can be followed for strength-increasing qualities. Data derived from this would indicate how adaptive the muscles are after postural correction in overhead athletes.

## APPENDIX A

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# **AUTHOR'S GUIDELINES: SOUTH AFRICAN JOURNAL OF SPORTS MEDICINE**

## **Author's Guidelines**

**Accepted manuscripts that are not in the correct format specified in these guidelines will be returned to the author(s) for correction, and will delay publication.**

### **AUTHOR(a&b)**

Named authors must consent to publication. Authorship should be based on substantial contribution to: (i) conception, design, analysis and interpretation of data; (ii) drafting or critical revision for important intellectual content; and (iii) approval of the version to be published. These conditions must all be met (uniform requirements for manuscripts submitted to biomedical journals; refer to [www.icmje.org](http://www.icmje.org) ).

### **CONFLICT OF INTEREST**

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

### **RESEARCH ETHICS COMMITTEE APPROVAL**

Provide evidence of Research Ethics Committee approval of the research where relevant.

### **PROTECTION OF PATIENT'S RIGHTS TO PRIVACY**

Identifying information should not be published in written descriptions, photographs, and pedigrees unless the information is essential for scientific purposes and the patient (or parent or guardian) gives informed written consent for publication. The patient should be shown the manuscript to be published. Refer to [www.icmje.org](http://www.icmje.org) .

### **ETHNIC CLASSIFICATION**

References to ethnic classification must indicate the rationale for this.

### **MANUSCRIPTS**

Shorter items are more likely to be accepted for publication, owing to space constraints and reader preferences.

*Original articles* not exceeding 3000 words, with up to 6 tables or illustrations, are observations or research of relevance to sports medicine and exercise science. References should be limited to 15. Please provide a structured abstract not exceeding 250 words, with the following recommended headings:

*Background, Objectives, Methods, Results, and Conclusion.*

**Short reports, Commentaries or Case Studies** should be 1 500 words or less, with 1 table or illustration and no more than 6 references. Please provide an accompanying abstract not exceeding 150 words.

**Editorials**, Opinions, etc. should be about 1000 words and are welcome, but unless invited, will be subjected to the SAJSM peer review process.

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

**Letters to the editor**, for publication, should be about 400 words with only one illustration or table, and must include a correspondence address.

**Obituaries** should be about 400 words and may be accompanied by a photograph.

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Refer to articles in recent issues for the presentation of headings and subheadings. If in doubt, refer to 'uniform requirements' – [www.icmje.org](http://www.icmje.org).

Manuscripts must be provided in **UK English**.

**Qualification, affiliation and contact details** of ALL authors must be provided in the manuscript and in the online submission process.

**Abbreviations** should be spelt out when first used and thereafter used consistently, e.g. 'intravenous (IV)' or 'Department of Health (DoH)'.

**Scientific measurements** must be expressed in SI units except: blood pressure (mmHg) and hemoglobin (g/dl). Liters is denoted with a lowercase 'l' e.g. 'ml' for milliliters). Units should be preceded by a space (except for %), e.g. '40 kg' and '20 cm' but '50%'. Greater/smaller than signs (> and <) should be placed immediately preceding the relevant number, i.e. 'women >40 years of age'. The same applies to  $\pm$  and  $^{\circ}$ , i.e. '35 $\pm$ 6' and '19 $^{\circ}$ C'.

**Statistical methods** must be described 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 (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.

**Numbers** should be written as grouped per thousand-units, i.e. 4 000, 22 160...

**Quotes** should be placed in single quotation marks: i.e. The respondent stated: '...'

Round **brackets** (parentheses) should be used, as opposed to square brackets, which are reserved for denoting concentrations or insertions in direct quotes.

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The manuscript must be in Microsoft Word or RTF document format. Text must be single spaced, in 12-point Times New Roman font, and contain no unnecessary formatting (such as text in boxes, with the exception of Tables).

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All references should be listed at the end of the article in numerical order of appearance in the **Vancouver style** (not alphabetical order). Approved abbreviations of journal titles must be used; see the List of Journals in Index Medicus.

Names and initials of all authors should be given; if there are more than six authors, the first three names should be given followed by et al. First and last page, volume and issue numbers should be given.

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**Journal references:**

Price NC, Jacobs NN, Roberts DA, et al. Importance of asking about glaucoma. *Stat Med* 1998;289(1):350-355. [<http://dx.doi.org/10.1000/hgjr.182>] [PMID: 2764753]

**Book references:**

Jeffcoate N. *Principles of Gynaecology*. 4<sup>th</sup>ed. London: Butterworth, 1975:96-101.

*Chapter/section in a book:*

Weinstein L, Swartz MN. Pathogenic Properties of Invading Microorganisms. In: Sodeman WA jun, Sodeman WA, eds. *Pathologic Physiology: Mechanisms of Disease*. Philadelphia: WB Saunders, 1974:457-472.

**Internet references:**

World Health Organization. *The World Health Report 2002 - Reducing Risks, Promoting Healthy Life*. Geneva: World Health Organization, 2002. <http://www.who.int/whr/2002> (accessed 16 January 2010).

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Author(s). Title. Publisher place: publisher name, year; pages.

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## APPENDIX B

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# **AUTHOR'S GUIDELINES: PREVENTIVE MEDICINE**

## **AUTHOR'S GUIDELINES**

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- Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); the resolution is too low.
- Supply files that are too low in resolution.
- Submit graphics that are disproportionately large for the content.

#### *Color artwork*

Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color on the Web (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. **For color reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article.** Please indicate your preference for color: in print or on the Web only. For further information on the of electronic artwork, see <http://www.elsevier.com/artworkinstructions> .

Please note: Because of technical complications which can arise by converting color figures to 'gray scale' (for the printed version should you not opt for color in print) please submit in addition usable black and white versions of all the color illustrations.

### *Figure captions*

Ensure that each illustration has a caption. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

### *Text graphics*

Text graphics may be embedded in the text at the appropriate position. If you are working with LaTeX and have such features embedded in the text, these can be left.

### *Tables*

Number tables consecutively in accordance with their appearance in the text. Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article.

Tables should be short, single-spaced and begin on a separate page. Table legends should provide details on the location and date of the study, and the study population (if applicable). The aim of presenting table results is not only to show adjusted effects but also to enable readers to understand the methods used, evaluate the results, and potentially integrate them into meta-analyses. Thus, presentation of sufficient detail in tables to permit readers to compute crude (unadjusted) effects is strongly encouraged. (For example, adjusted odds ratios should also be accompanied by subgroup sample sizes or percentages for each variable included in the model.)

### ***References***

#### **Reference List Style**

References should be arranged first alphabetically and then further sorted chronologically if necessary.

More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

**Author names** {last name & initial(s) - without period(s) or comma between} in the reference list should appear as follows:

1. Single author: the author's name and the year of publication;
2. Two authors: both authors' names and the year of publication;
3. Three or more authors: first nine (maximum) author's names followed by 'et al.' and the year of publication.

## **Examples:**

### **References to journal publications (list volume, but not issue, number):**

Milikan R, 2002. The changing face of epidemiology in the genomics era. *Epidemiology* 13:472-480.

Altman DG, Royston P, 2000. What do we mean by validating a prognostic model? *Stat Med* 19:453-73.

Blair A, Saracci R, Vineis P, Cocco P, Forastiere F, Grandjean P, Kogevinas M, Kriebel D, McMichael A, et al., 2009. Epidemiology, public health and the rhetoric of false positives. *Environ Health Perspect* 117:1809-1813.

### **Reference to a book:**

Strunk Jr W, White, EB, 1979. *The Elements of Style*, 3<sup>rd</sup>ed., Macmillan, New York.

### **Reference to a chapter in an edited book:**

Mettam GR, Adams LB, 1999. How to prepare an electronic version of your article, in: Jones, BS, Smith RZ (Eds.), *Introduction to the Electronic Age*. E-Publishing Inc., New York: 281-304.

## **Citations in the text**

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

### **All citations in the text should refer to:**

1. Single author: the author's name (without initials, unless there is ambiguity) and the year of publication;
2. Two authors: both authors' names and the year of publication;
3. Three or more authors: first author's name followed by 'et al.' and the year of publication. Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.

Examples: ‘as demonstrated (Allan, 1996a, 1996b, 1999; Allan and Jones, 1995). Kramer et al. (2000) have recently shown ....’

### *Reference links*

Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as

Scopus, CrossRef and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is encouraged.

### *Web references*

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

### *Reference management software*

This journal has standard templates available in key reference management packages EndNote (<http://www.endnote.com/support/enstyles.asp>) and Reference Manager (<http://refman.com/support/rmstyles.asp>). Using plug-ins to word processing packages, authors only need to select the appropriate journal template when preparing their article and the list of references and citations to these will be formatted according to the journal style which is described above.

### *Free Reference Style*

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume and issue/book chapter and the pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct. If you do wish to format the references yourself they should be arranged according to the following examples:

### *Journal abbreviations source*

Journal names should be abbreviated according to the

List of title word abbreviations: <http://www.issn.org/2-22661-LTWA-online.php>.

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Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages at <http://www.elsevier.com/artworkinstructions>. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and print versions for the portions of the article that refer to this content.

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Supplementary files offer the author additional possibilities to publish supporting applications, high resolution images, background datasets, sound clips and more. Supplementary files supplied will be published online alongside the electronic version of your article in Elsevier Web products, including

ScienceDirect: <http://www.sciencedirect.com>. In order to ensure that your submitted material is directly usable, please provide the data in one of our recommended file formats. Authors should submit the material in electronic format together with the article and supply a concise and descriptive caption for each file. For more detailed instructions please visit our artwork instruction pages at <http://www.elsevier.com/artworkinstructions>.

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The following list will be useful during the final checking of an article prior to sending it to the journal for review. Please consult this Guide for Authors for further details of any item.

### **Ensure that the following items are present:**

One author has been designated as the corresponding author with contact details:

- Email address
- Full postal address

- Telephone

All necessary files have been uploaded, and contain:

- Keywords
- All figure captions
- All tables (including title, description, footnotes)

**Further considerations**

- Manuscript has been 'spell-checked' and 'grammar-checked'
- All references mentioned in the Reference list are cited in the text, and vice versa
- Permission has been obtained for use of copyrighted material from other sources (including the Web)
- Color figures are clearly marked as being intended for color reproduction on the Web (free of charge) and in print, or to be reproduced in color on the Web (free of charge) and in black-and-white in print
- If only color on the Web is required, black-and-white versions of the figures are also supplied for printing purposes

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# APPENDIX C

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## DEMOGRAPHIC INFORMATION

## INFORMED CONSENT

### Demografiese inligting

Voorletters & Van: \_\_\_\_\_ Noemnaam: \_\_\_\_\_  
Geboortedatum: \_\_\_\_\_ Dominansie: \_\_\_\_\_  
Selnr: \_\_\_\_\_ Vriend in sport nr: \_\_\_\_\_  
Naam van naasbestaande: \_\_\_\_\_ Telefoonnr. van naasbestaande: \_\_\_\_\_  
Mediese kondisie: \_\_\_\_\_ Medikasie: \_\_\_\_\_  
Supplemente: \_\_\_\_\_ Viak van spel: \_\_\_\_\_

### Beseringsgeskiedenis

Site of injury: \_\_\_\_\_ Acute / Chronic  
Severity: Minor (*return to game / training session*) Game / Training  
Mild (*missed one week*)  
Moderate (*missed two weeks*)  
Severe (*missed more than two weeks*)  
Diagnosed by: (Doctor; physio; other)

### Liggaamsamestelling

Liggaamslengte: \_\_\_\_\_ Liggaamsmassa: \_\_\_\_\_

**BIOMECHANICAL EVALUATION**

**POSTURE**

Forward head: \_\_\_\_\_

Forward shoulders: (L) \_\_\_\_\_ (R): \_\_\_\_\_

Pelvic AP-tilt(L): \_\_\_\_\_ (R): \_\_\_\_\_

Adam's Test: \_\_\_\_\_

Scapula position (L): Spine to root \_\_\_\_\_ cm

Spine to medial wall \_\_\_\_\_ cm

Spine to inferior angle \_\_\_\_\_ cm

Wall to acromionprocess \_\_\_\_\_ cm

Scapula position (R): Spine to root \_\_\_\_\_ cm

Spine to medial wall \_\_\_\_\_ cm

Spine to inferior angle \_\_\_\_\_ cm

Wall to acromionprocess \_\_\_\_\_ cm

**GONIOMETRY**

Shoulder internal rotation (L): \_\_\_\_\_ / \_\_\_\_\_

Shoulder internal rotation (B)(L): \_\_\_\_\_ / \_\_\_\_\_

Shoulder external rotation (L): \_\_\_\_\_ / \_\_\_\_\_

Shoulder internal rotation (R): \_\_\_\_\_ / \_\_\_\_\_

Shoulder internal rotation (B)(R): \_\_\_\_\_ / \_\_\_\_\_

Shoulder external rotation (R): \_\_\_\_\_ / \_\_\_\_\_

Abdominal Stability test: \_\_\_\_\_ / \_\_\_\_\_

**CONFIDENTIAL**

**Informed consent form**



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

**PART 1**

**1. School / Institute:**

School for Biokinetics, Recreation and Sport Science

**2. Title of the project/trail:**

The effect of an exercise intervention on upper body and shoulder joint anatomical, postural, range of motion and strength characteristics in overhead sport participants.

**3. Full names, surname and contact details of project leader:**

Erna Jana Bruwer, (018) 299-2034, Erna.Bruwer@nwu.ac.za

**4. Rank/position of project leader:**

Lecturer of anatomy and orthopedic rehabilitation in the School for Biokinetics, Recreation and Sport Science

**5. Full names, surname and qualifications of supervisor of the project:**

Not applicable

**6. Name and address of supervising medical officer:**

Not applicable

**7. Aims of this project:**

- To determine postural, anatomical, range of motion and strength adaptations to the shoulder and glenohumeral joint of overhead sport participants.
- To determine the effect of a 6-week intervention program on the postural, anatomical, range of motion and strength adaptations of overhead sport participants.
- To determine whether the effect of the 6-week intervention program remains after a 3-month wash-out period.

**8. Explanation of the nature of all procedures, including identification of new procedures:**

***Demographic and general information***

The subject's demographic and personal information (age, gender, race, etc.) will be collected by means of a general information questionnaire. The subject's exercising habits, injury history and competing level will also be determined by means of this questionnaire. Data will be collected via a test battery which will include the following measurements.

## **Posture**

Static posture will be evaluated by means of the Qualysis motion capture system.

- Forward head
- Forward shoulders
- Scapula position
- Pelvic AP-tilt
- Q-angle

## **Range of Motion and functional testing**

A qualified Biokineticist will measure range of motion with a goniometer.

- Shoulder Internal Rotation (Block & End Range)
- Shoulder External Rotation
- Hip Internal Rotation
- Hip External Rotation
- Hamstring Straight leg raise (Block & End Range)
- Thomas & Kendall (Quads & Hipflexors)
- Ankle plantarflexion
- Ankle dorsiflexion
- Soleus flexibility
- Abdominal stability

## **Stability and strength testing**

The Biodex Isokinetic system and Qualysis motion capture system will be integrated with the Noraxon EMG-unit to measure the strength of the shoulder internal, shoulder external rotators, shoulder flexors and shoulder extensors. Scapular stability will be examined indirectly with the firing patterns of the serratus anterior muscle, lower trapezius muscle and the upper trapezius muscle by means of the EMG-unit. Abdominal stability will be measured with a goniometer and the Qualysis motion capture system will be used to determine pelvic and lower extremity stability while the athlete performs a single leg squat.

- EMG (Upper traps, Lower traps, Serratus anterior):
  - Shoulder forward flexion
  - Reaching task
  - Loaded Scapula-humeral rhythm
  - Single leg squat / step down
- Isokinetic testing
  - Shoulder IR/ER
  - Shoulder Flexion/Extension
- Abdominal stability

### **9. Description of the nature of discomfort or hazards of probable permanent consequences for the subjects which may be associated with the project:**

The exercise interventions for this project are based on stabilization interventions used for rehabilitation. Therefore, the participant may only experience discomfort during the flexibility interventions.

### **10. Precautions taken to protect the subjects:**

Only subjects that do not suffer from injuries at the time of testing and intervention will participate in the project. A warm-up and familiarization period will precede each of the testing sessions. Qualified

Biokineticists will perform all test procedures and the intervention sessions will also be guided by these Biokineticists.

**11. Description of the benefits which may be expected from this project:**

Athletes will gain a better understanding of the role of stabilization exercise sessions in injury prevention and long term performance outcomes.

**12. Alternative procedures which may be beneficial to the subjects:**

Baseline testing will equip athletes with knowledge of weak links in their postural, range of motion and strength characteristics.

**PART 2**

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

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

1. Participation in this project is voluntary.
2. You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of the project.
3. We encourage you to ask questions at any stage about the project and procedures to the project leader or personnel, who will readily give more information.
4. If you are a minor, we need written approval of your parent or guardian before you may participate.
5. We require that you indemnify the University from any liability due to detrimental effects of treatment to yourself or another person due to participation in this project, as explained in Part 1.
6. If you are married, it is required that your spouse abandon any claims that he/she could have against the University regarding treatment or death of yourself due to the project explained in Part 1.

**PART 3**

**Consent**

**Title of the project:**

The effect of an exercise intervention on upper body and shoulder joint anatomical, postural, range of motion and strength characteristics in overhead sport participants.

I, the undersigned ..... (full names) read/listened to the information regarding 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 with 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 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:.....

# APPENDIX D

## LETTER OF ETHICAL APPROVAL



Private Bag X5001, Potchefstroom  
South Africa 2520

Tel: 018 299-1111/2222  
Web: <http://www.nwu.ac.za>

To whom it may concern

Ethics Sub-committee  
Tel: 018 2992092  
Fax: 018 2992088  
Email: [Minnie.Greeff@nwu.ac.za](mailto:Minnie.Greeff@nwu.ac.za)

10 June 2013

Dear Prof./Dr./Mr./Ms

**Ethics Application: NWU-00026-12-S1**

**"The effect of an exercise intervention on selected postural, biomechanical and strength characteristics of overhead athletes"**

All ethical concerns were addressed and ethical approval is granted.

Yours sincerely



Prof. Minnie Greeff  
Acting Chairperson

Original details: Prof. Minnie Greeff\18187208\ C:\Users\13210572\Documents\ETBE\02012\ETHICS\NWU-00026-12-S1.docm  
10 June 2013  
File reference: NWU-00026-12-S1b

## APPENDIX E

### LETTER FROM LANGUAGE EDITOR



9 March 2017

I, Ms Cecilia van der Walt, hereby confirm that I took care of the editing of the dissertation of GJR Groenewald titled *The effect of exercise intervention on shoulder girdle biomechanics and isokinetic shoulder muscle strength in university level cricket players: a bilateral comparison.*

MS CECILIA VAN DER WALT

BA (*Cum Laude*)  
THED (*Cum Laude*),  
Plus Language editing and translation at Honours level (*Cum Laude*),  
Plus Accreditation with SATI for Afrikaans and translation  
Registration number with SATI: 1000228

Email address: ceciliavdw@lantic.net

Mobile: 072 616 4943

Fax: 086 578 1425

# APPENDIX F

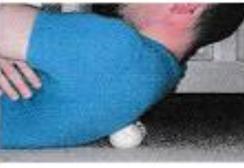
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## INTERVENTION PROGRAMME

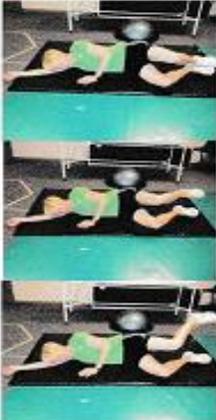
## Sports injury prevention project

### Exercise intervention for overhead athletes

<b>Program 1</b> (2 sessions of 45 minutes; 2 times per week for 2 weeks)	
	<p>Roll out lumbar &amp; thoracic area with foamroller 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Keep pelvic neutral Keep hips in line Relax shoulders</p>
	<p>Roll out latissimus dorsi (left &amp; right sides) 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Keep pelvic neutral Relax shoulders</p>
	<p>Roll out gluteus muscles (left &amp; right sides) 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Lean over to the side Relax shoulders</p>
	<p>Roll out quadriceps muscle group 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Tilt pelvis posterior ("buttocks to heels") Rotate legs (femurs) while rolling Relax shoulders</p>
	<p>Roll out TFL 1 x 10</p> <p><b>Special instructions:</b> Roll slowly – lean over to side Tilt pelvis posterior ("buttocks to heels") Relax shoulders</p>
	<p>Hamstring stretch (Gluteus &amp; peroneus longus also included) 2 x 30 sec (both sides)</p> <p><b>Special instructions:</b> Supine in pelvic neutral Leg which stretches = slightly bent Rotate femur to opposite shoulder &amp; pull leg towards opposite shoulder Relax shoulders</p>

	<p><b>Piriformis / Gluteus stretch</b> 2 x 30 sec (both sides)</p> <p><u>Special instructions</u> Upper leg (front) in line with trunk 90° bend in knee Posterior pelvic tilt Lean forward with straight back &amp; chin tuck</p>
	<p><b>Posterior capsule stretch</b> 2 x 30 sec</p> <p><u>Special instructions</u> Patient on side – lower arm's humerus= shoulder height &amp; 90° bend in elbow. Push with other hand on forearm to internally rotate humerus (upper arm).  Ball posterior underneath lateral rotators of humerus.</p>
	<p><b>Thoracic extensions</b> 3 x 5 sec (3 different positions – starting at lower thoracic region)</p> <p><u>Special instructions</u> Hips, knees and feet = in line. Neutral spine Shoulders to buttocks &amp; Chin tuck (long neck) Contract pelvic floor Inhale – extend thoracic spine over tennis balls on exhale – keep 5sec Keep stable lower back and pelvis position</p>
	<p><b>Bridging</b> 1 x 10</p> <p><u>Special instructions</u> Hips, knees and feet = in line. Shoulders to buttocks Chin tuck (long neck) Inhale – on exhale, contract pelvic floor &amp; gluts &amp; role up with hips Inhale – on exhale, keep contractions &amp; role down with hips (slowly)</p>
	<p><b>Bridging</b> 1 x 5 (hold for 5 sec)</p> <p><u>Special instructions</u> Hips, knees and feet = in line, Shoulders to buttocks, Chin tuck Inhale – on exhale, contract pelvic floor &amp; gluts &amp; role up with hips Inhale - on exhale, contract R glut &amp; IRL L foot 5cm from floor (5 sec) (keep hips in line &amp; keep pelvic floor contraction) Repeat above mentioned with other side Inhale – on exhale, keep contractions &amp; role down with hips (slowly)</p>
	<p><b>Modified crunches</b> 2 x 10</p> <p><u>Special instructions</u> Supine – hips, knees &amp; feet in line On exhale – contract pelvic floor, chin tuck &amp; lift upper body from floor Keep 10 sec, then 10 x small pumps with abdominals Relax shoulders</p>

	<p><b>Shoulder External Rotation in 45° humerus abduction</b> 2 x 10</p> <p><b>Special instructions</b> Feet shoulder width apart – foot “triangle” – knees slightly bent – pelvic neutral – shoulders slightly retracted &amp; depressed (to buttocks) – chin tuck. Humerus 45° abducted in scapular plane - 90° flexion in elbow – keep wrist straight Slurp humerus &amp; Externally rotate elastic band &amp; <u>slowly</u> back!!</p>
	<p><b>Exercise for lower trapezius</b> 2 x 10 (hold 5sec)</p> <p><b>Special instructions</b> Prone Upper arms (humerus) in 120° abduction &amp; externally rotated, elbows slightly bent Tilt pelvis posterior (buttocks to heels), chin tuck &amp; shoulders retracted &amp; depressed Lift forearms from the floor - push elbow down &amp; hold 5 sec</p>
<p><b>Adjustment 1</b> (2 sessions of 45 minutes; 2 times per week for 2 weeks)</p>	
	<p><b>Roll out lumbar &amp; thoracic area with foamroller</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Keep pelvic neutral Keep hips in line Relax shoulders</p>
	<p><b>Roll out latissimus dorsi (left &amp; right sides)</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Keep pelvic neutral Relax shoulders</p>
	<p><b>Roll out gluteus muscles (left &amp; right sides)</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Lean over to the side Relax shoulders</p>
	<p><b>Roll out quadriceps muscle group</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Tilt pelvis posterior (“buttocks to heels”) Rotate legs (femurs) while rolling Relax shoulders</p>
	<p><b>Roll out TFL</b> 1 x 10</p> <p><b>Special Instructions:</b> Roll slowly – lean over to side Tilt pelvis posterior (“buttocks to heels”) Relax shoulders</p>

	<p><b>Thoracic extensions</b>  <b>3 x 5 sec (3 different positions – starting at lower thoracic region)</b></p> <p><b>Special instructions</b>  Hips, knees and feet = in line,  Neutral spine  Shoulders to buttocks &amp; Chin tuck (long neck)  Contract pelvic floor  Inhale – extend thoracic spine over tennis balls on exhale – keep 5sec  Keep stable lower back and pelvis position</p>
	<p><b>Posterior capsule stretch</b>  <b>2 x 30 sec</b></p> <p><b>Special instructions</b>  Patient on side – lower arm's humerus = shoulder height &amp; 90° bend in elbow.  Push with other hand on forearm to internally rotate humerus (upper arm).  Note the ball posterior underneath lateral rotators of humerus.</p>
	<p><b>Bridging with tennis balls on upper traps / levator scap</b>  <b>1 x 5</b></p> <p><b>Special instructions</b>  Hips, knees and feet = in line, Shoulders to buttocks, Chin tuck  Inhale – on exhale, contract pelvic floor &amp; gluts &amp; roll up with hips  Inhale - on exhale, contract R glut &amp; lift L foot 5cm from floor  Hold 10 sec &amp; then small pumping actions with gluts x 10  (keep hips in line &amp; keep pelvic floor contraction)  Repeat above mentioned with other side  Inhale – on exhale, keep contractions &amp; roll down with hips (slowly)</p>
	<p><b>Thoracic extension + Lower Trapezulis exercise</b>  <b>(5 x 5 seconds)x2</b></p> <p><b>Special instructions</b>  Prone – arms 120° shoulder abduction – thumbs to roof (Humerus ER)  Posterior pelvic tilt – chin tuck (deep neck flexion) – then thoracic extension – shoulders retracted &amp; depressed  Tumbs up &amp; hold 5 second</p>
	<p><b>Clamp / hip abductions with 90° knee flexion / hip extensions (pulses)</b>  <b>2 x 10</b></p> <p><b>Special instructions</b>  Side lying – 120 hip flexion and 90 knee flexion  Hips and ribs apart &amp; pelvic neutral  Lift knees slowly up &amp; down x 10 reps  Keep up x 10 seconds</p> <p style="text-align: center;">↕</p> <p>Lift heels in line with knees and hold 10 seconds</p> <p style="text-align: center;">↕</p> <p>Kick backwards diagonally slowly x 10 reps</p>

	<p><b>Diagonal shoulder flexion</b> 2 x 15</p> <p><b>Special instructions</b> Stand with feet shoulder width apart – “triangle” in feet – knees slightly bend – neutral pelvis – shoulders retracted and depressed (set scapula) – chin tuck - Pull blue elastic band from opposite hip, diagonally to opposite shoulder with slightly bent elbow (keep wrist straight)</p>
	<p><b>Shoulder External Rotation in 45° humerus abduction on bosu</b> 2 x 15</p> <p><b>Special instructions</b> Feet shoulder width apart – foot “triangle” – knees slightly bent – pelvic neutral – shoulders slightly retracted &amp; depressed (to buttocks) – chin tuck. Humerus 45° abducted in scapular plane - 90° flexion in elbow – keep wrist straight Externally rotate humerus with elastic band &amp; slowly back!!</p>
<p><b>Adjustment 2</b> (2 sessions of 45 minutes; 2 times per week for 2 weeks)</p>	
	<p><b>Roll out thoracic area with thoracic extension</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly &amp; extend for 3sec with each roll Keep pelvic neutral Keep hips in line Relax shoulders</p>
	<p><b>Roll out latissimus dorsi (left &amp; right sides)</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Keep pelvic neutral Relax shoulders</p>
	<p><b>Roll out gluteus muscles (left &amp; right sides)</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Lean over to the side Relax shoulders</p>
	<p><b>Roll out quadriceps muscle group</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly Tilt pelvis posterior (“buttocks to heels”) Rotate legs (femurs) while rolling Relax shoulders</p>
	<p><b>Roll out TFL</b> 1 x 10</p> <p><b>Special instructions:</b> Roll slowly – lean over to side Tilt pelvis posterior (“buttocks to heels”) Relax shoulders</p>

	<p><b>Posterior capsule stretch</b> 2 x 30 sec</p> <p><b>Special instructions</b> Patient on side – lower arm's humerus = shoulder height &amp; 90° bend in elbow. Push with other hand on forearm to internally rotate humerus (upper arm).  Ball posterior underneath lateral rotators of humerus.</p>
	<p><b>Bridging with tennis balls on upper trapz / levator scap</b> 1 x 5 (both sides)</p> <p><b>Special instructions</b> Hips, knees and feet = in line. Shoulders to buttocks, Chin tuck Inhale – on exhale, contract pelvic floor &amp; gluts &amp; role up with hips Inhale - on exhale, contract R glut &amp; lift L foot 5cm from floor Hold 10 sec &amp; then small pumping actions with gluts x 10 (keep hips in line &amp; keep pelvic floor contraction) Repeat above mentioned with other side Inhale – on exhale, keep contractions &amp; role down with hips (slowly)</p>
	<p><b>Bridging</b> 1 x 10</p> <p><b>Special instructions</b> Hips, knees and feet = in line. Shoulders to buttocks Chin tuck (long neck) Inhale – on exhale, contract pelvic floor &amp; gluts &amp; role up with hips Inhale – on exhale, keep contractions &amp; role down with hips (slowly)</p>
	<p><b>Thoracic extension + Rhomboids &amp; Middel Trapezuis exercise on bosu</b> 2 x 10 seconds &amp; 10 pulses</p> <p><b>Special instructions</b> Prone on bosu – arms on side – palms facing down (Humerus ER) Posterior pelvic tilt – chin tuck (deep neck flexion) – then cervical extension – shoulders retracted &amp; depressed Lift palms from floor &amp; hold 10 second – then 10 pulses upwards</p>
	<p><b>Thoracic extension + Rhomboids &amp; Middel Trapezuis exercise on bosu</b> 2 x 10 seconds &amp; 10 pulses</p> <p><b>Special instructions</b> Prone on bosu – arms shoulder height – thumbs to roof (Humerus ER) Posterior pelvic tilt – chin tuck (deep neck flexion) – then cervical extension – shoulders retracted &amp; depressed Lift palms from floor &amp; hold 10 second – then 10 pulses upwards</p>
	<p><b>Exercise for lower trapezius with blue elastic band</b> 10 reps slowly out and in with forearms 10 seconds hold 10 reps pulses out and in with forearms } X 2</p> <p><b>Special instructions</b> Prone Upper arms (humerus) in 120° abduction &amp; externally rotated, elbows slightly bent Tilt pelvis posterior (buttocks to heels), chin tuck &amp; shoulders retracted &amp; depressed Lift forearms from the floor &amp; do reps as descibed above!!</p>



Clamp / hip abductions with 90° knee flexion / hip extensions (pulses) with blue elastic band above knees.  
2 x 10

Special instructions

Side lying – 120° hip flexion and 90° knee flexion  
Hips and ribs apart & pelvic neutral  
Lift knees slowly up & down x 10 reps  
Keep up x 10 seconds



Lift heels in line with knees and hold 10 seconds



Kick backwards diagonally slowly x 10 reps

