

THE ASSOCIATION BETWEEN ACTIVE MYOFASCIAL TRIGGER
POINTS OF THE SHOULDER EXTERNAL ROTATOR MYOTACTIC UNIT
ON ALTERING INTERNAL/EXTERNAL PEAK TORQUE AND SINGLE
REPETITION WORK RATIOS IN OVERHEAD ATHLETES.

By

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Technology: Chiropractic at the Durban Institute of Technology.

I, Gregg Audie, do declare that this dissertation is representative of my own
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DEDICATION

If you love life, don't waste time, for time is what life is made up of.

- - Bruce Lee

I dedicate this work to my family who has given so much time, effort and sacrifice to help me achieve my goals. Your love and support carried me through the most trying of times and I could never thank you enough.

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ABSTRACT

The purpose of this study was to investigate the association between active Myofascial Trigger Points in the dominant shoulder external rotator muscle group in overhead throwing athletes and an altered internal/external rotation peak torque and single repetition work ratio of the involved shoulder.

The repetitive throwing motion performed by overhead throwing athletes (tennis players, baseball pitchers and waterpolo players) places the shoulder rotator myotactic unit at a high risk of sustaining microtraumatic injury.

The throwing action involves a concentric contraction of the internal rotators (large muscle mass) of the dominant shoulder during the acceleration phase. During the deceleration phase, the external rotators (small muscle mass), contract eccentrically to decelerate the arm.

Numerous studies have been conducted on internal/external ratios of the shoulder in throwing athletes, revealing a relative external rotation strength deficit on the dominant shoulder. Many of these athletes complained of persistent Repetitive Stress Injuries (RSI) of the shoulder complex. It can be reasoned therefore, that the muscle imbalances create a predisposition toward shoulder injuries caused by overuse.

The activation of a myofascial trigger point is associated with some degree of mechanical abuse of the muscle in the form of muscle overload, which may be acute, sustained and/or repetitive. According to prevailing literature, the presence of myofascial trigger points could result in a combination of the following signs and symptoms: spasm of other muscles, weakness of involved muscle function, loss of co-ordination and decreased work tolerance of the involved muscle. The presence of myofascial trigger points in the shoulder external rotator myotactic unit could thus result in an altered internal/external rotation ratio in such athletes.

Sixty overhead throwing athletes were screened for active myofascial trigger points within the group and their specific location and severity noted. Subjects were evaluated using a standardized isokinetic testing protocol on a Cybex 700 Dynamometer on the following day. Internal/external rotation ratios were noted and compared to established normative values. To test for associations between an altered rotation ratio and the myofascial trigger points, the SPSS statistical package was used. For the various statistical tests which were applied, the alpha level used to assess significance of the p-value was 0.05. Two tailed tests were used in all instances.

The results show that mean internal/external rotation ratios for peak torque and work exceeded the normal value of 150% ($p < 0.001$), with 95% confidence intervals which did not overlap with 150%. Thus the mean ratios were significantly higher than normal. 90% of concentric ratios were above normal and 85% of eccentric contraction ratios were above normal. Since the majority of subjects had more than one trigger point, subjects were classified on the basis of whether their trigger points were mainly agonistic (i.e. they had more agonistic than antagonistic trigger points), mainly antagonistic, or equally agonistic and antagonistic. Most subjects (76.7%) had mainly agonistic trigger points.

The number and location of the trigger points were not significantly associated with altered internal/external ratios, although the data did show a trend of higher median number of trigger points in subjects with altered ratios. A possible reason being that the sample was too similar (i.e. The majority of athletes had altered ratios), which meant the sample group without altered ratios was too small to show any significant difference to the group with altered ratios.

The severity of trigger points was not statistically significant between the groups with altered and normal ratios, except for concentric peak torque ratio, where severity score for total trigger points was significantly higher in those with above normal ratio ($p = 0.037$). There was a visible trend of higher median trigger point severity score in the groups with altered ratios, although statistical significance was not achieved. The sample all had severe trigger points, not allowing much variation in the trigger point severity score. The sample size in the group without altered was too small to show any significant difference to the group with altered ratios.

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DEFINITION OF TERMS

AGONISTIC MUSCLE

Muscles, or portions of muscles, so attached anatomically that when they contract they develop forces that complement or reinforce each other (Travell, Simons and Simons, 1999: p1).

ANTAGONISTIC MUSCLE

Muscles, or portions of muscles, so attached anatomically that when they contract they develop forces that oppose each other (Travell, Simons and Simons, 1999: p2).

CONCENTRIC CONTRACTION

The development of tension by muscle while the origin and insertion approximate each other (Davies, 1992:p25).

ECCENTRIC CONTRACTION

The development of tension that occurs as the origin and insertion move away from each other (Davies, 1992:p25).

ISOKINETIC EXERCISE

The term isokinetic exercise refers to a process in which a body segment accelerates to achieve a pre-selected fixed speed with totally accommodating resistance through out the range of motion (Cybex, 1996:p1-9,c-2).

ISOTONIC CONTRACTION

A voluntary contraction that causes movement to occur and consists of 2 types of contraction; concentric and eccentric contractions (McAtee and Charland, 1999: p6).

MYOFASCIAL PAIN SYNDROME (MPS)

Myofascial Pain Syndrome (MPS) is a regional muscular disorder that results from myofascial trigger points (Lee et al., 1997: p81-89; Chaitow and Delany, 2002: p124). Both active and latent myofascial trigger points can result in MPS (Hou et al., 2002: p1411-1412).

MYOFASCIAL TRIGGER POINT (MTrp)

Is defined as “a hyperirritable spot ” in skeletal muscle that is associated with a hypersensitive palpable nodule in a taut band. Snapping or palpation of the band may produce a local twitch response. The spot is painful on compression and can give rise to characteristic referred pain, referred tenderness, motor dysfunction and autonomic phenomena” (Travell, Simons and Simons, 1999: p5; Chaitow and Delany, 2002: p18).

MYOTACTIC UNIT

Also termed functional unit (Lawrence et al., 1996: p73-74), is a group of agonist and antagonist muscles that function together as a unit because they share common spinal reflex responses (Travell, Simons and Simons, 1999: p3).

OVERHEAD ATHLETE

Athletes performing a wide variety of activities while the shoulder is placed in a position of elevation, abduction, and rotation. Examples of these superimposed activities include throwing, tennis, swimming and volleyball (Andrews, 1994: p524).

OVERUSE SYNDROME

The “typical” shoulder overuse injury is a composite of several things gone awry, including structural injury, muscle dysfunctions, and failed compensatory mechanisms, each complicating each other. The term Overuse Syndrome describes the clinical problem (Garrick and Webb, 1999: p121).

REPETITIVE STRESS/STRAIN INJURY (RSI)

Condition caused by a single repetitive activity or by a continuum of exposures that extend from the workplace to common activities of daily living. Highly repetitive work has been defined as activities in which the length of the fundamental work cycle is less than thirty seconds or in which more than fifty percent of the work cycle is spent performing the same bodily actions (Lawrence et al., 1997: p238).

ROTATOR CUFF MUSCLE GROUP

Four interrelated muscles (supraspinatus, infraspinatus, teres minor and subscapularis), originating from the scapula which provide the dynamic stability of the glenohumeral joint (Reid, 1992: p901).

CHAPTER ONE:

INTRODUCTION:

1.1 The Problem and its setting:

Shoulder problems have become common in the overhead athlete. Athletes are susceptible to injury and dysfunction because of the repetitive, high-velocity mechanical stress placed on the shoulder, often at extremes of glenohumeral motion (Glousman, 1993: p89-99). Most commonly, the shoulder is placed at risk of sustaining a microtraumatic injury when elevation, abduction, and rotation are required while performing a wide variety of activities. Examples of these superimposed activities include throwing, tennis, swimming, baseball and a variety of work-related activities such as painting and maintenance work. These types of patients are commonly referred to as the overhead athlete or worker (Andrews and Wilk, 1994: p524).

All these activities require internal rotation during acceleration of the throwing action phase, which involves a burst of activity of the internal rotators (Jobe et al., 1984: p218). During the deceleration phase, the posterior rotator cuff must contract eccentrically to decelerate the arm and reduce anterior translational forces (Atwater, 1979: p43; Jobe et al., 1984: p218).

Eccentric loading has been shown to cause intramuscular connective tissue tearing (Davies, 1984: p261-291; Nirschl, 1986: p322-337), which can lead to a cycle of chronic inflammation and muscular weakness (Hinton, 1988: p278). If these stresses are applied at a rate that is faster than the rate of tissue repair, progressive damage can occur (Jobe and Kvitne, 1989: p965).

It is important to recognize that several skeletal muscles working together in functional units, also termed myotactic units, perform most motions of the human body (Lawrence et al., 1996: p73-74). When all muscles within a particular myotactic unit function properly, the result is smooth and fluid joint motion. However, if just one muscle in the units fails to function adequately, the function of the entire unit is adversely affected, and joint motion will be erratic

(Lawrence et al., 1996: p73-74). When one rotator muscle fails to function properly, the end result is faulty shoulder joint motion, a predisposing factor for Repetitive Stress Injuries (RSI's). It is possible to observe a patient for these faulty joint movement patterns and visualize which muscle or muscles are overactivated and which are inhibited or underactivated (Lawrence et al., 1996: p73-74).

The functional unit of shoulder external rotation consists of the infraspinatus muscle which functions in parallel with the teres minor and posterior deltoid for external rotation of the arm (agonists). The subscapularis, pectoralis major and anterior deltoid muscles act as antagonists for external rotation of the arm, (Travell, Simons and Simons, 1999: p555-556).

Because of the small muscle mass of the external rotators and the prevailing lack of strength / endurance training for these muscles, it is not uncommon to see overuse syndromes associated with the external rotators as they attempt to provide their primary role of externally rotating the arm at the glenohumeral joint and stabilizing the head of the humerus in the glenoid cavity during movements of the arm. This is particularly true of the infraspinatus and teres minor muscles (Andrews and Wilk, 1994: p418).

Myofascial Pain Syndrome (MPS) is a regional muscular disorder that results from myofascial trigger points (MTrp's) (Lee et al., 1997: p81-89). The activation of a MTrp is usually associated with some degree of mechanical abuse of the muscle in the form of muscle overload, which may be acute, sustained and/or repetitive. The spot is painful on compression and can give rise to characteristic referred pain, autonomic phenomena and motor dysfunctions (Travell, Simons and Simons, 1999: p5). These motor dysfunctions, as defined by Travell, Simons and Simons, (1999:p21), includes spasm of other muscles, weakness of the involved muscle function, loss of co-ordination and decreased work tolerance of the involved muscle.

According to Lawrence et al. (1996: p73-74), MTrp's can be found in both hypertonic and inhibited muscles, and it is very common to find MTrp's in weak, inhibited muscles such as the infraspinatus. It is possible that the weakness in these muscles is a type of guarding mechanism in which the muscle is reflexively inhibited from full contraction due to pain. Travell, Simons and Simons (1999: p21), state that disturbances of motor functions caused by MTrp's include weakness of involved muscle function and that a muscle harboring a MTrp is prevented by pain from reaching its full stretch range of motion.

Isokinetic evaluation renders objective, reliable data regarding muscular performance during a dynamic contraction and has been utilized frequently for determining the strength ratios of throwing athletes (Montgomery, 1989: p315; Brown et al., 1988: p577; Wilk et al., 1990). Normal shoulder internal / external rotation ratios established through isokinetic testing are 3:2

or 150% (Alderink and Kluck, 1986: p163; Ivey et al., 1984: p127). The ratio may also be expressed as an external / internal rotation ratio, giving a normative value of 2:3 or 66,6% (Ivey et al., 1985: p384-386). The most commonly used parameter in isokinetic testing is peak torque, which is the single highest point on the torque curve (graph) regardless of where in the range of motion it occurs (Davies, 1992: p53). Taking into account changes due to biomechanical leverage and the muscular tension-length relationship that occurs throughout the range of motion, peak torque is indicative of maximum muscular tension capability (Cybex, 1996: pc-4). Thus, peak torque can be expressed as a unilateral ratio between agonist and antagonist muscle groups (Davies, 1992: p61).

Ellenbecker (1991: p9) used a Cybex II isokinetic dynamometer to measure both internal and external rotation strengths of the shoulder in highly skilled tennis players. The dominant arm internal / external rotation ratios in this study ranged from 153% to 154% for peak torque and 165% to 169% for single repetition work, showing a relative external rotation strength deficit on the tennis playing shoulder. The presence of increased unilateral shoulder internal / external rotation strength ratios has also been reported by Cook et al. 1987: p451; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; Koziris et al. 1991:p253 and Pedegana et al. 1982: p352.

Chandler et al. (1992:p455-458) studied baseball and tennis players complaining of persistent RSI's and found significant increases in the strength of internal rotation without subsequent strengthening of the external rotators. Hence they reasoned that the muscle imbalances create a predisposition toward shoulder injuries caused by overuse.

Numerous studies have investigated the presence and extent of disturbed internal/external rotation strength ratios in overhead athletes (Cook et al., 1987: p451; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; Koziris et al., 1991:p253 and Pedegana et al., 1982: p352), resulting in several possible explanations for the overhead athletes' decrease in external rotation strength and concomitant increase in shoulder internal rotation strength in their dominant arms in comparison to established normative values. (Cook, 1987: p451-461; Jobe and Moynes, 1982: p336-339; Pappas et al., 1985: p223-235; and Kendall et al., 1952: p103-154).

The researcher therefore aims to provide a greater insight into the effect of active MTrp's on altering internal/external ratios of the shoulder in throwing athletes.

1.2 Aim and Objectives of the study:

The aim of this investigation is to evaluate the role of MTrp's on altering internal/external ratios of the shoulder in throwing athletes.

Objective One:

To observe the internal/external rotation ratio of the dominant shoulder in throwing athletes using a Cybex 700 isokinetic dynamometer, and detect any altered ratios.

Objective Two:

To observe and quantify the following:

1. The specific location of the TrP's within the shoulder rotator muscle group.
2. The severity of the TrP's (active/latent).

Objective three:

To assess correlations between the objective clinical findings.

1.3 Benefits of the study:

A consistent pattern of relative external rotation strength imbalance has been observed in the dominant shoulder of competitive overhead athletes (Koziris et al., 1991: p253; Ellenbeker, 1991: p9; and Chandler et al., 1992: p455-458). This research aims to provide information regarding the role of MTrp's of the rotator muscle group as a possible etiology or perpetuating factor in shoulder lesions related to muscle imbalance i.e. RSI's.

A better understanding of the etiology or perpetuating factors will allow for further research comparing alternate treatment protocol(s) for shoulder lesions related to muscle imbalance.

With knowledge of specific conservative therapies, myofascial TrP's could then be employed for the treatment of such injuries and their benefits may alter some of the current treatment methods as well as alleviate the trauma, costs and complications of surgical intervention.

After balance is restored between agonists and antagonists within a myotactic unit, any residual muscle weakness can be addressed by therapeutic strengthening exercises (Lawrence et al., 1996: p74).

CHAPTER TWO:

REVIEW OF RELATED LITERATURE:

2.1 Introduction:

This chapter provides a review of available literature on the biomechanics of overarm throwing movements and of throwing injuries related to muscle imbalance, particularly the internal / external rotators of the shoulder. The information reviewed will provide a clearer understanding of the current concepts in the etiology, treatment and nature of repetitive stress injuries and overuse syndromes experienced by the overhead throwing athlete.

2.2 Anatomy of the Glenohumeral joint:

The glenohumeral joint is a multiaxial ball and socket joint and the most freely mobile joint in the body (Freedman, 1966: p1503). The humeral head is approximately one-third of a sphere, orientated at 45 degrees from the long axis of the shaft and retroverted 30 degrees. The glenoid labrum, a fibrocartilagenous rim attaches along its outer perimeter to the shallow pear-shaped glenoid cavity, which increases available contact area by approximately 70 percent. The fibrous capsule attaches peripherally to the margins of the glenoid cavity and the anatomic neck of the humerus, close to the articular margins. Three intrinsic capsular ligaments – the glenohumeral ligaments – provide reinforcement to the joint (Reid, 1989).

Muscles acting about the Glenohumeral joint:

Rotator Cuff Muscle Group:

- Supraspinatus muscle – Primary movement is abduction^a. Nerve supply is from the suprascapular nerve derived from C5-C6 (brachial plexus trunk).

a → prime movers

b → control and centralize position of head of humerus in the glenoid

- Infraspinatus muscle – Involved in external rotation^a, horizontal abduction^b, abduction^b. Nerve supply is from the suprascapular nerve derived from C5-C6 (brachial plexus trunk).
- Teres minor muscle – Movements include external rotation, extension, horizontal abduction^b and abduction^b. Nerve supply is from the axillary (circumflex) nerve derived from C5-C6 (posterior cord).
- Subscapularis muscle – Movements include abduction^b, adduction and internal rotation. Nerve supply is from the subscapular nerve derived from C5-C6 (posterior cord).

Other muscles involved:

- Deltoid muscle – A primary acting muscle involved in forward flexion^a, extension^a, horizontal adduction^a, horizontal abduction^a, abduction^a, internal rotation and external rotation. Nerve supply is from the axillary (circumflex) nerve derived from C5-C6 (posterior cord).
- Pectoralis major muscle – Movements include internal rotation^a, horizontal adduction^a, adduction^a and extension. Nerve supply is from the lateral pectoral nerve derived from C5-C6 (lateral cord).
- Latissimus dorsi muscle – Movements include adduction^a, extension^a and internal rotation. Nerve supply is from the thoracodorsal nerve derived from C6-C8 (posterior cord).
- Teres major muscle – Movements include extension, horizontal abduction^b, adduction and internal rotation. Nerve supply is from the subscapular nerve derived from C5-C6 (posterior cord).
- Coracobrachialis muscle – Forward flexion. Nerve supply is from the musculocutaneous nerve derived from C5-C7 (lateral cord).
- Triceps muscle – Extension. Nerve supply is from the radial nerve derived from C5-C8,T1 (posterior cord).
- Biceps muscle – Involved when strong forward flexion is required. Nerve supply is from the musculocutaneous nerve derived from C5-C7 (lateral cord).

(Magee, 1997: p192-193; Reid, 1992: p903).

It is important to recognize that several skeletal muscles working together in functional units, also termed myotactic units, perform most motions of the human body. (Lawrence et al., 1996: p73-74). A functional unit is a group of agonist and antagonist muscles that function together as a unit because they share common spinal-reflex responses (Travell, Simons and Simons, 1999: p3).

The shoulder external rotator myotactic unit consists of the agonists – infraspinatus, teres minor and posterior deltoid muscles. The infraspinatus muscle functions synergistically with the supraspinatus by stabilizing the head of the humerus in the glenoid cavity. The subscapularis, pectoralis major and anterior deltoid muscles act as antagonists for external rotation of the arm (Travell, Simons and Simons, 1999: p555).

2.3 Biomechanics of the glenohumeral joint:

The glenohumeral joint is a multiaxial, ball-and-socket, synovial joint that depends on muscles rather than bones or ligaments for its support, stability and integrity. The joint has three axes and three degrees of freedom. The glenohumeral joint is in a resting position at 55 degrees of abduction and 30 degrees of horizontal adduction while the close packed position is full abduction and lateral rotation. The capsular pattern of the glenohumeral joint is lateral rotation most limited, followed by abduction and internal rotation (Magee, 1997: p175).

The biomechanics of normal shoulder movement are dependent on the static and dynamic stabilizers about the shoulder that provide stability throughout a full, functional, range of motion (Souza, 1994: p46-51).

2.3.1 STATIC STABILITY:

Primary passive restraint in the shoulder is provided by the glenohumeral ligaments, the posterior capsule, and the coracohumeral ligaments. Tension on the capsule is created, statically and dynamically, by position due to the blended insertions of the rotator cuff musculature with the capsule (Terry et al., 1991: p26).

The coracohumeral ligament restricts and protects flexion and extension of the shoulder. Internal rotation stresses mainly the middle and inferior sections of the posterior capsule while external rotation stresses primarily the middle and inferior sections of the anterior glenohumeral ligament (Terry et al., 1991: p26).

The anterior glenohumeral ligament can be divided into three divisions: superior, middle, and inferior. As a whole unit the anterior glenohumeral ligament tenses with external rotation, extension, and abduction or any combination of these positions. The superior section supports the arm in the resting neutral position. The middle division provides support with the superior section in the resting position. Its contribution continues through about 45 degrees of elevation with a decreasing contribution past 90 degrees. The inferior section is the main stabilizer as the shoulder elevates past 90 degrees (O'Connell et al., 1990:p579).

2.3.2 BONY ARTICULATION:

The glenohumeral joint is inherently unstable. With only a 25 to 30 percent glenoid contact with the humeral head, little stability is evident (Poppen and Walker, 1976: p195).

2.3.3 GLENOID LABRUM:

The labrum, which is the ring of fibrocartilage, surrounds and slightly deepens the glenoid cavity of the scapula. When relaxed, the humerus sits in the upper part of the glenoid cavity; with contraction of the rotator cuff muscles, it is pulled into the lower, wider part of the glenoid cavity. If this 'dropping down' does not occur, full abduction is impossible (Magee, 1997: p175). The glenoid labrum functions to add stability to the glenohumeral joint, which is accomplished through deepening the socket and serving as an attachment site for the glenohumeral ligaments. The labrum is analogous to the knee meniscus in both type of injury and function. Like the meniscus, loss of labral integrity may lead to instability and degenerative changes (Andrews *et al.*, 1991: p901).

It appears that there are generally two mechanisms of injury common to the labrum. The first mechanism involves repetitive activity either in throwing activities such as pitching, tennis serves (in particular the deceleration phase), swimming, or weight training (bench and overhead presses). The second mechanism involves direct trauma, which usually involves a fall on an outstretched arm or with the lead shoulder of a batter or golfer grounding the bat or club, respectively (Howell *et al.*, 1988: p227)

2.3.4 DYNAMIC STABILITY:

The rotator cuff musculature is generally responsible for the dynamic stability of the glenohumeral joint, although there is a haziness in the use of dynamic because the simple presence of a muscle/tendon will statically provide stability in certain positions. Dynamically, though, muscles contraction contributes to stability by causing a compression force of the humeral head into the glenoid and contraction causing a tightening of the capsular insertions of the rotator cuff (the musculotendinous glenoid) (Souza, 1994: p51).

2.3.5 MUSCULAR EFFECTS:

The effectiveness of the shoulder musculature on positioning the arm, moving a hand-held load, and accelerating a load is dependent on the mechanical efficiency of its inherent design. Several muscular factors enter into this equation:

1. Muscle type: Muscles which consist primarily of type 1 slow twitch fibers will have a tendency to maintain long sustained contraction with relatively slow fatigue and a high oxidative capacity. Type 2 or fast twitch fibers are the opposite and are designed for fast contraction innervated by motor neurons that are more "purpose demand" activated, firing at high orientation of muscle fibers (Souza, 1994: p42-43).
2. Fiber orientation: Longitudinal fibers allow for maximum shortening resulting in greater speed while oblique fiber orientation is designed for strength (Souza, 1994: p42-43).
3. Muscle size: Larger muscles such as the pectorals and the latissimus are able to generate more force than smaller muscles such as the rotator cuff. (Souza, 1994: p42-43).
4. Length of the fibers: The position of a muscle relative to a joint can affect the fiber length and the lever length. There is a point referred to as the resting length of a muscle, which represents the best connection or bonding between actin and myosin. Either an increase or a decrease in this length may result in a decrease in available force (Tardieu et al., 1982: p97).
5. Type of contraction: The type of contraction required for a muscle may affect its force capabilities. With isotonic contractions there is a distinct favorability for the eccentric phase (contraction with lengthening) (Souza, 1994: p42-43).
6. Speed: Concentric contractions are decreased as much as 50% with speeds of 214 degrees/s (Perry, 1983: p247).
7. Lever length (a function of position) and type: When a muscle contracts it creates a force at both its sites of attachment and at the joint across which it works. When this force is directed parallel to the joint it causes a shear stress while a force, which is more perpendicular to the plane of the joint, creates a compressive force. Shear forces have a tendency to create instability and degeneration. A shear force, which is not neutralized by either the compressive forces of the inherent muscles or other muscles, will cause a strain to both dynamic and static stabilizing structures (Poppen and Walker, 1978: p165).

The major muscles involved in this equilibrium for the shoulder are the deltoid and rotator cuff. The relative oblique orientation of these muscles to the shoulder, results in a component of shear and compressive force with each contraction. This relationship changes with arm position, changing the relative pull of the muscle resulting in either an increase or decrease in either component (Perry, 1983: p247).

2.3.6 SHOULDER MOVEMENTS:

Resting Position

The support in the resting position is essentially soft tissue and specifically capsular and ligamentous. When challenged by either a weight or tug, shoulder musculature responds preferentially (Saha, 1971: p491).

Shoulder Elevation

Shoulder elevation consists primarily of humeral and scapular movement with a relationship between the two of approximately 2:1 in favour of glenohumeral movement. As an average throughout the full range of elevation the scapular component appears to be 2 degrees for every 3 degrees of humeral movement. Normal active elevation is approximately 180 degrees (Souza, 1994: p55).

Muscles involved in this action are the deltoid, supraspinatus, infraspinatus, subscapularis, teres minor and long head of biceps (if arm is laterally rotated first). (Magee, 1997: p193).

Flexion

Flexion is initiated primarily by the anterior deltoid. Additional assistance is given by the coracobrachialis, the clavicular section section of the pectoralis major, and the biceps. Normal active flexion is between 160-180 degrees. Passive restraint is provided primarily by the inferior glenohumeral ligament and the posterior capsule (Terry *et al.*, 1991: p26).

Extension

Extension of the arm is a rather limited movement as compared to flexion (approximately 60 degrees). The musculature involved includes the posterior deltoid, latissimus dorsi, teres major, and the triceps. Extension is limited by the restraint of the coracohumeral ligament and to a lesser degree some portions of the anterior glenohumeral ligament (O'Connell *et al.*, 1990: p579).

Adduction

Adduction is an extremely powerful movement that is used primarily for stabilization of the shoulder with the trunk. Adduction is normally 50-70 degrees if the arm is brought across the front of the body.

Scapula fixating muscles include the rhomboids, the trapezius, and the serratus anterior. The pectoralis major and latissimus dorsi are strong agonists for adduction (Souza, 1994: p62).

Internal/External Rotation

Internal rotation is inherently a stronger movement than external rotation due to the participation of more and larger musculature (pectoralis major, latissimus dorsi, subcapularis, anterior deltoid, and teres major) (Souza, 1994: p62).

Relatively more range of internal rotation as compared to external rotation is found with adduction of the arm to 90 degrees. Active external rotation is normally 80-90 degrees while internal rotation is normally 60-100 degrees. (Magee, 1997: p186).

External rotation is a weaker movement determined by only a few muscles: the teres minor, infraspinatus, and posterior deltoid. In general, internal rotation is limited by the posterior capsule whereas external rotation is limited by an anterior glenohumeral ligament (Souza, 1994: p62).

Horizontal Flexion/Extension

Most throwing sports, swimming, and racquet sports utilize the approximately 180 degrees of movement provided by this plane of motion. Horizontal flexion is the predominant component equal to 135 degrees of the total movement. In addition to a greater range, the musculature participation is comprised of the strongest shoulder movers, the pectoralis major assisted by the anterior deltoid (Perry, 1988: p1).

Horizontal extension coupled with external rotation is a movement pattern common to most throwing sports during the cocking phase. The primary muscles are the infraspinatus, teres minor, and posterior deltoid for the shoulder. Due to the position of the deltoid in relation to the axis of rotation, the more extension involved, the more of a fulcrum is created that forces the humeral head anterior. The external rotators such as the infraspinatus and teres minor can reduce this tendency by decreasing the effect of the posterior deltoid. Protection is also accomplished by the passive stretching of the anterior musculature, in particular the subscapularis (Perry, 1988: p17).

2.3.7 SCAPULAR POSITIONING:

Retraction

Also referred to as scapular adduction, retraction of the scapula is a necessary component of extension movements of the humerus. The most common example is with the arm at 90 degrees abduction. The medial musculature (middle trapezius and rhomboids), are activated to pull the medial border of the scapula toward the spine. Retraction is necessary for movement patterns in rowing, the recovery phase of swimming, and in the cocking phase of throwing (Souza, 1994: p66).

Protraction

Protraction, often referred to as scapular adduction is an extremely important component of forward arm movements such as the acceleration phase of throwing sports. The serratus anterior is the primary muscle involved. Any forward movement of the humerus must be accompanied by protraction of the scapula (glenoid) to provide a stable base for movement. (Souza, 1994: p67).

Scapular Depression

The scapula depresses when the trunk is lifted such as rising from a chair. The main muscles that initiate the movement are the inferior digitations of the serratus anterior and the lower trapezius muscles. Additional stabilization is provided by the pectoralis major and latissimus dorsi acting at the glenohumeral joint (Souza, 1994: p67).

2.4 Biomechanics of Overarm Sports: The Throwing Motion:

The performance of overhead sports activities such as racquet sports, volleyball, baseball pitching and swimming sports involves a similar pattern of motion (Glousman, 1993: p27-34). Overhead throwing motion places enormous stresses on the shoulder joint and supporting structures, at times, at the limits of its motion. Generation of humeral angular velocity in baseball pitchers has been recorded up to 7000-degrees/ second and rotation torque exceeding 14,000 inch-pounds (Digiovine *et al.*, 1992: p15-25; Kibler, 1991: p525-532). The movement pattern used for most throwing skills usually takes less than one second from the start of the action until object release. In fact, analysis of the overarm throw has revealed that the entire upward and forward arm swing takes less than 400 msec to complete before release, and that the resultant velocity of the ball with respect to a constant spatial reference

can increase from less than 6 m / sec (20 ft/sec) at 100 msec before release to more than 34 m / sec (112ft / sec) at release (Atwater, 1970).

Undoubtedly, the frequent repetition of such an intricately timed, high-velocity throw may be accompanied by relatively large internal forces and could produce severe stress on the muscles, bones, and joints involved (Atwater, 1979: p43). To compensate for these tremendous forces, joint stability is maintained with a combination of static ligamentous capsular constraints and dynamic muscle barriers, primarily, the rotator cuff (Arroyo, 1997: p69-78).

One of the primary functions of the rotator cuff during throwing is to provide a stable fulcrum from which the deltoid can elevate the arm and provide internal and external rotation (Noah, 1988 p1091-1096). The supraspinatus lies across the top of the glenohumeral joint and provides joint compression. This counteracts the shear force generated by the deltoid while elevating the arm. The supraspinatus also aids the deltoid in abduction. The infraspinatus and teres minor both function as external rotators of the arm, whereas the subscapularis acts as an internal rotator as well as a powerful dynamic barrier to anterior displacement of the humeral head (Glousman, 1993: p27-34).

Most overhead sports activities begin with a preparatory phase to position the arm. This is followed by cocking the arm to allow a forceful accelerated release. The muscles then act to decelerate the arm and prevent injury. The baseball throw can be divided into five stages. The first stage is the wind-up or preparation phase. Electroyographic studies in athletes have shown that the rotator cuff is essentially inactive (Jobe et al., 1983: p3-5). The early cocking phase (stage 2) involves shoulder abduction and external rotation. The deltoid supplies the primary force. Late cocking (stage 3) continues until maximum external rotation. The rotator cuff is the most active muscle group, in particular the subscapular. The subscapularis eccentrically contracts and act as a dynamic stabilizer anteriorly (Glousman, 1993: p89-99). Acceleration (stage 4) starts with internal rotation of the humerus and ends with ball release. Again the rotator cuff is almost electrically silent, whereas the pectoralis major and latissimus dorsi are extremely active, contracting in a concentric manner. The follow-through (stage 5) is the deceleration phase. During this phase, the posterior deltoid and posterior cuff musculature is the most active (Jobe et al., 1983: p3-5). In the follow-through phase, eccentric muscle contractions decelerate the upper extremity as the arm moves across the body (Jobe et al., 1986: p218-220).

Muscle Activity During the Stages of a Throw or Pitch

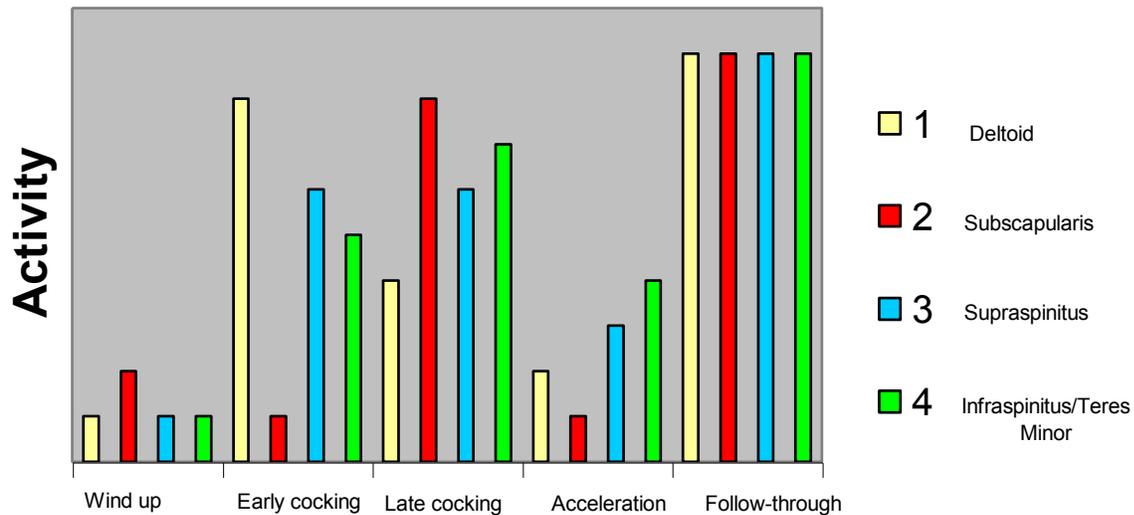


Figure 2.1. A summary of the muscle activity during the stages of a throw or pitch.

Adapted from Jobe et al. (1983: p3-5).

1. The muscle patterns are similar for an easy throw and a wind up pitch.
2. The anterior, middle, and posterior deltoid all have similar patterns with peak activity in the early cocking and follow-through stages.
3. The infraspinatus and teres minor have similar patterns with peak activity in the late cocking and follow-through stages.
4. The Supraspinatus is usually activated just prior to or simultaneously with the Infraspinatus and teres minor.
5. The subscapularis has peak activity at the end of the cocking stage and in the follow-through stage.

(Jobe et al., 1983: p3-5).

A large eccentric load is placed on the posterior RC group during the deceleration phase. Eccentric loading has been shown to increase intramuscular tearing (Davies, 1984: p261-291; Nirschl, 1986: p322-337) which can lead to a cycle of chronic inflammation and muscular weakness. In contrast, the internal rotator undergoes a plyometric type of training (maximally stretching muscle groups, then explosively contracting them in a concentric manner) with each throwing cycle. This type of training has been found to greatly enhance power in larger muscle groups (Miller, 1984: p68-83). These differences in muscular activity during the throwing cycle may partially explain the increase in strength of the dominant shoulder internal rotators, but not in the external rotators of many overhead athletes (Hinton, 1988: p278).

2.5 Incidence of Shoulder Injuries in Throwing Athletes:

A study by Yassi et al. (1996: p461-472), showed RSI's, especially RC tendonitis to be increasing and reaching epidemic proportions in certain industries and in most industrialized countries. The average time loss and cost of these injuries was significantly more than other non-repetitive strain injuries. Green et al. (1998: p354-359) stated that there is little evidence to support or refute the efficacy of common interventions for shoulder pain.

The repetitive throwing motion is a dynamic activity that places extraordinary stresses on the athletes shoulder, the capsuloligamentous complex, and in particular, the rotator cuff (RC) (Neer, 1972:p41). Although "isolated" problems (e.g. RC tendonitis), do occur in throwing athletes, more commonly several structures / functional mechanisms are involved. The "typical" shoulder overuse injury therefore is a composite of several things gone awry, including structural injury, muscle dysfunctions, and failed compensatory mechanisms, each complicating each other. The term Overuse Syndrome describes the clinical problem (Garrick and Webb, 1999:p121).

The RC has an essential role in overhead activities, providing dynamic glenohumeral joint stabilization. Along with the RC, static stabilizers and other scapular muscles work in harmony to maintain a balance of stability and mobility of the glenohumeral joint. Repetitive stresses on this harmonic system can lead to tendonitis, impingement, instability, and rotator cuff tears (Arroyo et al., 1997: p69).

Rotator cuff tendonitis is one of the most common causes of shoulder and dysfunction seen in athletes, and the most common shoulder injury in sports medicine (Brukner, 1996: p1743-5). It is prevalent in individuals who subject their shoulders to repeated stresses, overhead athletes

and middle-aged and elderly persons in whom a cause may not be apparent (Arroyo *et al.*, 1997: p69-78).

Chronic inflammation and degenerative tendonitis of the supraspinatus muscle for example is an important cause of intrinsic shoulder pain (Herberts *et al.*, 1981: p269-278; Hagberg, 1984: p269-278). Injury to this muscle is usually caused, not by a single event, but by slight to moderate trauma repeatedly to the same anatomic area. The term RSI is used to describe this form of microtrauma (McDermott, 1986: p196-200). When there is injury to a muscle, antagonistic muscles contract to immobilize the joint. This prevents use of the injured muscle. In time, these muscles will also suffer injury as a result of sustained contraction (Chaffin and Anderson, 1984: p324-353). RSI of the supraspinatus muscle in this case, is not an isolated event, but rather a form of microtrauma that affects the entire shoulder girdle (Rumney, 1960: p21).

In a survey by Van der Windt *et al.* (1995: p959-964), eighteen general practitioners representing a population of 35 150 patients in an observational study to study the incidence of and management of intrinsic shoulder disorders in Dutch general practice. During a period of one year the 18 general practitioners recorded 754 consultations concerning shoulder complaints in 472; 392 of the patients presented with an incident complaint. The cumulative incidence of shoulder complaints was calculated and the incidence estimated at 14,7 per 1 000 per year. The subacromial impingement syndrome was the disorder diagnosed most frequently, in particular rotator cuff tendonitis (29%). (Van der Windt *et al.*, 1995: p959-964).

Two orthopedic surgeons carefully analyzed the results of Arthroscopic examinations under anesthesia of 123 patients with painful shoulders to better understand the nature of rotator cuff lesions (Adolfsson and Lysholm, 1991: p275-278). Despite a thorough surgical clinical examination and arthroscopy, 55% of the patients remained with an “unclear” diagnosis. Impingement syndrome was identified in 32% of patients, although only 16% showed thickening and fibrosis with or without inflammation. Inflammatory changes that mostly affected the supraspinatus without thickening, fibrosis, or rupture were seen in 6% of patients. (This is suggestive of enthesopathy secondary to MTrp’s, but MTrp’s were not included in the description of examination). Authors familiar with MTrp’s consider them to be among the most common causes of pain in the shoulder (Weed, 1983: p101-102).

2.6 Incidence of Rotator Muscle Imbalances in Throwing Athletes:

A difference in shoulder internal/external rotation ratio is of extreme importance when considering normal shoulder joint biomechanics and its implication in overuse shoulder pathology (Perry, 1983: p247-270). An inability of the external rotators to handle the force

loads created in a repetitive internal rotation movement, such as a tennis serve, may predispose the athlete to shoulder injury (Kibler et al., 1988: p403-416; Cook et al., 1987: p451-461). It is the external rotators of the RC that provide the stabilization and caudal glide mandatory for normal shoulder joint biomechanics (Perry, 1983: p247-270).

Kibler et al. (1988: p403-419) reported that the shoulder was the most often injured joint in 97 junior elite tennis players. All of these injuries were classified as overload injuries. Because repetitive movements are a factor in causing these injuries, adequate strength and muscle balance may be a factor in their prevention (Chandler et al., 1992: p455-458).

Normal shoulder internal / external rotation ratios established through isokinetic testing are 3:2 or 150% (Alderink and Kluck, 1986: p163; Ivey et al., 1984: p127). The ratio may also be expressed as an external / internal rotation ratio, giving a normative value of 2:3 or 66,6% (Ivey et al., 1985: p384-386). The most commonly used parameter in isokinetic testing is peak torque, which is the single highest point on the torque curve (graph) regardless of where in the range of motion it occurs (Davies, 1992: p53), and it is indicative of maximum muscular tension capability (Cybex, 1996: pc-4). Ivey et al. (1985: p384-386) confirmed these ratios when testing internal / external strength ratios in 18 male and 13 female non-athletes. The strength assessment included peak torque and total work ratios for internal/external rotation.

Ellenbecker (1991: p9) used a Cybex II isokinetic dynamometer to measure both internal and external rotation strengths of the shoulders in 22 highly skilled junior tennis players. Significantly greater isokinetically measured internal rotation strength was found in the dominant upper extremity of the tennis players. The dominant shoulder external rotators did not produce a greater concentric strength compared with the non-dominant shoulder. The dominant arm internal / external rotation ratios in this study ranged from 153% to 154% for peak torque and 165% to 169% for single repetition work, showing a relative external rotation strength deficit on the tennis playing shoulder. These results are in agreement with isokinetic profiling studies of various level baseball players by Brown et al., 1988: p577; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; and Pedegana et al., 1982: p352.

A study by Koziris et al. (1991: p253) tested collegiate female tennis players on a Cybex II dynamometer. A consistent pattern of dominant shoulder strength and relative external strength imbalance were also reported in this population.

Cook et al. (1987: p451) performed a study on fifteen healthy, male, college level baseball pitchers between the ages of 18 and 25. The difference in shoulder strength ratios between a pitchers' throwing arm and his non-throwing arm was statistically significant for shoulder external / internal rotation. Cook states that the majority of pitchers' rotation ratios dropped

because shoulder external rotation was weaker in the throwing arm as compared to the non-throwing arm.

Chandler et al. (1992: p455-458) studied baseball and tennis players complaining of persistent Repetitive Stress Injury (RSI) and found significant increases in the strength of internal rotation without subsequent strengthening of the external rotators. Hence they reasoned that the muscle imbalances create a predisposition toward shoulder injuries caused by overuse.

Significantly greater isokinetically measured internal/external strength ratios have been established in the dominant arm of overhead athletes. These results imply that the overhead stroke/throw places unique stresses on the dominant arm, especially on the external and internal rotators of the shoulder. Because of the special demands placed on the overhead athlete's throwing shoulder, athletes, trainers, and clinicians should note that proper muscle balance and normal flexibility about the shoulder should be essential requirements for injury prevention (Cook et al., 1987: p451).

2.7 Pathophysiology of the Shoulder Rotators in Overhead Athletes:

Static stability of the glenohumeral joint is provided by the glenoid labrum and the glenohumeral ligaments. These static stabilizers provide a passive restraint at the anterior margin of the glenoid cavity. The dynamic stabilizers, particularly the rotator cuff and scapular rotators, provide the maximum available leverage necessary for generating tremendous forces while positioning the scapular for optimum stability in any overhead activity (Turkel et al., 1981: p1208-1217).

Because the glenohumeral joint is afforded only a minimal amount of passive stability by the capsule, glenohumeral ligaments, and glenoid labrum, the primary source of stability is balanced muscular control (Perry, 1983: p247-270).

With such a complex stabilizing mechanism, a small deficiency in either the dynamic or static stabilizers may have cumulative effect on shoulder function. Repetitive throwing motions place a tremendous stress on these shoulder stabilizers. If these stresses are applied at a rate that is faster than the rate of tissue repair, progressive damage can occur. Therefore, without proper warm-up, conditioning, or throwing mechanics, the athlete's shoulder performing at or near its physiologic limit runs the risk of breaking down from overuse. Repetitive throwing motions or overhead activities may lead to progressive attenuation of these anterior, static restraints leading to mild anterior instability. The dynamic stabilizers become affected as the rotator cuff activity increases to compensate for this mild instability. With continued overhead activity, fatigue of these dynamic stabilizers allows anterior translation of the humeral head. This may

cause direct contact with the coracoacromial arch and eventually lead to impingement or rotator cuff pathology (Jobe and Kvitne, 1989: p963-975).

Research has shown that many competitive overhead athletes display an altered internal/external rotation ratio of the dominant shoulder (Chandler et al., 1992: p455-458; Cook et al., 1987: p451; Koziris et al., 1991: p253 and Alderink and Kluck, 1986: p163-172). Weakness in external rotation, or lack of external rotation strength proportional to internal rotational strength, seems to be a primary cause of muscle imbalances in the dominant shoulder of overhead athletes (Chandler et al., 1992: p455-458; Cook et al., 1987: p451).

There are several possible explanations for the overhead athletes' decrease in external rotation strength and concomitant increase in shoulder internal rotation strength in their dominant arms in comparison to established normative values. There may be an imbalance of training of the two rotations in the act of throwing. Failure to submit antagonistic muscle groups i.e., the external rotators, to similar degrees of stress may result in a muscle imbalance (Cook et al., 1987: p451-461).

Another explanation for a weakening of the external rotators in the dominant arm of overhead athletes has been suggested by both Jobe and Moynes, (1982: p336-339) and Pappas et al. (1985: p223-235). They theorize that athletes who engage in repetitive overhead throwing motion may display weakness and atrophy of the infraspinatus muscle due to suprascapular nerve entrapment. With repetitive circling and overhead motions of the upper limb, there may be repetitive minor traction on this nerve, thus generating an injury. The suprascapular nerve is particularly stretched when the arm is taken across the body into adduction and forward flexion (Black and Lombardo, 1990: p225).

During the deceleration phase of the throwing act, the posterior cuff musculature is most active, checking humeral internal rotation and horizontal adduction (Jobe et al., 1983: p3-5). The scapular retractors should act in complementary manner, by decelerating gross shoulder girdle protraction and horizontal adduction. However, this muscle group is often weaker on the dominant side. Kendall et al. (1952: p103-154) says a possible explanation for this is that these shoulder girdle retractors develop a stretch weakness that is due to the exaggerated, protracted, depressed posture which the dominant side shoulder girdle tends to assume (Andrews et al., 1985: p337-341; Kulund, 1982: p291-292). Therefore, a large eccentric load is placed on the posterior rotator cuff group during the deceleration phase. Eccentric loading has been shown to cause intramuscular connective tissue tearing, (Davies, 1984: p261-291; Nirschl, 1986: p322-337) which can lead to a cycle of chronic inflammation and muscular weakness. In contrast, the internal rotator / adductor musculature undergoes a plyometric type of training (maximally stretching muscle groups, then explosively contracting them in a

concentric manner) with each throwing cycle. This type of training has been found to greatly enhance power in larger muscle groups (Miller, 1984: p68-83).

For whatever reason, these differences in muscular activity result in lowered external / internal rotator strength, power, and work ratios in the dominant shoulder in overhead athletes (Hinton, 1988: p274-279).

2.8 Introduction to Myofascial Pain Syndrome (MPS):

Myofascial Pain Syndrome is a regional muscular disorder resulting from myofascial trigger points (Lee et al., 1997: p81-89). A trigger point is a hyperirritable spot in skeletal muscle that is associated with a hypersensitive palpable nodule in a taut band. The activation of trigger points is usually associated with some degree of mechanical abuse of the muscle in the form of muscle overload, which may be acute, sustained and/or repetitive. The spot is painful on compression and can give rise to characteristic referred pain, autonomic phenomena and motor dysfunctions, (Travell, Simons and Simons, 1999: p5).

Muscular pain is the most common work-related injury and the second most common cause of visits by patients to physicians (in general) (Hubbard, 1998: p16).

In a review article written by Han and Harrison (1997: p90) the incidence of MPS was reported as high as 85% at certain American pain clinics, yet it remains to be one of the least understood conditions, often being misdiagnosed, mistreated or simply unrecognized (Auleciems, 1995: p18)

2.8.1 Definitions:

AN ACTIVE MYOFASCIAL TRIGGER POINT

A Myofascial Trigger point that causes a clinical pain complaint. "it is a focus of hyperirritability in a muscle or it's fascia that is symptomatic with respect to pain; it refers to a pattern of pain at rest and/or in motion that is specific for the muscle. An active trigger pint is always tender, prevents full lengthening of a muscle, weakens the muscle, usually refers pain on direct compression, mediates a local twitch response of the muscle fibers when adequately stimulated and often produces specific autonomic phenomena, generally in its referral zone" (Travell, Simons and Simons, 1999: p1).

A LATENT MYOFASCIAL TRIGGER POINT

“It is defined as a focus of hyperirritability in a muscle or its fascia that is clinically quiescent with respect to spontaneous pain: it is only painful when palpated. A latent myofascial trigger point may have all the other characteristics of an active trigger point, from which it is to be distinguished” (Travell, Simons and Simons, 1999: p4).

Chaitow and Delany (2002: p124) and Travell, Simons and Simons (1999 1: p12), agree that the main difference between active and latent myofascial trigger points is that only active myofascial trigger points can spontaneously refer pain.

Table 2.1 Comparison between active and latent trigger points

Common Features:	
Latent myofascial trigger points	Active myofascial trigger points
Decreased stretch range of motion.	Decreased stretch range of motion.
Muscular stiffness.	Muscular stiffness.
Local twitch response.	Local twitch response.
Painful and weak muscle on contraction.	Painful and weak muscle on contraction.
Different Features:	
Latent myofascial trigger points	Active myofascial trigger points
Localized pain on manual compression.	Localized and referred pain on manual compression.
No spontaneous pain referral.	Spontaneous pain referral.
Recognition of an unfamiliar or previous pain.	Recognition of current pain.

As compiled by Wilks (2003: p21).

2.8.2 Incidence of MPS:

Han and Harrison (1997: p89-101), in a review article found that myofascial pain appeared to be the most common phenomenon in the clinical setting. Schneider (1995: p1-8) found MPS

one of the most predominant soft tissue syndromes seen in clinical practice. American studies based at pain clinics indicate that the incidence of MPS may be as high as 85 % (Han and Harrison, 1997: p90).

Reports of the prevalence of myofascial trigger points in patient populations can be found as early as the 1950's where physicians noted MPS as one of the most common frequent problems seen by physicians (Sola, Rodenberger and Getty, 1955: p585).

MPS occurs in both sexes but appears to be more prevalent in females (2:1) (Han and Harrison, 1997: p89). Travell Simons and Simons (1999 1: p13) and Han and Harrison (1997: p90), suggested that individuals in their later years (30 – 49) are more likely to suffer from MPS.

Bruce (1995: p469-473) explains that, currently, the majority of research conducted in the field of epidemiology of MPS has been completed in a clinical setting. As a result the prevalence with regard to MPS in the general population can only be estimated indirectly.

2.8.3 Natural History of MPS:

According to Travell, Simons and Simons (1999 1:20), with adequate rest and in the absence of perpetuating factors an active trigger point may revert spontaneously to a latent state. Pain symptoms disappear but reactivation of the myofascial trigger point by exceeding the muscles stress tolerance can account for the history of recurrent episodes of the same pain over a period of years.

2.8.4 Etiology of MPS:

There is still uncertainty over the etiology of MPS as no studies conducted indicate positive predictive values for any one combination of factors. However Travell, Simons and Simons (1999 1: p19) and Chaitow and Delany (2002: p20), agree on several primary factors which may result in the development or activation of MTrp's.

Primary Factors

- Mechanical abuse: acute sustained or repetitive muscle overload i.e.: prolonged muscular contraction.

- Trauma: this includes the precipitation of MTrp's by means of a local inflammatory response.
- Leaving a muscle in shortened position: for a prolonged period of time especially if the muscle is contracted in the shortened position.
- Nerve compression: can cause identifiable neuropathic electromyography changes and results in disturbed microtubule communication between the neuron and the endplate.
- Adverse environmental conditions: which includes, but is not limited to, excessive heat, cold or dampness.
- Systematic biochemical imbalances: this may include hormonal disturbances.

Secondary Factors (Baldry, 1993)

- Compensating synergistic or antagonistic muscles to those housing MTrp's may as a result develop myofascial trigger points.
- Satellite MTrp's can evolve in referral zone of primary trigger points.
- Low oxygenation of tissues.
- The development of active and latent MTrp's occur as a result of the same factors mentioned above (primary and secondary) but to varying degrees (Travell, Simons and Simons, 1999 1: p19).

Friction et al. (1985: p621), suggested a multi-factorial etiologic basis for MPS and suggested that the development of MTrp's can be divided into two basic groups:

1. Factors that directly traumatize by direct injury, repetitive microtrauma from habits that produce muscle tension.
2. Factors that weaken a muscle and predispose it to the development of myofascial trigger points through such factors as nutritional deficiencies, structural disharmony, lack of exercise, sleep disturbances or the presence of other disorders such as joint problems.

According to Auleciems (1995: p18-28), the event that activates a trigger point is usually quite different from the factors that perpetuate them. Therefore the long-term prognosis improves with treatment of perpetuating factors, not just pain relief. Esenyl (2000: p48-52) found that once perpetuating factors are corrected pain is more likely to be resolved.

Perpetuating factors may include any of the following, as outlined by Travell, Simons and Simons (1999 1: p110 -112).

- Mechanical stresses: such as skeletal asymmetry (short leg or small hemipelvis), poor posture, prolonged immobility and/or muscular abuse.
- Nutritional inadequacies: commonly occur with mechanical stresses. Low levels of vitamin B1, B6, B12, folic acid and iron can aggravate MTrp's. Inadequate levels of calcium, potassium and several trace minerals can cause abnormal muscle functioning.
- Metabolic and endocrine inadequacies: such as hypoglycemia, hyperuricemia and hypothyroidism all perpetuate MTrp's.
- Chronic infection: viral, bacterial or parasitic.
- Psychological factors: anxiety or depression can delay recovery of MTrp's.
- Miscellaneous factors: such as fatigue, cold or damp weather, allergy, chronic visceral disease or radiculopathy.

2.8.5 Presentation of MPS of the External Rotator Myotactic unit:

Patients with MPS will typically present complaining of regional persistent pain. It may range from a mild ache to excruciating pain either sharp or dull. The patient may complain of decreased range of motion and muscle strength (Han and Harrison, 1997: p92).

Motor disturbances as described by Travell, Simons and Simons (1999 1: p21) include:

- Muscle weakness
- Spasm of synergistic and/or antagonistic muscles and
- Decreased muscle power or work tolerance.

The shoulder external rotator myotactic unit consists of the agonists – infraspinatus, teres minor and posterior deltoid muscles. The infraspinatus muscle functions synergistically with the supraspinatus by stabilizing the head of the humerus in the glenoid cavity. The subscapularis, pectoralis major and anterior deltoid muscles act as antagonists for external rotation of the arm (Travell, Simons and Simons, 1999: p555).

Presentation of Myofascial Trigger Points in the external rotator myotactic unit:

Antagonistic muscles of external rotation.

- **Subscapularis -** There are two common lateral TrP locations and a medial Trigger area in this muscle. The lateral TrPs lie inside the Lateral border of the scapula on the ventral aspect. The Medial area is located along the vertebral border of the Scapula. Referred pain from active trigger points concentrates in the posterior deltoid area and may extend medially over the scapula, down the posterior aspect of the arm and then skip to a band around the wrist. Patient examination identifies involvement of this muscle by a marked reciprocal limitation of either abduction or external rotation of the arm at the glenohumeral joint and an even greater restriction of the combined movement. (Travell, Simons and Simons, 1999: p596-601).
- **Pectoralis Major -** Trigger points can be located in the clavicular section, three central TrP locations of the intermediate sternal section and two central TrPs in the lateral free margin. Active trigger points may localize substernally, may include the anterior chest and breast, and may extend down the ulnar aspect of the arm to the 4th and 5th digits. Patient examination reveals shortening of the pectoralis major muscle which often pulls the shoulders forward to produce a stooped, round shouldered, head-forward posture (Travell, Simons and Simons, 1999: p819-820).
- **Anterior Deltoid -** TrPs are found close to midmuscle section. Pain from active trigger points spreads locally in the region of the affected part of the muscle. Patients present with painful restriction of the Back-rub Test and painfully weakened abduction of the externally rotated arm (Travell, Simons and Simons, 1999: p623-625).

b) Agonistic muscles of external rotation.

- **Infraspinatus -** Trigger points in this muscle are usually found caudal to the medial edge of the scapular spine and caudal to the midpoint of the scapular spine but may be located further laterally. The referred pain from active trigger points causes a deep intense pain in the front of the shoulder, especially when sleeping on their side. Patients complain of inability to

reach behind to a back pocket. Examination of patients reveals restricted internal and external rotation at the glenohumeral joint, demonstrated by the Hand-to-shoulder Blade Test. (Travell, Simons and Simons, 1999: p552-557).

- Teres Minor - Trigger points in this muscle can be found in the mid belly of the muscle, along the lateral edge of the scapula, between the infraspinatus above and the teres major muscle below. Patients with active trigger points experience posterior shoulder pain and may include dysesthesia of the 4th and 5th fingers. Patient examination reveals slight restriction of internal rotation at the glenohumeral joint on performance of the Hand-to-shoulder Blade Test (Travell, Simons and Simons, 1999: p565-567).
- Posterior Deltoid - Trigger points are found close to midmuscle section. Pain from active trigger points spreads locally in the region of the affected part of the muscle. Patients present with painfully weakened abduction of the internally rotated arm (Travell, Simons and Simons, 1999: p623-625).

The infraspinatus functions synergistically with the supraspinatus and other rotator myotactic unit musculature by stabilizing the head of the humerus in the glenoid cavity during movements of the arm.

- Supraspinatus - Trigger points in this muscle are located in the lateral area of the muscle and in the mid belly. Active trigger points cause a deep ache of the shoulder concentrating in the mid-deltoid area. The ache may extend down the arm and forearm and sometimes focuses strongly over the lateral epicondyle of the elbow. The pain is felt strongly during abduction of the arm at the glenohumeral joint. Patients may report difficulty in combing their hair, brushing their teeth and complain of restricted shoulder motion during sports activities that require arm elevation, such as serving a tennis ball (Travell, Simons and Simons, 1999: p538-543).

2.8.6 Diagnosing of MPS:

It is the opinion of Travell, Simons and Simons (1999:p34-35) that no one diagnostic examination alone is a satisfactory criterion for the identification of a trigger point. According to Travell and Simons (1983:p12-16) the signs of a trigger point are as follows:

- Referred pain in the zone of reference
- Local twitch response
- Palpable taut band and
- Focal tenderness

Lee et al. (1997:p81-89), Gerwin et al. (1997:p65-73) and Banks et al. (1998:p23-24) all reported to using these criteria to identify trigger points.

The recommended criteria for identifying a latent or active trigger point according to Travell, Simons and Simons (1999:p35) are as follows:

Essential criteria:

1. Taut palpable band
2. Exquisite spot tenderness of a nodule in a taut band
3. Painful limit to full stretch range of motion
4. Subject's recognition of current pain complaint by pressure on the tender nodule.

Confirmatory Observations:

1. Visual or tactile identification of local twitch response
2. Pain or altered sensation on compression of the tender nodule.

For the diagnosis of myofascial TrPs all 4 essential criteria must be present (Travell, Simons and Simons (1999:p35) and Murphy (1989:p627-631). The presence of the confirmatory signs serve to reinforce the diagnosis.

2.8.7 Differential Diagnosis:

Pain in the region of the shoulder may arise from rotator cuff lesions or tears, tendonitis, bursitis, neuropathy, radiculopathy, arthritis, thoracic outlet syndrome, adhesive capsulitis, impingement syndrome, angina pectoris, lung cancer, hiatal hernia, mediastinal emphysema and irritation of the bronchi, pleura or esophagus (Travell, Simons and Simons, 1999 1: p539-

820). Patients presenting with any such conditions need to be excluded from this study to prevent extraneous causes interfering with the shoulder strength and MTrp assessments.

2.8.8 Management of MPS:

A large part of patient management is recognizing the underlying problems, which influence the patient's pain by increasing the tension and irritability of the involved muscle (Fomby and Mellion, 1997: p3). The treatment protocol must therefore take into consideration the contributing and perpetuating factors, so that long-term relief can be obtained (Esenyl et al., 2000: p51).

Rosen (1993: p261-266) suggests that the most important goal of successful rehabilitation is not that of pain relief but rather restoration of normal range of motion to the tissues and achievement of strength and endurance. Bruce (1995: p473) is of the opinion that a multidisciplinary approach to treatment is important and that treatment should first be directed towards correct diagnosis and elimination of perpetuating factors.

However Esenyl et al. (2000: p49), feels the main goal of treatment is to relieve the pain and spasm of the involved muscle.

Previous treatment for MPS includes: myofascial trigger point injection, dry needling, exercise, massage, transcutaneous electrical nerve stimulation (TENS), medication and stretch and spray (Han and Harrison, 1997: p95; Hubbard, 1998: p23). Of these numerous techniques available it seems that the choice of treatment is based more on personal preference than on clinical evidence (Anderson, 1997). Rosen (1993: p261-266) feels that the most commonly used treatment techniques include spray and stretch and MTrp injecting.

Some of the many treatment techniques are discussed below.

a) Trigger Point Pressure Release:

This concept has replaced ischemic compression. Travell, Simons and Simons (1999: p140), found that the pressure release seems to be clinically more effective than ischemic compression. To perform the technique the involved muscle must be stretched or lengthened to a point of increased resistance within the patient's comfort zone. Pressure is then gradually applied until the finger encounters an increase in tissue resistance. The patient should experience discomfort but not pain. The pressure is maintained until a decrease in tension

under the finger is felt. Pressure is then increased until a new point of tension is felt and then maintained until the tension releases again.

This approach appears to be more patient friendly and therefore more likely to be used by the patient at home (Travell, Simons and Simons, 1999: p140).

b) Modalities:

The use of modalities in the treatment of MTrp's is limited.

Transcutaneous electrical nerve stimulation (TENS) has been successfully used in the treatment of MPS; however it does not have any long-term effect on the condition (Han and Harrison, 1997: p97).

Gam et al. (1998: p73) in a randomized control trial found that ultrasound gave no pain reduction and was ineffective in the treatment of MPS.

c) Spray and stretch:

Spray and stretch using a vapocoolant spray (e.g. Fluori-Methane or ethyl chloride) along with passive stretching of the involved muscle has been described as an effective treatment for MPS by Hubbard (1998: p25). The aim of this method is to decrease pain, increase range of motion and restore the muscle to its normal length. The sudden drop in skin temperature results in a temporary anesthesia by blocking the spinal stretch reflex and the sensation of pain in the higher centers of the brain (Han and Harrison, 1997: p97).

d) MTrp injection and Dry needling:

Trigger point injections have been widely used to inactivate MTrp's (Esenyl et al., 2000: p49) and are commonly used in the management of MPS with wide spread clinical acceptance (Alvarez, 2002: p657).

According to Han and Harrison (1997: p96), MTrp injection is preferred to dry needling because of the analgesic effect that the local anesthetic agent offers to the surrounding muscle tissue.

However Garvey et al. (1989: p962-964) conducted a randomized double-blind study comparing four different treatment methods in 63 patients with active MTrp's. The results of the study show that dry needling and acupuncture are more effective than transcutaneous injection of either local anesthetic or local anesthetic and steroids. This led the researchers to

believe that the relief is likely due to the mechanical stimulation of the MTrp by the needle as apposed to the substance injected.

Tschopp and Gysin (1996: p306) and Hong (1994: p256), share this opinion in stating that the long term therapeutic effect of MTrp injection and dry needling appears to be attributed to the needle rather than any substance injected into the MTrp.

Han and Harrison (1997: p96), propose the following mechanism by which both needling and MTrp injection relieve the MTrp pain:

1. Mechanical disruption of muscle fibers, causing a release of potassium, which results in depolarization of nerve fibers.
2. Mechanical disruption of nerve fibers.
3. Interruption of central feedback mechanism that perpetuates pain.
4. Local dilution of nociceptive substances by the local anesthetic or saline that is infiltrated.
5. Vasodilatory effect of local anesthetics, which increase the removal of metabolites.

2.9 Isokinetic Dynamometry:

2.9.1 Isokinetic Exercise:

The term isokinetic exercise refers to a process in which a body segment accelerates to achieve a pre-selected fixed speed with totally accommodating resistance through out the range of motion. The subject can never exceed the speed no matter how much effort he exerts. The amount of force exerted by the subject is always matched by that of the machine. As a result, isokinetics has the capability to load a muscle maximally throughout the entire range of motion. Two types of isokinetic contractions are possible: concentric or eccentric contractions (Cybex, 1996: p1-9, c – 2).

a) Concentric contractions: Defined as the development of tension by muscle while the origin and insertion approximate each other. This is also referred to as positive work (Davies, 1992:

p25). This involves the shortening of the muscle fibers with the origin and insertion approximating (Cybex, 1996: p1-9, c – 2).

b) Eccentric contractions: Defined as the development of tension that occurs as the origin and insertion move away from each other. This is also referred to as negative work of the muscle (Davies, 1992: p25). This involves the lengthening of muscle fibers with the origin and insertion separating.

2.9.2 Advantages of Isokinetic Exercise and Testing:

- Permits isolation of muscle groups.
- Provides accommodating resistance to maximal exercise throughout the Range of Motion.
- Inherent safety factor, due to accommodating resistance, therefore minimal risk to the patient.
- Presents quantifiable data for peak torque, work and power (Perrin, 1993: p7).
- Reduces chance of overload injury.
- Accommodation to pain and fatigue.
- Full range of speed for testing and exercise (within limits of machinery).
- Reproducible measurements.
- Physiological overflow of strength.
- Validity and reliability of equipment.
- Decreases reciprocal innervation time of agonist/antagonist contractions.

(Cybex, 1996: p1 – 10; Davies, 1992: p19-20).

2.9.3 Limitations of Isokinetic Exercise and Testing:

- Eccentric loading stimulus to the muscle causes delayed onset muscle soreness.
- Some artificial parameters until the limb actually moves to reach the velocity of the dynamometer or decelerates.
- Angular velocity movements that do not approach functional speeds.
- Cost and availability of equipment.
- Time consuming if more than one joint is tested.

(Perrin, 1993: p7; Davies, 1992: p20)

2.9.4 Contraindications to Isokinetic Sessions:

a) Absolute Contraindications

- Soft tissue healing constraints
- Severe pain
- Extremely limited range of motion
- Severe joint effusion
- Unstable joint
- Acute strain

b) Relative Contraindications

- Pain
- Limited range of motion
- Effusion or synovitis
- Chronic third degree sprain
- Subacute sprain
- Pregnancy

(Cybex, 1996: p1 – 13)

2.9.5 Isokinetic dynamometry as a tool:

The term isokinetic exercise refers to a process in which a body segment accelerates to achieve a pre-selected fixed speed with totally accommodating resistance through out the range of motion (Cybex. 1996:p1-9). Recent developments in Isokinetic Dynamometry have made it possible to isolate certain muscle groups and determine the presence and extent of weakness (Davies, 1992: p362). Evidence suggests that this type of measurement is considered the most appropriate tool as a direct indicator of functional status (Wright, 2003).

Isokinetic dynamometry also has the advantage of a limited diagnostic capability by analysis of torque curve characteristics. A perfect curve from an unaffected joint muscle unit with good neuromuscular facilitation should have a curve which looks like an inverted 'U' (<http://www.isokinetics.net>).

Any irregularities or deformations in particular patterns of the torque curve may be correlated with various pathologies (Davies, 1992: p61). However a characteristic diagnostic curve may not always be present (Chan and Maffulli, 1996: p11, 43, 128). The machine can also be used as a tool in the rehabilitation of injuries involving muscular weakness (Perrin, 1993: p120-4; Chan and Maffulli, 1996: p10; and Davies, 1992: p125-134).

2.9.6 Physical Testing:

Assessing the muscular strength, by either manually testing the muscles or using an isokinetic (Cybex, Biodex) system, will not only allow identification of certain deficiencies in strength but also provide a baseline against which to document later strength gains during rehabilitation. Selective testing of shoulder muscles may indicate underlying tendonitis, muscle strain, tears, or nerve injuries. Weakness should also alert the examiner to the need for strengthening these muscles during rehabilitation, in order to provide the proper synchrony about the shoulder and prevent the development of the instability complex (Jobe and Kvitne, 1989: p963-975).

Isokinetic evaluation renders objective, reliable data regarding muscular performance during a dynamic contraction (Rothstein,1985; Montgomery et al., 1989, p315-322; Kendall and McCrearey, 1983). Isokinetic testing has been utilized frequently for determining the strength ratios of throwing athletes (Alderink and Kluck, 1986: p163-172; Cook et al., 1987: p451-461; Hinton, 1988: p274-279).

2.9.7 Parameters from Isokinetic Testing:

a) Peak Torque.

This is the single highest point on the torque curve regardless of where in the range of motion it occurs (Davies, 1992: p53). Taking into account changes due to biomechanical leverage and the muscular tension-length relationship that occurs throughout the range of motion, peak torque is indicative of maximum muscular tension capability (Cybex, 1996: pc-4).

The shape of the torque curve can be analyzed subjectively by looking at the characteristics of the curve. The time rate of torque development (angle of initial upward deflection of the slope of the curve to peak torque), the force decay rate (angle of the downward deflection of the slope of the curve from peak torque), and any irregularities in the curve may be correlated with various pathologies (Davies, 1992: p61).

b) Opposing Muscle Group Torque Ratios.

This is the unilateral ratio comparison between the agonist and antagonist muscle groups which is most useful in identifying particular weaknesses in certain muscle groups (Davies, 1992: p61-63).

c) Total Work.

The total area underneath the curve is the total work of the torque curve with each repetition regardless of speed, range of motion or time (Davies, 1992: p59). This is dependant on the subject's muscular power capability at the test velocity, as well as available anaerobic energy stores and pH tolerance in the working muscles. For work measurements to be comparable it is essential that the same range of motion be used for every test (Cybex, 1996: pc-7).

d) Opposing Muscle Group Work Ratios.

This is similar to opposing muscle group torque ratios except the work ratios establish a unilateral ratio of the agonist and antagonist based on the total work performed by the respective muscle groups. The muscle group torque ratios only calculate the relationship based on the peak torque measurements (Davies, 1992: p62).

2.9.8 Interpretation of Isokinetic Data:

a) Unilateral Ratios.

Comparing the relationship between the agonist and antagonist muscles may identify particular weaknesses in certain muscle groups (Davies, 1992: p63).

b) Normative Data.

Normative data can be used as guidelines for testing and rehabilitation when used relative to a specific population (Davies, 1992: p63). Through the use of normative data, clinicians can correlate isokinetic testing results with the physical demands of a specific population (Cybex, 1996: p1-9).

2.9.9 Conclusion:

Reproducibility and reliability of isokinetic testing for a desired protocol should be sufficient enough so that training or injury induced changes in muscle strength are not attributed to instrument or testing error. The ability to quantify reliable and relatively precise values for maximal strength and endurance, as measured by Isokinetic Dynamometry, would provide a valuable tool for the evaluation of muscular capability and injury assessment, especially in the Sports Medicine setting (Pincivero, Lephart and Karunakara, 1997).

2.10 Summary

The repetitive throwing motion performed by overhead throwing athletes (tennis players, baseball pitchers and waterpolo players) places the shoulder rotator myotactic unit at a high risk of sustaining microtraumatic injury.

The throwing action involves a concentric contraction of the internal rotators (large muscle mass) of the dominant shoulder during the acceleration phase. During the deceleration phase, the external rotators (small muscle mass) contract eccentrically to decelerate the arm.

Numerous studies have been conducted on internal/external ratios of the shoulder in throwing athletes, revealing a relative external rotation strength deficit on the dominant shoulder (Cook et al., 1987: p451; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; Koziris et al., 1991:p253 and Pedegana et al., 1982: p352).

Many of these athletes complained of persistent Repetitive Stress Injuries (RSI) of the shoulder complex. It can be reasoned therefore, that the muscle imbalances create a predisposition toward shoulder injuries caused by overuse (Chandler et al., 1992: p455-458).

The use of isokinetic dynamometry has been proven to be a valuable tool for assessment and evaluation of muscular function and pathology (Pincivero, Lephart and Karunakara, 1997), and renders objective, reliable data regarding muscular performance during a dynamic contraction (Rothstein, 1985; Montgomery et al., 1989, p315-322; Kendall and McCrearey, 1983).

The activation of a MTrp is associated with some degree of mechanical abuse of the muscle in the form of muscle overload, which may be acute, sustained and/or repetitive. According to reviewed literature, the presence of MTrp's could result in a combination of the following signs and symptoms: spasm of other muscles, weakness of involved muscle function, loss of coordination and decreased work tolerance of the involved muscle. The weakness and loss of work tolerance are often interpreted as an indication for increased exercise, but if this is attempted without having inactivated the responsible MTrp's, the exercise is likely to encourage and further ingrain substitution by other muscles with further weakening and deconditioning of the involved muscle (Travell, Simons and Simons, 1999: p21). Thus, the purpose of this study is to determine the role of MTrp's of the external rotator myotactic unit in the clinical presentation of the altered internal/external rotation strength ratios in such athletes

CHAPTER 3:

MATERIALS AND METHODS:

3.1 Introduction

The aim of this research is to evaluate the role of myofascial trigger points on altering internal/external strength ratios of the shoulder in overhead throwing athletes.

Therefore this chapter gives a description of:

- The methodology,
- The subjects,
- The measurement and observation techniques,
- The design and
- The interventions used.

Each measurement parameter is discussed and an overview of each scale is given. Statistical analysis is also discussed.

3.2 Methodology:

3.2.1 Type of study:

A pilot non-intervention clinical assessment study.

3.2.2 Sampling:

The study was limited to overhead throwing athletes residing in the Kwazulu-Natal province. The public was informed of the study by advertisements placed at local gyms, sports clubs and on the DIT Campus advertising for free participation in a research program being conducted on shoulder pain. The advert called on competitive overhead male athletes between the ages of 18 and 40 years of age suffering from shoulder pain (Appendix A). Subjects presenting at the Chiropractic Day Clinic at the Durban Institute of Technology were considered. Non-probability based, convenience sampling technique was used to attract patients.

3.2.3 Inclusion criteria:

- ❖ Participants must be between the ages of 18-40 years, so as to maintain group uniformity and homogeneity, and to help eliminate causes of rotator cuff dysfunction found almost exclusively in patients older than 40 years of age i.e. “Tears of the rotator cuff, biceps ruptures, and bone changes”, (Neer, 1983:p70-77).
- ❖ All subjects must have read a letter of information (Appendix K) and signed an informed consent form (Appendix L) which outlines the benefits and potential risks of the testing procedures.
- ❖ Only male subjects will be required as to maintain sample homogeneity.
- ❖ Criteria to identify the presence of active MTrp's. Participants may present with any number of the following:
 - Restricted shoulder range of motion
 - Referred pain in and about the shoulder
 - Shoulder pain during activity
 - Shoulder girdle fatigue
 - Perceived stiffness about the shoulder(Travell, Simons and Simons, 1999: p557-820).

3.2.4 Exclusion Criteria:

- If there is a history of traumatic shoulder dislocation or if there is a positive drop arm test which could indicate a rupture of the rotator cuff, (shoulder regional – Appendix G).
- If there is a history of shoulder surgery, (Appendix C).
- If subjects have, or if the physical examination (Appendix D) suggests they have, cardiac, pulmonary or systemic diseases which may refer pain to the shoulder.
- If subjects have had any treatment for the shoulder within the previous six weeks or on any course of anti-inflammatory agents (Poul et al., 1993:p1000-1003).
- Subjects with neurological deficits of the upper limbs (Appendix E, F and G).
- If pain is as a result of Nerve Root Entrapment (cervical regional – Appendix E).
- If subjects meet any of the contra-indications for dynamometer testing.
- Any subject failing to sign the informed consent form (Appendix L) will be excluded immediately from the study.
- If subjects present without any active MTrp's within the shoulder external rotator myotactic unit.

3.1.5 The Method:

All respondents underwent a cursory telephonic discussion with the examiner to exclude subjects that obviously do not fit the criteria for the study (Appendix B). Suitable subjects then underwent an initial consultation at the Durban Institute of Technology Chiropractic Day Clinic, consisting of a full case History (Appendix C), relevant Physical Examination (Appendix D), Cervical (Appendix E), Thoracic (Appendix F) and Shoulder Regional Examinations (Appendix G). Prior to being accepted into the study all subjects received a letter of information (Appendix K), completed an informed consent form (Appendix L) and were given an opportunity to ask questions.

Each subject was assessed for trigger points within the shoulder rotator myotactic unit (Appendix H) and the severity of the trigger points noted (Appendix I). Diagnostic criteria for identification of trigger points was in accordance with: Travell and Simons (1983:p12-16), Lee et al. (1997:p81-89), Gerwin et al. (1997:p65-73) and Banks et al. (1998:p23-24).

Sixty suitable competitive overhead throwing athletes were considered for isokinetic testing.

3.3 Measurement and Observation:

3.3.1 The Data:

The data contained in this study was both of the primary and secondary types.

3.3.1.1 The primary data:

The primary data consisted of:

- case History (Appendix C)
- Physical Examination (Appendix D)
- Cervical (Appendix E)
- Thoracic (Appendix F)
- Shoulder Regional Examinations (Appendix G)
- Myofascial Diagnostic Scale (Appendix I)
- Location of Shoulder External Rotator Myotactic Unit MTrp's (Appendix H)
- Isokinetic Dynamometer readings for internal/external rotation ratios.

3.3.1.2 The Secondary Data:

The secondary data was obtained from various sources including journal articles, textbooks and medical search engines on the Internet (Mantis, Pubmed and Medscape).

3.3.2. Methods of Objective Measurement

3.3.2.1 The Cybex 700 Isokinetic Assessment:

a) Test Protocol:

Subjects performed a concentric/ concentric shoulder internal/external isokinetic test at a test velocity of 60° per second and a eccentric/ eccentric shoulder internal/external isokinetic test at a test velocity of 60° per second.

Testing at low velocities (90° per second and slower) were restricted to sets of no more than 6 repetitions performed maximally and reassessed every 2-3 weeks otherwise further symptoms may be invoked by testing (<http://www.isokinetics.net>).

b) Test Procedure:

Testing of subjects was performed in a comfortable seated position in 90 degrees of shoulder abduction and 90 degrees elbow flexion. In testing shoulder internal/external rotation, the axis of rotation is aligned through the center of the olecranon and the shaft of the humerus. This test (Wilk et al., 1991: p63-69) position closely approximates that of the normal throwing motion while ensuring muscle isolation.

Subjects received the isokinetic assessment no more than 1 day after the trigger point screen and were given strict instructions not to perform any sporting activities, which may alter the state of the shoulder during the interim period.

Subjects were given standardized, scripted verbal encouragement while performing the test. (Perrin, 1993: p39; Chan and Maffulli, 1996: p16; Pincivero, Lephart and Karunakara, 1997: p113-117; Cybex, 1996: p1-31).

The first ratio to be evaluated was concentric contraction of the internal rotators versus concentric contraction of the external rotators. The second ratio to be evaluated was eccentric contraction of the internal rotators versus eccentric contraction of the external rotators. These values were compared to established normative values (Wright, 2003).

The machine was calibrated weekly for the duration of the study (Appendix J).

c) Patient Positioning:

- Subjects were seated in a comfortable position in 90° shoulder abduction and 90° elbow flexion.
- Straps were placed around the torso and involved elbow to stabilize the limb being tested.
- The axis of rotation is aligned through the center of the olecranon and the shaft of the humerus.
- Patients were instructed to grip the handle of the machine at all times.
- Strict standard verbal instruction was provided.
- Patients were allowed to see the computer screen during testing.
- Patients were given standardized, scripted verbal encouragement while performing the test.
- All data with regard to patient position and machine set up was recorded.

d) Patient Procedure:

Subjects completed a 5 minute warm up cycle.

Testing of the uninvolved shoulder first served several functions: (1) it established a database for the involved shoulder, (2) it evaluated the athlete's willingness to be tested, and (3) it served to decrease apprehension by allowing the subject to experience the movement on the contralateral extremity first (Wilk, 1990: p123-150; Davies, 1987)

i) Concentric-Concentric Test

4 Sub-maximal warm-up repetitions at 90 degrees/sec

1 min rest

2 trial repetitions of maximal effort at 60 degrees/sec

1 min rest

3-5 repetitions of maximal effort at 60 degrees/sec

4 min rest

ii) Eccentric-Eccentric Test

2 Sub-maximal warm-up repetitions at 90 degrees/sec

1 min rest

2 trial repetitions of maximal effort at 60 degrees/sec

1 min rest

3-5 repetitions of maximal effort at 60 degrees/sec

If subjects experienced any pain that prevented them from completing the test, they were excluded from the study.

Peak torque values for concentric and eccentric internal/external rotation were recorded as a ratio. For statistical purposes, single repetition work values for individual subjects were combined and an average was taken (total work) for each individual subject in each concentric and eccentric test and expressed as a ratio.

This protocol was adapted from: Davies (1992:p43-4), Perrin (1993:p48) Wilk et al. (1991:63-70) and Wright (2003).

e) Isokinetic Data

i) Recorded Data:

Isokinetic data was recorded at the Kings Park Sports Medicine Center in Durban and analyzed using the SPSS version 12.0.1. statistical package (SPSS Inc. Chicago, ill).

The recorded values from the subjects were compared to established normative values. Unfortunately the body of normative data is extremely limited. This meant that only certain of these parameters could be compared due to normative values. Those parameters for which no norms could be found were recorded for future use.

ii) Normative values:

Normal shoulder internal / external rotation strength ratios established through isokinetic testing are approximately 3:2 or 150% (Alderink and Kluck, 1986: p163; Ivey et al., 1984: p127). The ratio may also be expressed as a external / internal rotation ratio, giving a normative value of 2:3 or 66,6% (Ivey et al., 1985: p384-386). The most commonly used parameter in isokinetic testing is peak torque, which is the single highest point on the torque curve (graph) regardless of where in the range of motion it occurs (Davies, 1992: p53). The corresponding total work ratios are calculated from the total area underneath the torque curve with each repetition regardless of speed, range of motion or time (Davies, 1992: p59).

Isokinetic measured internal/external rotation ratio values for overhead athletes have been recorded in numerous studies (Ellenbecker, 1991: p9; Brown et al., 1988: p577; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; and Pedegana et al., 1982: p352), showing a relative external rotation strength deficit on the dominant shoulder. The dominant arm internal/external rotation ratios in these studies ranged from 153% to 154% for peak torque and 165% to 169% for single repetition work.

3.3.2.2 Diagnosis and assessment readings related to active Myofascial Trigger Points

It is the opinion of Travell, Simons and Simons (1999:p34-35) that no one diagnostic examination alone is a satisfactory criterion for the identification of a trigger point. According to Travell and Simons (1983:p12-16) the signs of a trigger point are as follows:

- Referred pain in the zone of reference
- Local twitch response

- Palpable taut band and
- Focal tenderness

Lee et al. (1997:p81-89), Gerwin et al. (1997:p65-73) and Banks et al. (1998:p23-24) all reported to using these criteria to identify trigger points.

The recommended criteria for identifying a latent or active trigger point according to Travell, Simons and Simons (1999:p35) are as follows:

Essential criteria:

5. Taut palpable band
6. Exquisite spot tenderness of a nodule in a taut band
7. Painful limit to full stretch range of motion
8. Subjects recognition of current pain complaint by pressure on the tender nodule.

Confirmatory Observations:

3. Visual or tactile identification of local twitch response
4. Pain or altered sensation on compression of the tender nodule.

For the diagnosis of myofascial TrPs all 4 essential criteria must be present (Travell, Simons and Simons (1999:p35) and Murphy (1989:p627-631). The presence of the confirmatory signs serve to reinforce the diagnosis.

a) Location of the MTrp's:

Refer to pg 26-27 (location of MTrp's within the external rotator myotactic unit).

b) Severity of the MTrp's: The Myofascial Diagnostic Scale (MDS).

(Chettiar 2001), (Appendix I)

The Myofascial Diagnostic Scale is made up of four indicators. The first indicator consists of five grades of soft tissue tenderness. Each grade is scored as follows: grade 0 – no tenderness =0, grade 1 – tenderness to palpation without grimace or flinch =1, grade 2 – tenderness with grimace and/or flinch to palpation =2, grade 3 – tenderness with withdrawal =3, grade 4 – withdrawal to non-noxious stimuli =4. The second and third indicators represented the presence of the local twitch response and the taut band respectively. These

indicators were given a value of 4 each. The fourth indicator was the presence of referred pain. Since this sign is the strongest indicator of an active trigger point, this indicator was given a value of 5. Total values of 9 or more were indicative of an active trigger point. Only patients with active trigger points were included in the study.

3.4 Validity and Reliability:

3.4.1 An Isokinetic Dynamometer:

The Cybex "NORM"TM Isokinetic dynamometer (Appendix M: Declaration of Conformity) at King's Park Medicine Center will be used using standardized testing protocols, as discussed with Mr. J. Wright, adapted from Davies (1992:p43-44), Perrin (1993:p48), Chan and Maffuli (1996: p10) and Wilk et al. (1991: p 63-69). Values attained from these tests were compared to established, accepted normative values attained on similar machinery (see 3.3.2.1.e.ii Normative Values). Normative data can be used as guidelines for testing and rehabilitation when used relative to a specific population (Davies, 1992: p63).

Over 20 years of independent clinical research have proven Cybex isokinetic testing to be accurate, objective, reproducible and safe. More than a 1000 published articles, studies and presentations have shown Cybex systems to provide objective measurement of impairment and documentation of rehabilitation effectiveness (Cybex, 1996: p1-9).

Chan and Maffulli (1996:p22-3) report correlation co-efficients between 0.93 and 0.99 when using an Isokinetic Dynamometer (no p-value stated). Pincivero, Lephart and Karunakara (1997) report intraclass correlation co-efficients of 0,88 to 0.97 at 60 degrees per second, demonstrating that isokinetic values are highly reproducible provided there is adequate calibration, gravity correction and patient positioning is recorded and standardized. Davies (1992:p35) states that several studies have been conducted confirming the reliability and validity of the Cybex (no p-value stated).

3.4.2. The Myofascial Diagnostic Scale:

The myofascial diagnostic scale assesses the extent to which the patient suffers from myofascial pain syndrome. This scale was developed by Chettiar (2001), as there were no satisfactory laboratory tests or imaging techniques currently available that may be clinically utilized as objective tools when assessing severity of trigger points.

The purpose of this scale is to determine the extent to which a patient suffers from MTrp's.

The scale is rated out of 17 points. A score of 9 or above is considered indicative of an active trigger point. A score of less than 9 is indicative of a latent trigger point.

Even though the Myofascial Diagnostic Scale is not yet fully validated, it is the most appropriate tool that can be applied to achieve a consistent result (Chettiar, 2001), and has been used by Dippenaar (2003).

3.5 Demographic Data:

Demographic data recorded included the following: average age, weight and height. Only males were included in the study so as to maintain sample homogeneity.

Individual subject characteristics such as activity level, right or left shoulder dominance and type of overhead activity were also recorded at the initial consultation.

3.6 Statistical Analysis:

Data were analyzed in SPSS version 12.0.1. (SPSS Inc. Chicago, Ill).

Quantitative variables were checked for departure from normality, and in the absence of a significant departure from normality were described using means, standard deviations and 95% confidence intervals. Variables which were not normally distributed were described using medians and inter-quartile ranges. Categorical variables were described using proportions. Paired t-tests were used to compare two related means in parametric data, and non-parametric paired variables were compared using Wilcoxon signed ranks test.

Parametric correlations were done using Pearson's correlation coefficient, and non-parametric correlations used Spearman's rho. Bivariate associations between categorical variables were examined by cross-tabulating two variables and performing chi square tests or Fisher's exact tests where appropriate.

Non-parametric Mann-Whitney tests were used to compare medians between two independent groups of subjects. The two tailed exact significance value was used. Kruskal –Wallis tests were used to compare medians between more than two unpaired groups in non-parametric data, or where group sizes were small. For the various statistical tests which were applied, the

alpha level used to assess significance of the p-value was 0.05. Two tailed tests were used in all instances.

3.7 Ethics:

The ethical procedures were adhered to in accordance with the Durban Institute of Technology guidelines.

Each patient was required to complete and sign an informed consent form (Appendix L). The research involved no more than minimal risk and all information was treated as confidential.

CHAPTER 4:

THE RESULTS:

4.1 Introduction:

This chapter presents results obtained from the study. Firstly demographics of participants are presented, followed by statistical analysis of the study data. Statistical analysis is divided into 1) descriptive analysis, where data are summarized and presented, and 2) analytical statistics, where hypotheses are tested statistically. Where appropriate, means and standard deviations, together with ranges and 95% confidence intervals are presented. For non-parametric data, medians and inter-quartile ranges are presented. Frequencies for categorical variables are displayed as number and percentage. There was no missing data.

Statistical methods:

Data were analyzed in SPSS version 12.0.1. (SPSS Inc. Chicago, Ill).

Abbreviations

n = number

% = percentage

CI = Confidence interval

SD = standard deviation

p = probability value

Kg = Kilograms

Cm = centimeters

m = meters

df = degrees of freedom

IQR = inter-quartile range

4.2 Demographics:

Sixty male athletes took part in the study. The participants were between the ages of 18 and 40, with a mean age of 26.3 years (SD 6.0 years). Their weights ranged from 61 to 125 Kg with a mean of 87.1 Kg and a SD of 13.1 Kg. Heights were between 1.68 m and 2.03m, with a mean of 1.8 m and a SD of 7 cm.

The majority (n=55, 91.7%) were right shoulder dominant, while 5 (8.3%) were left shoulder dominant. The most common sport was waterpolo (n=27, 45%), followed by baseball (n=18, 30%). The distribution of sports played are shown in Figure 1.

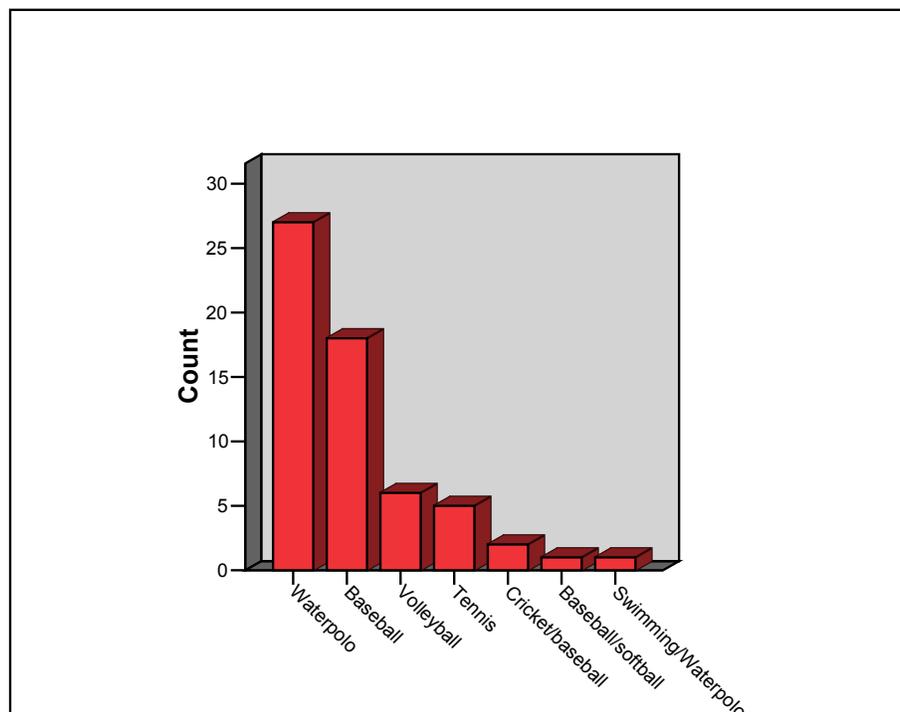


Figure 4.1: Sports played by the participants in the study

4.3. Statistical Analysis of the Data

4.3.1 Descriptive Analysis

4.3.1.1 Internal/External ratios:

Concentric contractions:

The mean internal/external ratio for peak torque in the 60 participants was 204.9% (95% CI 195.6 – 214.2). The range was 123 %– 268%, and SD was 36.9. The distribution of the ratio is shown in Figure 2 below.

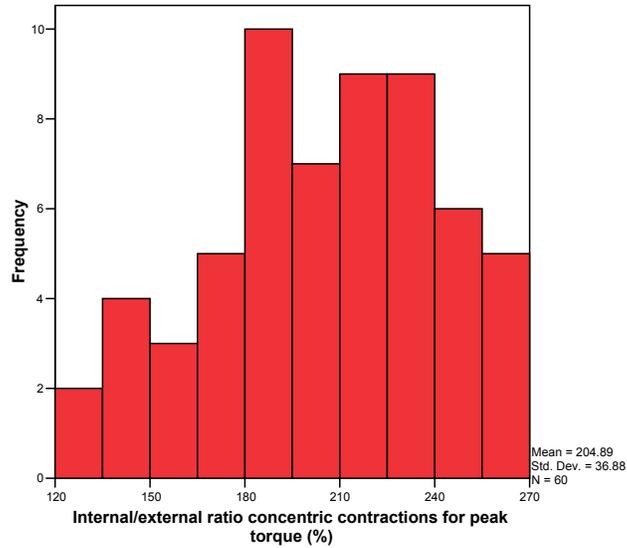


Figure 4.2: Histogram of internal/external ratio for concentric contractions for peak torque

The mean ratio for concentric contractions for work was 214.6 % (SD 39.3). The 95% CI for the mean was 204.7 – 224.6. The distribution of values is shown in Figure 3. Values ranged from 121% to 298%.

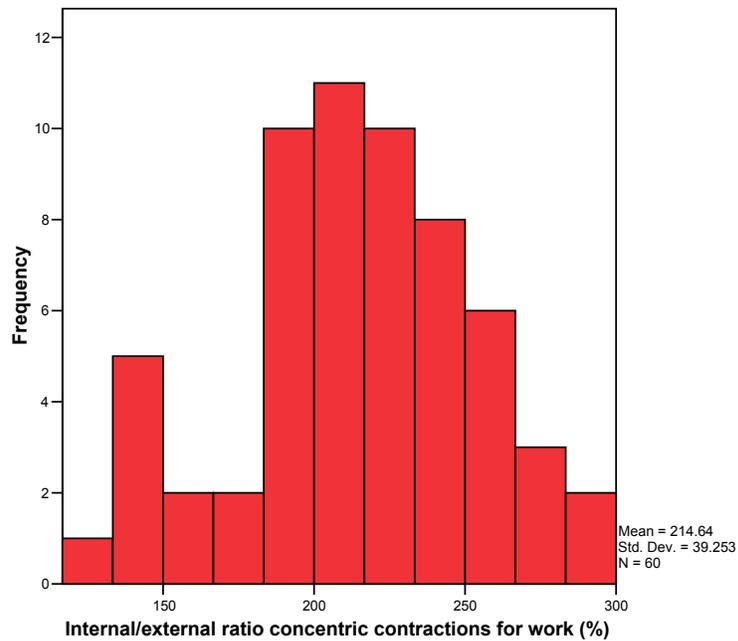


Figure 4.3: Histogram of internal/external ratio of concentric contractions for work

Eccentric Contractions:

The mean ratio for eccentric contractions for peak torque was 179.2 % (SD 37.4), 95 % CI 169.7 – 188.66, with a range from 94% to 259%. The distribution is shown in Figure 4 below.

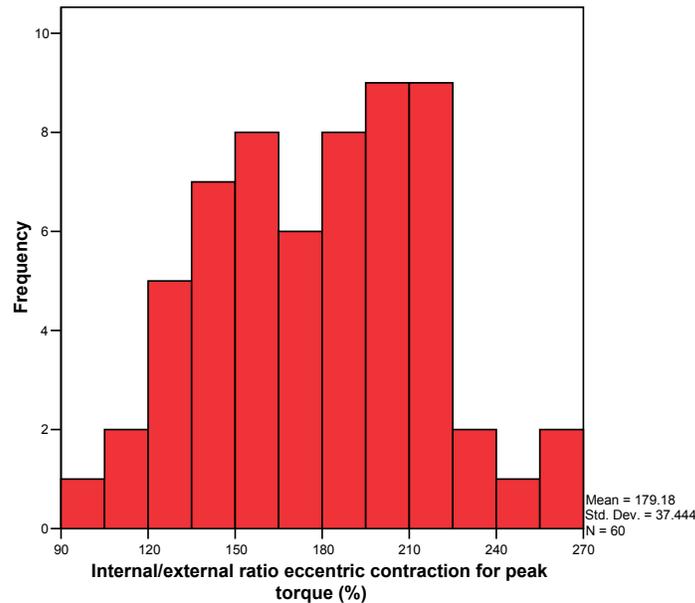


Figure 4.4: Histogram of internal/external ratio for eccentric contractions for peak torque

Ratios for eccentric contractions for work ranged from 102 to 274 % with a mean of 184.4 % and a SD of 36.7. The 95% CI was 175.1 – 193.7. The histogram is shown in figure 5.

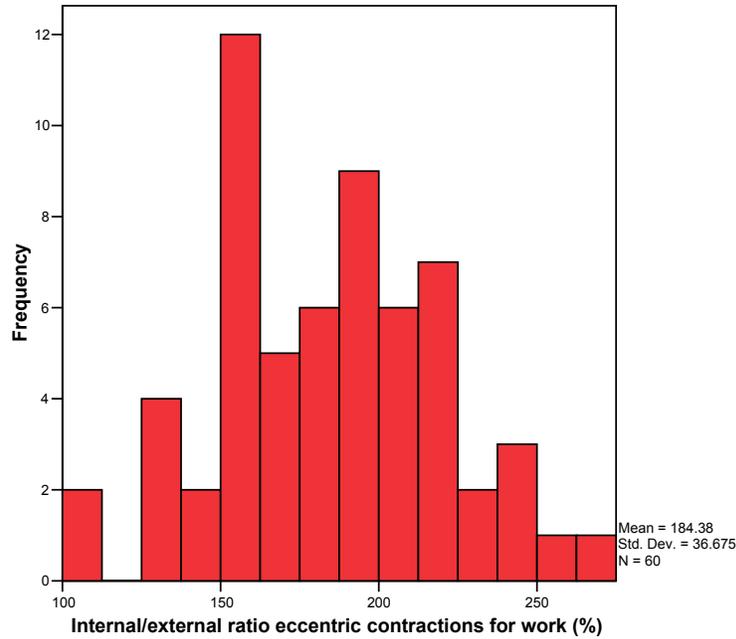


Figure 5.5: Histogram of internal/external ratio for eccentric contractions for work

Subjects were categorized according to whether they had a ratio of $\leq 150\%$ (normal) or $>150\%$ (above normal). For concentric contraction peak torque and work, 90% (n=54) subjects had a ratio of greater than 150%. For eccentric contraction peak torque and work, 85% (n=51) subjects had a ratio of greater than 150%.

4.3.1.2 Number, location and severity of trigger points:

Number of agonistic, antagonistic and total trigger points present is shown in Table 1. It can be seen that 65% of participants had more than one trigger point, and more subjects had agonistic trigger points than had antagonistic trigger points.

Since the majority of subjects had more than one trigger point, subjects were classified on the basis of whether their trigger points were mainly agonistic (i.e. they had more agonistic than antagonistic trigger points), mainly antagonistic, or equally agonistic and antagonistic. The frequency distribution of these groups is shown below in Table 2.

Table 4.1: Number and percentage of trigger points present in subjects

Trigger points	number	n	%
Agonistic trigger points	0	2	3.3
	1	30	50.0
	2	25	41.7
	3	3	5.0
Antagonistic trigger points	0	36	60.0
	1	21	35.0
	2	3	5.0
Total number of trigger points	1	21	35.0
	2	25	41.7
	3	12	20.0
	4	1	1.7
	5	1	1.7

Table 4.2: Location of trigger points

Location	n	%
mainly antagonistic	3	5.0
mainly agonistic	46	76.7
equal agonistic and antagonistic	11	18.3
Total	60	100.0

Severity scores of trigger points by agonistic, antagonistic and in total is shown in Table 3. Total severity score ranged from 10 to 57 with a median of 25 (IQR 13-32).

Table 4.3: Descriptive statistics for trigger points severity score

		Severity score for agonistic trigger points	Severity score for antagonistic trigger points	Total severity score
N		58	24	60
Median		16.50	12.00	25.00
Minimum		10	10	10
Maximum		42	26	57
Percentile	25	12.75	11.00	13.00
	75	27.25	13.50	32.00

4.3.2 Analytical Statistics**4.3.2.1 Test for altered internal/external ratios**

Table 4 shows the results of a one-sample t-test which examines the statistical significance of the increase in mean ratio above 150%. For all four ratios the mean was highly significantly different from 150% ($p < 0.001$). Thus it can be concluded that the ratios were all significantly greater than 150%.

Table 4.4: One-sample t-test for comparison of mean ratios to normal value of 150%

	Test Value = 150					
	t	df	p (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Internal/external ratio concentric torque	11.528	59	<0.001*	54.887	45.36	64.41
Internal/external ratio eccentric torque	6.037	59	<0.001*	29.182	19.51	38.86
Internal/external ratio concentric work	12.755	59	<0.001*	64.637	54.50	74.78
Internal/external ratio eccentric work	7.262	59	<0.001*	34.383	24.91	43.86

* statistically significant at 0.001 level

4.3.2.2 Comparison of concentric and eccentric ratios:

Table 5 shows that there was a significant difference between mean concentric and eccentric contractions for both peak torque and work ($p < 0.001$). The positive mean difference in both instances indicates that ratios for concentric contractions were higher than those for eccentric contractions.

Table 4.5: Paired t-tests of the internal/external ratio comparisons between concentric and eccentric contractions

Internal/external ratio comparisons	Mean difference	Std. Deviation	95% Confidence Interval of the Difference		t	df	p (two tailed)
			Lower	Upper			
Concentric vs. eccentric contractions for peak torque	25.704	30.542	17.815	33.594	6.519	59	<0.001*
Concentric vs. eccentric contractions for work	30.255	30.549	22.363	38.146	7.671	59	<0.001*

* statistically significant at the 0.001 level

4.3.2.3 Correlation between work and peak torque ratios:

High and statistically significant correlations were observed between peak torque and work ratios for concentric contractions ($R = 0.857$, $p < 0.001$), and eccentric contractions ($R = 0.915$, $p < 0.001$). These were higher than the correlation coefficients observed between concentric and eccentric peak torque ratios ($R = 0.662$, $p < 0.001$) and concentric and eccentric work ratios ($R = 0.678$, $p < 0.001$). Thus work measurements are highly correlated with peak torque measurements.

4.3.2.4 Associations between trigger points and internal/external ratios:

Number of trigger points

There was no correlation between number of agonistic and number of antagonistic trigger points ($R = -0.031$, $p = 0.817$), nor between the severity score for agonistic and antagonistic trigger points ($R = 0.282$, $p = 0.204$). Thus the presence and severity of agonistic trigger points was not related to the presence and severity of antagonistic trigger points.

Median number of trigger points was compared between the presence or absence of an altered ratio (i.e. a ratio of greater than 150%) using a non-parametric Mann-Whitney test. There was no significant differences in median number of trigger points between groups, although the median total number of trigger points was consistently higher in those with altered ratios than in those with normal ratios. See Table 6.

Table 4.6: Comparison of median number of trigger points between subjects with altered and normal ratios

		Agonistic Trigger points		Antagonistic Trigger points		Total trigger points	
		Median (IQR)	p	Median (IQR)	p	Median (IQR)	p
Concentric peak torque ratio	< = normal (n=6)	1 (1)	0.102	0 (1)	0.727	1 (1)	0.082
	> normal (n=54)	1.5 (1)		0 (2)		2 (2)	
Eccentric peak torque ratio	< = normal (n=9)	1 (1)	0.425	0 (1)	0.220	1 (1)	0.151
	> normal (n=51)	1 (1)		0 (1)		2 (2)	
Concentric work ratio	< = normal (n=6)	1 (1)	0.352	0.5 (1)	0.746	1.5 (1)	0.477
	> normal (n=54)	1 (1)		0 (1)		2 (1)	
Eccentric work ratio	< = normal (n=9)	1 (1)	0.425	0 (1)	0.220	1 (1)	0.151
	> normal (n=51)	1 (1)		0 (1)		2 (2)	

Location of trigger points

There was no significant difference between median ratios across the three groups of location of trigger points (mainly agonistic, antagonistic or equally agonistic and antagonistic). Results of the Kruskal- Wallis tests are shown in Table 7 below.

Table 4.7: Comparison of median ratios by location of trigger points

	Internal/external ratio concentric torque	Internal/external ratio eccentric torque	Internal/external ratio concentric work	Internal/external ratio eccentric work
Kruskal-Wallis test statistic	0.971	0.380	2.761	1.060
Df	2	2	2	2
p value	0.615	0.827	0.251	0.589

Grouping Variable: Location of trigger points

Severity of trigger points

Since severity scores were not normally distributed, non-parametric Mann-Whitney tests were used to compare them between groups with altered and normal ratios. See Table 8.

Table 4.8: Comparison of trigger points severity scores between groups with altered and normal ratios

		Severity score for agonistic trigger points n=58			Severity score for antagonistic trigger points n=24			Severity score for total trigger points n=60		
		Median (IQR)	n	p	Median (IQR)	n	p	Median (IQR)	n	p
Concentric peak torque ratio	< = normal	12 (10)	5	0.72	^	2	0.116	12 (14)	6	0.037
	> normal	21 (15)	53	5	12 (3)	22		25.5 (18)	54	
Eccentric peak torque ratio	< = normal	14 (11)	9	0.66	^	2	0.168	14 (17)	9	0.152
	> normal	21 (15)	49	7	12 (3)	22		25 (18)	51	
Concentric work ratio	< = normal	17 (11)	5	0.62	^	3	0.500	18 (18)	6	0.391
	> normal	16 (15)	53	0	12 (4)	21		25 (18)	54	
Eccentric work ratio	< = normal	14 (11)	9	0.66	^	2	0.168	14 (17)	9	0.152
	> normal	21 (15)	49	7	12 (3)	22		25 (18)	51	

* statistically significant at the 0.05 level

^ omitted due to too few valid values in this category

CHAPTER 5:

DISCUSSION OF THE RESULTS:

5.1 Introduction:

This chapter involves the discussion of the demographic data and the results after statistical analysis of the data obtained from the objective (Myofascial Diagnostic Scale readings, location of MTrp's readings and isokinetic ratio readings) correlation tests. Problems encountered through the course of this study are also discussed in this chapter.

The results will be discussed in two parts:

- Demographic data
- Correlation comparisons

5.2 Demographic Data:

Sixty male athletes took part in the study to maintain sample homogeneity. Their weights ranged from 61 to 125 Kg with a mean of 87.1 Kg and a standard deviation of 13.1 Kg. Heights were between 1.68 m and 2.03m, with a mean of 1.8 m and a standard deviation of 7 cm. The majority (n=55, 91.7%) were right shoulder dominant, while 5 (8.3%) were left shoulder dominant.

5.2.1 Age Distribution:

Jobe and Kvitne (1989: p963) classify shoulder pathology among athletes into two types of disorders: those affecting the older population (over 35 years of age), and those affecting the younger population (18-35 years).

Shoulder disorders in the older population can often be attributed to a degenerative process. Repetitive overhand activities over a prolonged period of time can result in the development of

acromion process overgrowth, subacromial space narrowing, impingement of structures and eventual rotator cuff tearing (Neer, 1983: p70).

However, in the younger population, repetitive high-velocity throwing motions can result in chronic microtrauma involving the stabilizing mechanisms of the glenohumeral joint (Jobe, 1983: p117).

The participants of this study were between the ages of 18 and 40, with a mean age of 26.3 years and a standard deviation of 6.0 years. This is lower than the mean age between 18-40 being 29, which could indicate that the pain is of a microtraumatic nature as opposed to being the result of a degenerative process, or simply that the nature of the sports involve younger participants.

5.2.2 Sport Distribution and Activity Level of Subjects:

See Figure 4.1

Sixty male athletes took part in the study. The sporting activities included waterpolo, baseball, volleyball, tennis, cricket, softball and swimming. A small number of subjects were competing at various levels of two of the aforementioned activities, with one always being an overhead throwing sport.

The most common sporting activity was waterpolo with twenty-eight of the subjects. One of these subjects competed in swimming at a national level in addition to waterpolo. Fourteen subjects competed at a national level. The other fourteen subjects competed at club and provincial levels. Subjects trained an average of fifteen hours per week.

The second most common activity was baseball with twenty-one subjects. One of these subjects competed in softball at a national level in addition to baseball. Another two subjects competed in cricket at a club level in addition to baseball. Four subjects competed at a national level, while the other fourteen competed at club and provincial levels. Subjects trained an average of twelve hours per week.

Six subjects were volleyball players competing at a provincial level. Subjects trained an average of ten hours per week.

Five subjects were tennis players competing at a club level. Subjects trained an average of nine hours per week.

5.2.3 Comments:

The higher incidence of waterpolo players maybe attributed to the time of the study, which was after the annual Currie Cup Waterpolo Tournament. The high percentage of baseball players maybe attributed to the provincial selection tournament, prior to the time of the study. Had the study been conducted at another time of the year it is the researcher's opinion that these percentages would not be as high.

The majority of waterpolo players competed at a national level or higher. The training includes a large amount of swimming and this involves mainly internal rotation of the arm during the normal freestyle stroke without any external rotation training. The large internal rotation acceleration force generated to throw a waterpolo ball, combined with the swimming, could predispose such athletes to muscle imbalance about the shoulder purely from internal rotator muscle hypertrophy. The muscle imbalance could lead to abnormal biomechanics and dysfunction of the overhead throw, resulting in microtraumatic injuries.

Baseball players generate extremely high speeds during an overhead throw/pitch. Many players competed for club aswell as the provincial sides. This means that the repetitions of overhead throwing would increase per week. Thus, high repetition combined with the large eccentric activity required to decelerate an arm rotating internally at such a high speed could predispose such athletes to microtrauma of the external rotators, resulting in weakness and decreased work tolerance of the involved muscle function.

5.3 Objective Measurement: Isokinetic measurement in comparison to normative values:

5.3.1 Internal/External ratios: Concentric contractions for peak torque

This measurement determines the maximum amount of torque (measured in Nm) produced by the internal and external rotators of the dominant shoulder, regardless of at what point in the range of motion it occurs.

The mean internal/external rotation ratio in the 60 participants was 204.9%. The 95% confidence interval for the mean was 195.6 – 214.2. The range was 123% - 268%, and the standard deviation was 36.9. This demonstrates a significant increase in the ratio when compared to the established normative values of 150%. This may be due to the fact that the throwing action involves a large amount concentric contraction of the internal rotators with very little concentric contraction of the external rotators. Many repetitions over a long period of time

would increase the strength of the internal rotators without subsequent strengthening of the external rotators, thus creating the muscle imbalances.

The repetitive, stressful demands placed on the shoulder could result in eccentric trauma to the external rotators. Eccentric overload can cause intramuscular tearing and inflammation of the muscle. This could cause MTrp and scar tissue formation, thus creating poor external rotator muscle performance.

The mean ratios for these participants were remarkably high when compared to previous research done (Brown et al. 1988: p577; Hinton, 1988: p274; Alderink and Kluck, 1986: p163-172; and Pedegana et al. 1982: p352; Koziris et al. 1991: p253; Cook et al. 1987: p451), all of which established values above 150%. A reason for this could be that the Cybex Isokinetic Dynamometer does not offer gravity correction for this specific test position (Wright, 2003). The weight of the lever handle would be a factor in elevating these ratios to a certain extent, although, according to Wright (2003) this would be extremely difficult to calculate. This could however be eliminated in the future by establishing a normative ratio in non-athletes on this machine which could be used as a control group.

5.3.2 Internal/External ratios: Concentric contractions for work

The total area underneath the curve is the total work of the torque curve with each repetition regardless of speed, range of motion or time. The mean ratio for concentric contractions for work was 214.6 %. The 95% confidence interval for the mean was 204.7 – 224.6. Values ranged from 121% - 298% with a standard deviation of 39.3. The distribution of values is shown in Figure 3. According to Wright (2003), the work values are an indication of the athlete's ability to maintain a uniform contraction over a prolonged period of time. The body of research in this field is extremely limited and does warrant further investigation.

This study has shown high and statistically significant correlations between peak torque and work ratios for concentric contractions, which indicates that the majority of the subjects were able to maintain their maximum amount of torque for the duration of the test procedure. Therefore, possible explanations for the significant increase in the concentric work ratio when compared to the established normative values are similar to those of peak torque in 5.3.1 above. The throwing action involves a large amount concentric contraction of the internal rotators with very little concentric contraction of the external rotators and the Cybex Isokinetic Dynamometer does not offer gravity correction for this specific test position.

The repetitive, stressful demands placed on the shoulder could result in eccentric trauma to the external rotators. Eccentric overload can cause intramuscular tearing and inflammation of

the muscle. This could cause MTrp and scar tissue formation, thus creating poor external rotator muscle performance.

5.3.3 Internal/External ratios: Eccentric contractions for peak torque

This measurement determines the maximum amount of torque (measured in Nm) produced by the internal and external rotators of the dominant shoulder, regardless of at what point in the range of motion it occurs.

The mean ratio for eccentric contractions for peak torque was 179.2 % with a standard deviation of 37.4. The 95 % confidence interval for the mean was 169.7 – 188.66 with a range from 94% - 259%. The distribution is shown in Figure 4.4.

The mean ratio for eccentric contractions for peak torque was higher than established normative values (150%). This may be due to the fact that the throwing action involves a large amount eccentric contraction of the external rotators (deceleration phase), with very little eccentric contraction of the internal rotators. Eccentric loading has been shown to cause intramuscular connective tissue tearing (Davies, 1984: p261-291 and Nirschl, 1986: p322-337), which can lead to a cycle of chronic inflammation and muscular weakness. Most subjects (76.7%) had mainly agonistic trigger points (located in the external rotator group). It is possible that the higher eccentric ratios could have been caused by pain inhibition or by frank weakness of the external rotators during eccentric contraction. However, more specific investigation is required to determine the cause of the relatively higher eccentric ratios.

One possible option would be to review these ratios after treatment of the MTrp's in order to assess their role in creating the trigger points.

5.3.4 Internal/External ratios: Eccentric contractions for work

The total area underneath the curve is the total work of the torque curve with each repetition regardless of speed, range of motion or time. The mean ratio for concentric contractions for work was 184.4%. The 95% confidence interval for the mean was 175.1 – 193.7. Values ranged from 102% - 274% with a standard deviation of 36.7. The distribution of values are shown in Figure 4.5.

This study has shown high and statistically significant correlations between peak torque and work ratios for eccentric contractions. Therefore, possible explanations for the significant increase in the eccentric work ratio when compared to the established normative values are

similar to those of peak torque in 5.3.3 above. The throwing action involves a large amount eccentric contraction of the external rotators (deceleration phase), with very little eccentric contraction of the internal rotators. Repetitive eccentric contractions can eventually lead to chronic inflammation and weakness of the involved muscle/s.

5.4 Demographics of the MTrp's:

5.4.1 Total Number of MTrp's:

Number of agonistic, antagonistic and total trigger points present is shown in Table 4.1. It can be seen that 65% of participants had more than one trigger point, and more subjects (76.7%) had agonistic trigger points (trigger points located in shoulder external rotators- supraspinatus, infraspinatus, teres minor and posterior deltoid muscles) than had antagonistic trigger points (trigger points in the group of internal rotators that oppose the external rotation- pectoralis major, subscapularis and anterior deltoid muscles). It is important that the concept of agonist and antagonist is well understood. When referring to the action of external rotation at the shoulder, the above paragraph applies. When one looks at the act of throwing i.e. internal rotation at the shoulder, the infraspinatus, teres minor and posterior deltoid muscles now become antagonists to this motion (firing eccentrically).

Most of the athletes in this study displayed a relative external rotation strength deficit (increased ratios) and had a higher number of trigger points located in the external rotators. This implies that the number of trigger points may play a role in the muscle imbalances seen in such athletes.

5.4.2 Location of MTrp's:

Since the majority of subjects had more than one trigger point, subjects were classified on the basis of whether their trigger points were mainly agonistic (i.e. they had more agonistic than antagonistic trigger points), mainly antagonistic, or equally agonistic and antagonistic. The frequency distribution of these groups is shown in Table 4.2. Most subjects (76.7%) had mainly agonistic (external rotator group). Competitive athletes perform numerous overhead strokes per week, putting a large strain on the external rotators to perform their function of decelerating the arm by contracting eccentrically. Eccentric loading has been shown to cause intramuscular connective tissue tearing which can lead to a cycle of chronic inflammation. The activation of a trigger point is usually associated with some form of muscle overload, which may be acute, sustained and/or repetitive. It can be reasoned that the repetitive eccentric contraction of the

external rotator group may predispose overhead athletes to myofasciitis of the external rotator muscles.

5.4.3 Severity of MTrp's:

Severity scores of trigger points by agonistic, antagonistic and in total is shown in Table 4.3. Total severity score ranged from 10 to 57 with a median of 25 and an inter-quartile range of 13 – 32. Higher severity scores for the trigger points in the agonistic group (external rotators) were evident. Increased pain in this area may cause a vicious circle, especially with regard to overuse syndromes, whereby pain leads to disuse or an altered throwing stroke to compensate for the pain, which leads to muscle atrophy and dysfunction, which leads to increased vulnerability to injury and recurrence of pain on attempted resumption of activity.

5.5 Statistical Results for Correlation Comparison:

5.5.1 Test for altered internal/external ratios:

The mean internal/external ratios for peak torque and work exceeded the normal value of 150%. Table 4.4 shows the results of a one-sample t-test which examines the statistical significance of the increase in mean ratio above 150%. For all four ratios the mean was highly significantly different from 150% ($p < 0.001$). Thus it can be concluded that the ratios were all significantly greater than 150%.

This was a limitation of the study as the group was too similar i.e. the group without altered ratios was too small and so finding significant associations between trigger points and altered ratios could not occur, if any difference existed in reality. Future studies should include a control group of non-athletes without altered ratios.

5.5.2 Comparison of concentric and eccentric ratios

Table 4.5 shows that there was a significant difference between mean concentric and eccentric contractions for both peak torque and work ($p < 0.001$). The positive mean difference in both instances indicates that ratios for concentric contractions were higher than those for eccentric contractions.

During the deceleration phase of throwing, a large eccentric load is placed on the external rotators of the shoulder. Eccentric loading has been shown to cause intramuscular connective tissue tearing which can lead to a cycle of chronic inflammation and muscular weakness. In

contrast, the internal rotator musculature undergoes a plyometric type of training (maximally stretching muscle groups, then explosively contracting them in a concentric manner) with each overhead stroke. This type of training has been found to greatly enhance power in larger muscle groups (Miller, 1984: p68-83).

These differences in muscular activity during the overhead stroke may partially explain why the overhead athletes show a consistent increase in strength of the dominant shoulder internal rotators, but not in the external rotators. These adaptations result higher internal/external strength and work ratios in the dominant shoulder. Such a situation may allow excessive anterior displacement and increased distraction of the humeral head during the throwing motion (Hinton, 1988: p274-279). According to Andrews *et al.* (1985: p337-341) this may increase the decelerating load on the long head of the biceps, which would increase the forces on the already stressed biceps-labral complex, resulting in dysfunction and possible injury.

A lack of concentric training or activity in the external rotators may therefore be a factor for the ratio differences between the two sets of values and should be considered in training programs and rehabilitation programs for competitive overhead athletes.

5.5.3 Correlation between work and peak torque ratios:

High and statistically significant correlations were observed between peak torque and work ratios for concentric contractions ($R=0.857$, $p < 0.001$), and eccentric contractions ($R=0.915$, $p < 0.001$). These were higher than the correlation coefficients observed between concentric and eccentric peak torque ratios ($R = 0.662$, $p < 0.001$) and concentric and eccentric work ratios ($R = 0.678$, $p < 0.001$). Thus work measurements are highly correlated with peak torque measurements. According to Wright (2003), the body of literature available on work ratios correlating with peak torque is very limited if available at all. Results were recorded for future research on this topic.

5.5.4 Associations between MTrp's and internal/external ratios:

5.5.4.1 Comparison of number of MTrp's between subjects with altered and normal ratios:

There was no correlation between number of agonistic and number of antagonistic trigger points ($R = -0.031$, $p = 0.817$). According to the classification system in section 4.3.1.2; 76.7% of subjects had mostly agonistic trigger points (trigger points located within the external rotators of the shoulder). Most of the subjects had altered ratios which suggests that there is

an association between trigger points located in this muscle group and the presence of the relative external rotation strength deficit. This leads to the question of trigger points being a causative factor in the presentation of the disturbed ratios or as a result of training induced muscle imbalance which does overload this muscle group. Research which reviewed the ratios of such athletes after receiving MTrp treatment could help answer this question.

Median number of trigger points was compared between the presence or absence of an altered ratio (i.e. a ratio of greater than 150%) using a non-parametric Mann-Whitney test. There was no significant differences in median number of trigger points between groups, although the median total number of trigger points was consistently higher in those with altered ratios than in those with normal ratios. The likely explanation for this not reaching statistical significance is due to the small sample size in those who did not have an altered ratio. See Table 4.6. A likely explanation for a higher number of trigger points being found in the subjects with altered ratios could be as a result of pain inhibition. A greater number of active trigger points would result in greater pain over the shoulder and inhibit subjects from executing a full smooth muscle contraction. Athletes with greater pain will also develop biomechanical changes in their strokes so as to avoid entering into a painful range. This would lead to recruitment of other muscle groups and result in further muscle imbalance, thus perpetuating the dysfunction cycle.

5.5.4.2 Comparison of location of MTrp's between subjects with altered and normal ratios:

There was no significant difference between median ratios across the three groups of location of trigger points (mainly agonistic, antagonistic or equally agonistic and antagonistic). Results of the Kruskal- Wallis tests are shown in Table 4.7.

Again, the majority of subjects had more trigger points located in the agonist group. When there is injury to a muscle, antagonistic muscles contract to immobilize the joint, thus preventing use of the injured muscle. In time, the sustained contraction of the antagonists could result in injury of the involved muscles. This could result in the development of trigger points in these muscles i.e. the internal rotators. This emphasizes the importance, when treating repetitive strain injuries to assess the entire myotactic unit.

Repetitive concentric contracting of the internal rotators during the overhead stroke could result in them becoming overactivated, tightened, and shortened. This is important clinically as tight muscles tend to predominate over weak muscles in movement patterns and hypertonic muscles will reflexively inhibit their antagonists, thereby weakening them further. More research in this area is required especially when considering causative factors of trigger points between agonist and antagonistic muscle groups.

5.5.4.3 Comparison of MTrp's severity scores between subjects with altered and normal ratios:

There was a highly significant difference between subjects' severity score for agonistic trigger points and their score for antagonistic trigger points ($p < 0.001$). In the 22 subjects who had both agonistic and antagonistic trigger points, the scores for antagonistic trigger points were significantly lower than those for agonistic trigger points.

Since severity scores were not normally distributed, non-parametric Mann-Whitney tests were used to compare them between groups with altered and normal ratios. The only significant association observed was with concentric contraction peak torque ratio and total severity score. Those who had a greater than normal ratio had a slightly significantly higher severity score than those who had a normal or less ratio ($p = 0.037$). From Table 4.8 it can be seen that most median severity scores were higher in those with abnormal ratios, although this did not reach statistical significance in most cases. The likely explanation for this not reaching statistical significance is due to the small sample size in those who did not have an altered ratio.

According to Lawrence et al. (1996: p73-74), it is possible that the weakness in these muscles is a type of guarding mechanism in which the muscle is reflexively inhibited from full contraction due to pain. Travell, Simons and Simons (1999: p21), state that disturbances of motor functions caused by MTrp's include weakness of involved muscle function and that a muscle harboring a MTrp is prevented by pain from reaching its full stretch range of motion.

CHAPTER 6:

CONCLUSIONS AND RECOMMENDATIONS:

6.1 Conclusions:

This study confirms the presence of both a concentric and eccentric altered internal/external strength ratio of the dominant shoulder in competitive throwing athletes, in terms of peak torque and work values, at an isokinetic test velocity of 60 degrees per second.

The data presented indicate that overhead sports impose adaptive strength changes in the dominant arm of such athletes. The results imply that the act of the overhead stroke places unique stresses on the dominant shoulder, especially the internal and external rotators. Primarily, the changes occur by increasing the strength of the internal rotator muscle groups without subsequent strengthening of the external rotator muscle groups. The inability of the external rotators to handle the eccentric force loads created in a repetitive internal rotation movement, may predispose the athlete to shoulder injury. Because of these special demands placed on the athletes shoulder, trainers, athletes and clinicians should note that exercises to strengthen the external rotators in overhead athletes will help maintain a favorable internal/external strength balance and may prevent or lessen the severity of repetitive overload injuries.

The MTrp assessment revealed that 65% of the subjects had more than one trigger point. Although myofascial trigger points were found in both the agonist and antagonistic muscle groups, most subjects (76.7%) had mainly agonistic (external rotator group) trigger points. This suggests that overhead athletes may be predisposed to developing trigger points in the external rotator group. It is unclear whether the trigger points are the cause of the muscle imbalance or develop as a result thereof.

The number and location of trigger points were not significantly associated with altered internal/external ratios, although the data did show a trend of higher median number of trigger points in subjects with altered ratios. Severity of trigger points was not statistically significant between the groups with altered and normal ratios, except for concentric peak torque ratio, where severity score for total trigger points was significantly higher in those with above normal ratio ($p = 0.037$). There was a visible trend of higher median trigger point severity score in the

groups with altered ratios, although statistical significance was not achieved. This was due to the fact that the majority of subjects had severe trigger points resulting in a sample size that was too similar. The majority of subjects also had disturbed ratios, resulting in a similar sample size. Associations were not significant because of a lack of variation between the two groups.

This study reinforces previous research which states that eccentric muscle groups i.e. infraspinatus and teres minor, are more likely to developing trigger points due to the greater forces which are generated during their contraction than the concentric counterparts.

According to Lawrence et al. (1996: p73-74), it is possible that the weakness in these muscles is a type of guarding mechanism in which the muscle is reflexively inhibited from full contraction due to pain. Travell, Simons and Simons (1999: p21), state that disturbances of motor functions caused by MTrp's include weakness of involved muscle function and that a muscle harboring a MTrp is prevented by pain from reaching its full stretch range of motion.

This research therefore indicates that there is a certain degree of association between the presence of myofascial trigger points and a disturbed internal/external ratio in overhead athletes. Further, more specific, investigation of eccentric and concentric strength ratios is indicated by this study.

6.2 Recommendations:

- At present the body of normative data for isokinetic testing is very small and difficult to access. Studies need to be conducted to accurately determine normative data at all testing speeds and for all isokinetic parameters. Such studies should be conducted in a standardized manner so research can be conducted using identical protocols, enabling comparisons to be made.
- A larger sample should be considered for studies such as this. This would ensure that conclusions drawn are accurate and improve statistical validity, and thus would avoid a type II error. However budget considerations and the cost of using outside facilities was a limiting factor in this study. .
- The majority of participants had altered ratios. The sample size in the group without altered ratios was too small to show any significant difference in MTrp location and severity to the group with altered ratios, if any difference existed in reality. The cost of using outside facilities was again a limiting factor here. To show an association between altered ratios and trigger points, further research could perform a case-control study comparing athletes with altered ratios to non athletes with normal ratios and examine the presence, location and severity of trigger points between the two groups
- One ratio which was not included in the study but the researcher feels would give an accurate description of how the shoulder functions dynamically during the throwing motion would be comparing concentric internal rotation to eccentric external rotation. A program could be designed which would simulate the rapid reversal from concentric internal rotation to eccentric external rotation that occurs at ball release, although isokinetic machines cannot switch muscle action in mid-arc of motion which could present a problem. This ratio would be more representative of how the two groups of muscles (agonists and antagonists) compare in the actual act of throwing and should be considered as an option for further study.
- Unfortunately, most existing isokinetic data examine only the concentric component of rotator cuff action and specifically concentric external rotation (Andrews and Wilk, 1994: p574). Because the supraspinatus is not primarily an external rotator and the rest of the cuff musculature acts primarily eccentrically, concentric analysis of external rotation may be inadequate. Future studies should aim at comparing and analyzing the eccentric action of the rotator cuff.

- Further research should focus on the treatment of MTrp's in the management of athletes with muscle imbalances. This would help establish whether they are perpetuating, causative or concomitant factors in such athletes.
- An effort should be made to determine the possibility of the external rotator muscle inhibition, secondary to pain about the shoulder as this will affect both treatment and rehabilitation protocols for such conditions.
- A follow-up study could review the ratios in this study after receiving treatment for the MTrp's. Thus giving a better understanding of the role that trigger points play in creating the imbalance.

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