The effectiveness of needling of myofascial trigger points on internal- external muscle peak torque and total work ratios of the shoulder rotator myotatic unit in overhead throwing athletes suffering from myofascial pain and dysfunction syndrome.

By

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Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic at the Durban Institute of Technology.

I, Nicholas Royce, do declare that this dissertation is representative of my own work in both conception and execution.

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DEDICATION

Change and growth take place when a person has risked himself, and dares to become involved in experimenting with his own life.

Herbet Otto

This is dedicated to my family and girlfriend who have provided unwavering support through both the good and the bad times. I have been blessed to have you by my side, thank you.

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Thanks to my family, for always being there every step of the way.

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ABSTRACT

The purpose of this study was to determine whether dry needling of myofascial trigger points (TrP's), found in the shoulder rotator myotatic unit, had an effect on the peak torque and total work parameters of the shoulder myotatic unit and by inference, the relative external rotation strength deficit in over-head throwing athletes.

Athletes who perform overhead throwing sports such as: baseball, javelin, swimming/waterpolo and tennis, are susceptible to sustaining a micro-traumatic injury of the rotator myotatic unit of the shoulder, owing to repetitive high velocity mechanical stress placed on the shoulder at the extreme ranges of motion.

The inherent structure of the shoulder, with three external rotators and five internal rotators, causes a muscle imbalance before an activity, such as throwing occurs, and this can predispose an athlete to Repetitive Stress Injuries (RSI) as a result of overuse or overload.

The incidence and activation of TrP's in shoulder muscles can be accounted for on the basis of mechanical stress such as overuse / overload and thus could change muscle fiber co-ordination (muscle activity) and precipitate a painful lesion. It can be seen in current literature that TrP's produce a number of signs and symptoms such as:

- spasm of other muscles,
- weakness of involved muscle function,
- loss of co-ordination and
- decreased work tolerance of the involved muscle.

Therefore the TrP's present in the shoulder rotator unit could contribute to changes in internal/external rotation ratios in over head athletes, and thus by de-activating or eliminating these TrP's, it is possible that these ratios may be

improved along with the relative external rotation strength deficit in these athletes.

This study was structured as a pilot intervention clinical assessment study which included thirty symptomatic participants who were found to have active TrP's. Each participant underwent a case history, physical and shoulder regional examination. They were then treated on two occasions, using the dry needling technique, and then re-assessed on the Cybex 700 Isokinetic Dynamometer in order to determine if there was any improvement on the internal/external ratios and by inference strength deficit of the external rotators of the rotator muscles of the shoulder.

The SPSS statistical package was used in order to measure the relationship between the peak torque and total work of the internal and external ratios of the shoulder and to establish a comparable clinical profile.

The intervention significantly reduced the number and severity of trigger points. The cybex readings increased somewhat post intervention, with work concentric internal and eccentric external readings increasing significantly. The ratios all increased, but none showed statistical significance. The mean internal/external rotation ratios for peak torque and work were above the normal value of 150% ($p<0.001$) post -treatment.

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Glossary

AGONISTIC MUSCLE:

Muscles, or portions of muscles, so attached anatomically that when they contract they develop forces that complement or re-inforce 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 CONTRACTIONS:

Concentric contractions are defined as the development of tension by a muscle while the origin and insertion approximate each other. This involves the shortening of the muscle fibers with the origin and insertion approximating. This is also referred to as positive work by Davies (1992: 25).

ECCENTRIC CONTRACTIONS:

The development of tension that occurs as the origin and insertion move away from each other defines an eccentric contraction. This involves the lengthening of muscle fibers with the origin and insertion separating. Davies (1992: 25) refers to this as negative muscle work.

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).

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).

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).

MYOFASCIAL PAIN SYNDROME:

A regional muscular disorder that results from myofascial TrP's (Lee et al, 1997:p81-89). Both active and latent TrP's can result in MPS (Hou et al., 2002: p1411-1412).

A MYOFASCIAL TRIGGER POINT (TrP's):

A TrP is a hyperirritable spot in skeletal muscle that is associated with a hypersensitive palpable nodule in a taut band. The activation of a TrP 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 and Simons (1983:p21), includes spasm of other muscles, weakness of the involved muscle function, loss of coordination and decreased work tolerance of the involved muscle.

A LATENT MYOFASCIAL TRIGGER POINT:

A focus of hyperirritability in a muscle or its fascia that is clinically quiescent with respect to pain, but may have all the other clinical characteristics of an active trigger point (Travell and Simons, 1999).

AN ACTIVE MYOFASCIAL TRIGGER POINT:

An active myofascial TrP, as defined by Travell and Simons (1999), causes a clinical pain complaint. It is a focus of hyperirritability in a muscle or its fascia that is symptomatic with respect to pain. It is always tender, prevents full lengthening of the muscle, weakens the muscle, refers a patient – recognized pain on direct compression, mediates a local twitch response of muscle fibres when adequately stimulated and, when compressed within the patients pain tolerance, produces referred motor phenomena, and often autonomic phenomena, generally in its pain reference zone, and causes tenderness in the pain reference zone.

AMI is a pre-synaptic, ongoing reflex inhibition of musculature surrounding a joint following distension or damage to structures of that joint.

Myofascial Pain Syndrome: a regional muscular disorder that results from myofascial TrPs (Lee et al, 1997: 81-89).

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 and Moore and Dalley 1999: p697).

ANTAGONIST MUSCLES TO SCAPULA ELEVATION:

Pectoralis, lattisimus dorsi and levator scapula. agonistic muscles to shoulder abduction: infraspinatus, teres minor, supraspinatus and trapezius (Jacobson et-al, 1989:p1037).

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).

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 wrong, 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).

SUBLUXATION:

An aberrant relationship between two adjacent articular structures that may have functional or pathological sequelae, causing an alteration in the biomechanical and/or neurophysiolog reflections of these articulate structures, their proximal structures, and/or body systems that may be directly or indirectly affected by them (Bergmann et al, 1993: p766).

PLYOMETRIC MOVEMENTS:

A quick rapid movement that involves the pre-stretch of a contracting muscle to activate the stretch shortening cycle. Therefore, by taking advantage of the muscles length-shortening cycle, one can increase power (Davies, 1992: p226).

OVERUSE INJURY:

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, i.e. overload of activity on a particular structure, (muscle, tendon, ligament, joint capsule) and this may result in the inability of a structure to perform its specific function (Garrick and Webb, 1999: p121).

ACTION POTENTIAL:

When a neuron is stimulated or excited above a certain threshold, there is a brief reversal of the polarity of its membrane potential which is termed the action potential. They are propagated down the axon and invade the nerve terminals (Crossman and Neary, 1995: p1).

MOTOR ENDPLATE:

The point at which a motor neuron contacts a muscle fiber (Davies 1992: p26).

PEAK TORQUE:

Defined as the highest muscular torque produced by the muscle. Peak torque indicates the muscle's maximum strength capability. Peak torque can be evaluated specific to time (Torque at .20sec) or to ROM (Torque at 30º). Peak torque is an absolute value, when used alone peak torque is difficult to assess the strength specific to a person, (Marrule, 1996: 110-114)

TOTAL WORK:

The total volume of work under the torque curve with each repetition regardless of speed, range of motion or time (Davies, 1992: p 59).

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).

UNILATERAL RATIOS:

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

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).

CHAPTER 1
INTRODUCTION

1.1 THE PROBLEM AND ITS SETTING:

Athletes, particularly those who are involved in sporting activities requiring repetitive overhead use of the arm (viz. tennis, swimming, baseball, javelin throwing), (Kennedy,and Hawkins, 1980: p151-158), may develop a painful shoulder (Kennedy, 1980). This pain occurs as a result of high velocity mechanical stress placed on the shoulder (Andrews, p1994: 113 and Julian et-al, 1997: p69). Similar injuries may occur as a result of a variety of overhead work-related activities, such as painting and maintenance work (Andrews and Wilk, 1994: p524).

High demands placed on the shoulder muscles during throwing may result in subsequent muscle fatigue, eccentric overload, inflammation and eventual tendon failure (Andrews and Wilks, 1994: p370), which could result in micro-trauma leading to posterior shoulder injuries (Atwater, 1979: 63).

The inherent structure of the shoulder with 3 external rotators and 5 internal rotators causes a muscular imbalance before the commencement of any activity (Andrews and Wilks, 1994: p643). This naturally occurring muscle imbalance can become exaggerated in overhead throwing athletes as a result of over-training of the internal rotators from plyometric-type movements used during the acceleration phase of throwing, while the external rotators are neglected. This can eventually lead to a lack of external rotation strength and endurance training (Chandler et al, 1992: p455). The small muscle mass of the external rotators and the lack of strength / endurance training of these muscles, results in the formation of overuse syndromes (Andrews and Wilk, 1994: p418). These overuse syndromes can result in the formation of a vicious cycle or “Repetitive Strain Injury” (RSI), (Hinton, 1988: p278 and Jacobson et-al, 1989: 1037).

The RSI is characterized by repeated micro-trauma to the same anatomical area (Jacobson et-al, 1989: 1037) and is the hypothesized mechanism for tensile rotator cuff (RC) failure

(Neer, 1972: p41). When there is injury to a muscle, its antagonist muscles contract to immobilise the joint, this prevents further damage to the already injured muscle. In time, the antagonist muscles to scapula elevation as well as agonistic muscles to shoulder abduction may also suffer injury owing to sustained contraction (Jacobson et-al, 1989: p1037).

It is therefore not uncommon to have more then one structure involved in an overuse injury, such as: muscle dysfunctions, structural injury and failed compensatory mechanisms (Garrick and Webb, 1999: p121).

An intact myotatic unit allows for normal function of the upper extremity along with smooth coordinated movement and this provides mobility and stability to the shoulder complex (Andrews and Wilks, 1994: p15). RSI's can significantly alter the coordinated shoulder complex motion (Andrews and Wilk, 1994: p15 and Lawrence et-al, 1996: p73-74).

In respect of the above it would therefore seem that there is some degree of mechanical abuse of the muscle in the form of muscle overload prior to the onset of RSI syndromes. This is supported by Sola et al, (1955: p588) and Haines (2002: p192), who found that the incidence of TrP's in various muscles can be accounted for on the basis of mechanical stress. This stress can activate TrP's resulting in a Myofascial Pain Syndrome (Lee et al, 1997: p81-89).

Lawrence et al (1996: p73-74) supports this and states that trigger points can be found in both hypertonic (e.g. trapezius) and inhibited (or weak) muscles (e.g. infraspinatus). Therefore, it is possible that the weakness in these muscles is as a result of the TrP in the muscle, reflexively inhibiting the muscle (arthrogenic muscle inhibition) from full contraction due to pain or other presenting symptomatology (Lawrence et al, 1996: p73-74 and Hopkins 2000 and Ingersoll and Palmieri, 2003). In addition to this, tight muscles tend to predominate over weak muscles in movement patterns and hypertonic muscles will reflexively inhibit their antagonists, thereby weakening them further (Lawrence et al, 1996: p73-74). Thus the presence of TrP's could lead to the development of an RSI (Lawrence et -al, 1996: p73-74 and Hopkins, Ingersoll and Palmieri, 2000).

Isokinetic test results document objective patient progression and/or regression regarding muscle performance (Andrews and Wilk, 1994: p523). One of the biggest advantages of isokinetic assessments is the ability to evaluate individual muscle patterns in a dynamic orientation while providing some inherent stability to the testing position (Andrews and Wilk, 1994: p42).

Isokinetic dynamometry has been used frequently for determining the peak torque and strength ratios of throwing athletes (Montgomery, 1989:p315; Brown et al. 1988: 577; Wilk et al. 1990). Current literature regarding isokinetic testing indicates that normative peak torque values for shoulder internal / external rotation ratios are 3:2 or 150% (Alderink and Kluck, 1986: p163; Ivey et al. 1984: p127). Numerous studies have been conducted (Cook et al. 1987: p451; Ellenbecker, 1991: p9; Hinton, 1988: p274; Koziris et al. 1991:p253) on shoulder internal / external rotation strength ratios, and it has been confirmed that a relative external rotation strength deficit exists.

This study, therefore, aims to provide a greater insight into the effect that treatment of myofascial TrP's of the shoulder might have on altering internal-external ratios of the shoulder in throwing athletes and thus possibly reducing the long term effects of RSI while the condition may still be reversible.

1.2 Aims and Objectives of the study:

The aim of this investigation is to evaluate the therapeutic effect of dry needling, for active myofascial trigger points (TrP's), on the association between internal-external ratios of the shoulder rotator myotatic unit in overhead throwing athletes which might aid the clinician in treating the problem of RSI prior to definitive pathological changes in the muscle – such as actual muscle tearing.

Objective 1 :

To assess and quantify the following within the shoulder rotator muscle group:

1. The number of TrP's.
2. The severity of the TrP's (active/latent).
3. The specific location of the TrP's.

Objective 2 :

To assess the internal-external ratio of the dominant shoulder in throwing athletes using a Cybex 700 dynamometer after intervention.

Objective 3 :

To establish a comparable clinical profile of the participants.

Hypothesis 1:

Dry needling will decrease the adverse effects and number of TrP's in the rotator unit of the shoulder, thereby increasing muscle strength and improving the internal-external ratio of the dominant shoulder in overhead throwing athletes.

Rationale and Benefits:

2. A consistent pattern of relative external rotation peak torque and total repetition work imbalance has been observed in the dominant shoulder of competitive overhead athletes (Koziris et-al, 1991; Ellenbeker, 1991, and Chandler et-al, 1992). This research aims to provide a greater insight into the role of myofascial TrP's as an etiological factor.

3. To assess the effectiveness of invasive myofascial trigger point (TrP) therapy. De-activation or elimination of TrP's may improve altered shoulder biomechanics which may contribute to restoring the balance within the myotatic unit. This is necessary as myofascial trigger points can cause motor dysfunctions in a muscle, such as: spasm, weakness of the involved muscle function, loss of co-ordination and decreased work tolerance of the involved muscle (Travell, Simons and Simons, 1999: p5 and p 21) and this may alter the co-ordinated shoulder complex motion and the peak torque and total work ratios of the shoulder myotatic unit (Andrews and Wilk, 1994: p15 and Lawrence et-al, 1996: p73-74).

CHAPTER 2
REVIEW OF RELATED LITERATURE

2.0 Introduction:

A common factor related to many sports is the need to throw and although there may be obvious differences when comparing these sports, there exists a large similarity in the gross movement used (Souza, 1994: p 71). It is evident that a naturally occurring muscle imbalance exists within the shoulder and this imbalance may contribute to shoulder injury and overuse syndromes especially in those athletes who are involved in overhead throwing, where this imbalance is exaggerated (Cook et-al,1987: p456-457). This occurs as a result of over-training of the internal rotators from plyometric-type movements that are used during the acceleration phase of overhead throwing (Chandler et al, 1992: p455). While the internal rotators are strengthened from these movements, the external rotators are neglected leading to a lack of external rotation strength and endurance training (Chandler et al., 1992: p455-458; Cook et al., 1987: p451).

The gross movements used in overhead throwing inflict trauma on the muscles used and can result in the formation of TrP's within these muscles. This movement may damage the muscle, with resultant formation of TrP's, directly after excessive or unusual activity or after repetitive episodes of minor trauma and repetitive overload (Baldry, 1993: p76). It has been shown by Travell, Simons and Simons, (1999: p5 and p21) that these TrP's may have a number of effects on the involved muscle, and one of the more important ones includes weakness of the involved muscle. A discussion of the current literature may provide a greater insight into the role of Myofascial Pain Syndrome in overuse syndromes in throwing athletes as well as treatment of this syndrome.

2.1 Anatomy of the Shoulder Joint:

The glenohumeral (shoulder) joint is a ball and socket type of synovial joint comprising the humerus, scapula and clavicle. There are three joints that are involved in shoulder biomechanics and those include (Hains, 2002: p193):

- sternoclavicular joint,
- acromioclavicular joint,
- glenohumeral joint.

These joints permit multi axial movements at the shoulder. The scapulothoracic articulation, although not a true joint, also helps the shoulder perform these movements, especially abduction (Hains, 2002: p193).

The characteristics of this joint that make it biomechanically unique are (Nicholas and Hershman 1995: p45):

- Its nearly spherical articular surfaces,
- A high size difference between the glenoid and the humerus,
- Extensive complex motion, greater then any other joint in the human body.

During any given time only 25% to 30% of the humeral head articulates with the glenoid thereby creating a potentially unstable joint (Nicholas and Hershman 1995: p45). Thus, the mechanics of the shoulder allow a large and wide range of movement but at the expense of stability (Moore and Dalley 1999: p788).

Glenohumeral (GH) joint stability is achieved by three important components which include:

- Joint geometry (Static stabilizers),
- Ligamentous structures (Static stabilizers),
- Neuromuscular structures (Dynamic stabilizers) (Nicholas and Hershman 1995: p45).

2.1.1 Static stabilizers:

The shallow glenoid cavity is deepened by a fibrocartilaginous glenoid labrum (Moore and Dalley 1999: p788) and intact ligamentous attachments at its perimeter (Nicholas and Hershman 1995: p45). This labrum provides stability to the GH joint and serves as an attachment site for the GH ligaments. If there is a loss of labral integrity, instability of the shoulder joint will result and will eventually lead to degenerative changes (Souza, 1994: p48-49). There are two major mechanisms that contribute to labral injury and these include: repetitive activity and throwing activities such as pitching, tennis serves, swimming and weight training. The second mechanism includes direct trauma to the labral region such as falling on an outstretched hand (Souza, 1994: p48-49). The static stabilizers of the shoulder are relatively unstable and must rely on the shoulder musculature to a large extent for stability during activities such as overhead throwing (Davies, 1992: p389). The ligaments of the shoulder contribute to static stability and these include: Glenohumeral ligaments (superior, middle, inferior with anterior, middle and posterior bands), Coracohumeral ligament, Coracoacromial ligament and Transverse humeral ligament (Nicholas and Hershman 1995: p45 and Souza, 1994: p47 and Moore and Dalley 1999: p789 and Magee, 1997: p207-208).

2.1.2 Dynamic stability:

The dynamic stabilizers of the shoulder include: the rotator cuff muscles (subscapularis, supraspinatus, infraspinatus and teres minor muscles) (Nicholas and Hershman 1995: p216), the long head of biceps brachii, deltoid and the scapulothoracic muscles (trapezius, rhomboids and serratus anterior) (Nicholas and Hershman 1995: p46 and Davies, 1992: p389).

The rotator cuff muscles perform many functions:

- Dynamic stabilizers,
- Prime mover (especially with external and internal rotation),
- Fine tuner during strenuous exercise.

However, dynamic stability is their main function and this is accomplished through joint compression and co-contraction of the muscles during activity (Davies, 1992: p389). The co-contraction causes a tightening of the capsular insertions of the rotator cuff and results in compression of the humeral head into the glenoid (Souza, 1994: p51). The humeral head is therefore actively centered into the glenoid cavity during most shoulder motion except when the arm is in extreme abduction and external rotation (Nicholas and Hershman 1995: p46).

This depressive function aids in preventing upward migration of the humeral head leading to impingement on the overlying acromion and coracoacromial ligemant and structures passing under the coracoacromial arch (Nicholas and Hershman 1995: p216). Overhead throwing can cause sheer forces over the labrum and articular cartilage, especially during forward acceleration and therefore if there is any degree of ligamentous weakness or detachment, this could result in abnormal translation. This weakness of the static stabilizers could place added strain on the dynamic stabilizers and lead to subluxation (Nicholas and Hershman 1995: p46). Injury to the dynamic stabilizers, especially the rotator cuff, can lead to difficulty or a cessation in throwing and other overhead work activities as it would cause pain and dysfunction. Therefore, one can see that the shoulder joint relies heavily on the dynamic stabilizers and that the rotator cuff muscles are critical in providing functional stability to the GH joint (Davies, 1992: p390).

Table 1a: The following table outlines the muscles that make up the functional unit of shoulder and their innervation: (Travell and Simons, 1983: 555-556 and Moore, 1999: 710-711 and Magee, 1997: p235-236).

Actions	Muscles Acting	Nerve Supply	Nerve Root Derivation
External rotators (agonists)	• Infraspinatus • Posterior Deltoid • Teres Minor	• Axillary • Axillary • Suprascapular	• C5-C6 • C5-C6 • C5-C6
Internal rotators (antagonists for external rotation of the arm)	• Pectoralis Major • Anterior Deltoid • Subscapularis	• Lateral Pectoral • Axillary • Subscapular	• C5-C6 • C5-C6 • C5-C6

2.2 Biomechanics of the Shoulder in the Overhead Throwing Athlete:

Throwing is the most common motion used in sporting activities therefore; the throwing motion has been analyzed to a large extent in overhead throwing athletes (Nicholas and Hershman, 1995: p41). Throwing involves launching an object into the air by using one or both arms. Although they may vary slightly between different sports, the goals of throwing are very similar and constitute speed and accuracy in different combinations and it is therefore the objective of the thrower to produce a sequence of joint actions in order to achieve the desired hand speed and direction at release. This then imparts the direction and speed to the object that is released by the hand (Atwater, 1979: p43).

The movement pattern that is used during most throwing sports usually takes less then a second to occur (Atwater, 1979: p43). Although the shoulder girdle allows a range of motion that exceeds 180 degrees in many planes, it can maintain stability without compromising mobility to a large extent, by combining co-ordinated glenohumeral and scapulothoracic motion with movements from the acromioclavicular and sternoclavicular joints. If there is an interruption in this smooth coordinated motion it can lead to pathology (Hawkins, 1987: p373).

Experienced throwing athletes rarely use more then 90 º of abduction even though their arms move rapidly from extremes of external to internal rotation. The entire throwing mechanism requires good upper and lower body positioning and accurate timing in order to decrease the stress on the glenohumeral joint and create maximum power (Nicholas and Hershman, 1995: p41). This can be achieved by a good body position, the correct rhythm of muscle contraction and proper throwing mechanics and muscle conditioning (Arroyo et al, 1997: p75).

As discussed earlier, the rotator cuff acts as a force couple with larger muscles (deltoid, pectoralus major and latissimus dorsi) which insert farther distally on the humerus, and it is these muscles, along with the long head of biceps muscle that help maintain the axis of shoulder motion centrally at the glenohumeral joint. This creates a stable fulcrum from which the deltoid is able to elevate the arm thereby allowing external and internal rotation. The supraspinatus causes shoulder joint compression because of its positioning across the top of the glenohumeral joint and this counteracts the sheer forces that are produced by the deltoid muscle as it elevates the arm. Another function of the supraspinatus muscle is to assist the deltoid in abducting the arm (Arroyo et al, 1997: p70).

External rotation of the arm is produced by the teres minor and infraspinatus muscles and the subscapularis not only internally rotates the arm, but also acts as a powerful dynamic barrier to anterior displacement of the humeral head (Arroyo et al, 1997: p70). The trapezius and serratus anterior muscles help stabilize the scapulothoracic articulation which is important in overhead activity as this allows smooth rotation of the scapula during abduction. They also assist glenoid rotation with the humerus, thereby creating a stable contact surface for the humeral head (Arroyo et al, 1997: p70).

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 (Davies, 1992: p53). These ratios were confirmed by Ivey et al. (1985: p384-386), in a study when he tested internal / external strength ratios in 18 male and 13 female non-athletes. Both peak torque and total work ratios for internal/external rotation were assessed.

Internal/external strength ratios measured isokinetically, were found to be greater in the dominant arm of overhead athletes. This indicates that overhead throwing places large amounts of stress on the dominant arm. A large amount of this stress is placed on the internal and external rotators of the shoulder and it is for this reason that normal shoulder flexibility and optimal muscle balance within the shoulder be attained in order to avoid overuse syndromes and injury (Cook et al., 1987: p451).

The throwing mechanism requires a specific sequence of body motion that involves the pelvis, upper trunk rotation, upper arm, forearm and hand (Nicholas and Hershman, 1995: p41).

The baseball throw has been divided into five stages (Glousman, 1993:89-99 and Jobe et-al, 1983:3-5 and Arroyo et al, 1997: p70):

1. Preparation and wind up (positions the arm),
2. Early cocking (involves external rotation and abduction),
3. Late cocking (maximum external rotation is reached to allow a forceful accelerated release),
4. Forward acceleration (starts with internal rotation of the humerus and ends with ball release) and
5. Follow through (deceleration phase needed for injury prevention).

Table 1b: Muscles responsible for phases of throw (Cook et al, 1987: p452):

Throwing phases	**Muscles involved**
Wind-up phase	humeral external rotators, posterior, anterior and middle deltoid, infraspinatus, teres minor, shoulder abductors, suprspinatus, shoulder flexors, coracobracialis and pectoralis major.
Acceleration	shoulder internal rotators, pectoralis major and minor, subscapularis, teres major, latissimus dorsi and anterior deltoid.
Follow through phase	rotator cuff and deltoid muscles which are firing eccentrically to decelerate the arm.

The internal rotators (in tennis players and overhead throwing athletes) concentrically contract resulting in acceleration of the arm and conversely, the external rotators contract eccentrically to control and slow shoulder movement during the follow through (Davies, 1992: p390).

Pectoralis major, lattisimus dorsi, triceps and serratus anterior provide a propulsive force during the acceleration phase which involves internal rotation (Frank, W. et-al, 1989:p964 and Jobe et-al, 1984:p281). During the act of throwing, the internal rotators undergo plyometric type training which improves power in bigger muscle groups to a large extent (Hinton, 1988: p278). In the follow through phase, eccentric muscle contractions of the RC muscles (especially the infraspinatus and teres minor muscles) decelerate the upper extremity as the arm moves across the body and this decreases anterior translation forces (Frank, W. et-al, 1989:p964 and Atwater, 1979:p43). Owing to the repetitious, high velocity mechanical stress placed on the shoulder at extremes of motion, throwing athletes are susceptible to shoulder injury and dysfunction which may manifest as an overuse injury (Arroyo et al, 1997: p69). Such a syndrome usually develops in the absence of a specific injury and is therefore described as an injury of attrition (Nicholas and Hershman, 1995: p222).

Both the anterior and posterior shoulder structures may be injured during throwing. Anterior shoulder injuries usually occur when the anterior shoulder structures are stretched just before release. This stretch can be increased further if the humerus is rotated into a position of maximum external rotation and this may result in micro-tears of the rotator cuff and other soft tissue structures. It seems that posterior shoulder injuries can manifest prior to release as the humerus is horizontally abducted however, they are most likely to occur after release as the follow through of the arm causes stretching of the posterior structures (Atwater, 1979: p72-73).

There are many factors that assist in effective positioning of the arm, especially when it involves a hand-held load and acceleration of that load. These factors are (Souza, 1994: p40-41):

1. Muscle type
2. Fiber orientation
3. Muscle size
4. Length of fibers
5. Type of contraction
6. Speed
7. Lever length and type

Muscles are mainly made up of one of two types of muscle fibers i.e. type one or type two. Type one fibers (slow twitch) are able to sustain long contractions and have slow fatigue rates (Souza, 1994:p42). Type two muscle fibers (fast twitch) are innervated by motor neurons that fire at high frequencies and therefore have a fast contraction however; their fatigue rate is much quicker. Fiber orientation also has a bearing on muscle effectiveness. Longitudinal fibers allow for maximum shortening which results in greater speed production whereas oblique fibers are designed for strength, as this allows for a greater number of muscle cells to be included in a given space (Souza, 1994: p42). It is also known that the size of a muscle also has a bearing on the force of contraction that is produced. The position of a muscle in relation to a joint can affect the fiber and lever length (Souza, 1994: p41-43).

It has been documented that a naturally occurring muscle imbalance is found between the internal and external rotators of the shoulder and this is emphasized by the fact that the shoulder has 3 major external rotators and 5 major internal rotators (Cook et al, 1987: p456 and Andrews and Wilks, 1994: 643). This imbalance appears to be exaggerated among competitive overhead athletes who 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). The shoulder external rotators and flexors are weaker than the shoulder extensors and internal rotators (Cook et al, 1987: p456). This internal rotation strength dominance seems to occur in sports where plyometric-type movements are used during the acceleration phase such as in overhead throwing (Chandler et al, 1992: p455).

Therefore, owing to the small muscle mass of the external rotators and the lack of external rotation strength and endurance training of these muscles proportional to the internal rotators, overuse syndromes are commonly seen especially in the dominant shoulder of overhead athletes (Chandler et al., 1992: p455-458; Cook et al., 1987: p451). These syndromes are 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 especially true for the infraspinatus and teres minor muscles (Andrews and Wilk, 1994: p418).

Possible explanations for the overhead athletes decrease in external rotation strength and increase in shoulder internal rotation strength in their dominant arms (when compared to established normative values):

1. External or internal rotator training imbalance during overhead throwing (Cook et al., 1987: p451-461).
2. Suprascapular nerve entrapment from repetitive overhead throwing may cause weakness and atrophy of the infraspinatus muscle (Jobe and Moynes, 1982: p336-339 and Pappas et al. 1985: p223-235).
3. With the external rotators being weaker on the dominant side of throwing athletes they may not be able to perform their function of checking humeral internal rotation and horizontal adduction during throwing (Jobe et al., 1983: p3-5). The exaggerated, protracted, depressed posture which the dominant side shoulder girdle tends to assume, causes the shoulder girdle retractors to develop a stretch weakness as a large eccentric load is placed on the posterior rotator cuff group during the deceleration phase, and this may explain this weakness (Kendall et al. 1952: p103-154 and Andrews et al., 1985: p337-341; Kulund, 1982: p291-292)

4. Davies, (1984: p261-291) and Nirschl, (1986: p322-337), suggest that eccentric loading causes intramuscular connective tissue tearing, which will eventually result in the formation of a cycle of chronic inflammation and muscular weakness.
5. However, the internal rotators of the shoulder react differently to overhead throwing as they undergo plyometric-type training which has been found to greatly enhance power in larger muscle groups (Miller, 1984: p68-83).

Ellenbecker, (1991: p9-21) performed a study where a Cybex II isokinetic dynamometer was used to measure external and internal rotation peak torque and single repetition work ratios of the shoulder in highly skilled tennis players. It was found in this study that the internal/external ratios of the dominant arm ranged from 153% to 154% for peak torque and 165% to 169% for single repetition work (strength). This revealed a relative external rotation strength deficit on the dominant arm. Cook et-al, (1987: p451) and Hinton, (1988: p274) have also produced concurrent results revealing an increased unilateral shoulder internal/external rotation strength ratio amongst throwing athletes.

A Cybex II dynamometer was used in a study by Koziris et-al, (1991: p253) to test female collegiate tennis players. It was found in this group of sports woman that there was a consistent pattern of dominant shoulder strength as well as external strength imbalances. A study by Chandler et-al, (1992: p455-458) involved tennis and baseball players that complained of persistent repetitive stress injury (RSI). They found that there was a noticeable increase in the strength of internal rotation without a subsequent strength increase of the external rotators. They therefore reasoned that the muscle imbalances create a predisposition towards shoulder injuries resulting from overuse.

2.3 Physiology of Concentric and Eccentric Isokinetic Muscle Contraction:

There are two types of muscle contractions that are used in daily living as well as athletic activities, such as throwing, and these are concentric and eccentric contractions (Davies, 1992: p25). A study performed by Bigland and Lippold (Davies, 1992: p27) indicated that a lower level of EMG activity was generated from an eccentric contraction than a concentric contraction. This may occur because muscles are lengthening during eccentric activity and therefore a contribution to the force that is being developed during this activity may come from elastic elements (tendons, sarcolemma and hinged crossbridges of myosin) that are undergoing stretch during the lengthening of the muscle and thereby providing resistance to the stretch (Davies, 1992: p26-p27).

2.3.1 Structure and Neural Activation of Skeletal Muscle:

Skeletal muscle mass consists of about 85% contractile protein (actin and myosin) and 15% as connective tissue (collagen, reticular elastic fibers). Compliant elastic elements of muscle contribute to smooth muscle contraction. The cross-bridges of a myosin filament are attached to six actin filaments and during a muscle contraction the actin shifts to the centre of the sarcomere using a ratcheting action. This leads to shortening of the sarcomere and results in tension (Davies, 1992: p25).

When the myosin heads are prevented from attaching to the actin filaments, it results in relaxation. This process is controlled by intracellular calcium levels and two proteins known as troponin and tropomyosin (Davies, 1992: p26). Alpha and gamma motor neurons are the activating factors of skeletal muscle during activity. When an action potential travels down a motor neuron to the end-plate, a muscle contraction is initiated. This causes the release of Acetylcholine (ACh), a neurotransmitter which initiates an action potential on the sarcolemma causing influx of calcium into the muscle fiber which begins the muscle contraction (Davies, 1992: p26). If the action potentials stop, active transport pumps that are present in the sarcolemma remove the intracellular calcium from the cell and pump it into the extracellular fluid (Davies, 1992: p26).

The calcium pump is powered by Adenosine Triphosphate (ATP). Factors such as: ischaemia, metabolic distress and mechanical damage to the muscle cell membrane, can disrupt this pump which may lead to a flooding of calcium ions and sustained contracture of the sarcomeres in this region of the muscle. This is known as the “energy crisis hypothesis” (Schneider,1995: p68).

2.4 Cybex Isokinetic Dynamometer:

One of the biggest advantages of isokinetic assessments is the ability to evaluate individual muscle patterns in a dynamic orientation while providing some inherent stability to the testing position (Andrews and Wilk, 1994: p42). Isokinetic evaluation renders objective, reliable data regarding muscular performance during a dynamic contraction and has been utilized frequently for determining the peak torque and strength ratios of throwing athletes (Montgomery, 1989:p315; Brown et al. 1988: 577; Wilk et al. 1990). Therefore, isokinetic test results document objective patient progression and/or regression regarding muscle performance (Andrews and Wilk, 1994: p523). Normal shoulder internal / external rotation (peak torque) ratios established through isokinetic testing are 3:2 or 150% (Alderink and Kluck, 1986: p163; Ivey et al. 1984: p127).

Wilk et al (1991), recognizing inconsistencies in testing methodology of different published articles, suggested a standardized isokinetic testing protocol for the shoulder. This standardized isokinetic testing protocol is referred to as the “thrower’s series”, and highlights the variables existing, which must be standardized and controlled to ensure an objective, reliable and reproducible isokinetic evaluation of the shoulder.

Isokinetic exercises have a fixed speed with a variable resistance that is completely accommodating to the subject throughout the range of motion i.e. the amount of force exerted by the subject is always matched by that of the machine, therefore the subject can never exceed the speed no matter how much effort they exert. As a result, isokinetics has the capability to load a muscle maximally throughout the entire range of motion (Cybex Int, 1996:1-9). This occurs because the velocity is constant at pre-selected dynamic rates and the resistance varies to accurately match the force that is applies at every point in the range of motion. As a result, isokinetics has the capability to load a muscle maximally throughout the entire range of motion (Cybex Int, 1996:1-9,) and therefore maximum resistance throughout the full range of motion is developed by controlling the velocity of the exercise (Davies, 1992: p13).

This makes isokinetic exercise a safer and more efficient form of exercise than isotonic exercise, which maximally loads the muscle at its weakest points. Additionally, when the patient begins to fatigue and is unable to continue with the exercise they are still loaded maximally with the isotonic resistance, unlike isokinetic resistance, which will accommodate to this variable (http://www.biodex.com).

Isokinetic dynamometry can be used in a limited fashion as a diagnostic tool 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).

2.5 Introduction to Myofascial Pain Syndrome (MPS):

A number of authors (Rachlin, 1994: p17 and Schneider, 1995: p78) have discussed the importance of MPS since the 1980's. MPS is now recognized as the leading cause of neuro-musculoskeletal pathologies within health care circles and it should therefore be suspected in any patient suffering from chronic pain (Haines, 2002: p194).

Both active and latent myofascial trigger points can result in myofascial pain syndrome (Hou et al, 2002: p124) .This is a very common type of muscular disorder that often presents to primary health care practitioners and is of a multi-factorial origin (Gatterman, 1990: p287, Hubbard, 1998: p16, Chaitow and Delany, 2002: p18-20).

2.5.1 Incidence of MPS:

Muscular pain is one of the most common work- related injuries as well as the second most common cause of visits to primary health care practitioners (Hubbard, 1998: p16, Chaitow and Delany, 2002: p18-20). According to Travell and Simons (1999: p12), MPS is defined as the sensory, motor and autonomic symptoms that are caused by TrP's. MPS and TrP's are a very common condition with latent TrP's presenting more commonly than active TrP's (Travell and Simons, 1999:12). The prevalence of TrP's in patient populations has been reported as early as the 1950's (Sola, Rodenberger and Getty, 1955: p585).

Individuals of any age or sex can develop TrP's (Travell and Simons, 1983: p13), as found in a study by Sola et al (1955), where among 200 asymptomatic young adults, he found that there were latent trigger points in the shoulder girdle muscles of 54% of the females and 45% of the males. Schneider (1995), found MPS to be one of the most prominent soft tissue syndromes seen in clinical practice. American studies based at pain clinics indicate that the incidence of MPS could possibly be as high as 85% (Han and Harrison, 1997: p90).

Most of the research that is being conducted at the moment on the epidemiology of MPS has been completed in a clinical setting. Therefore, the prevalence with regard to MPS in the general population can only be estimated in the general population (Bruce, 1995).

2.5.2 Pathophysiology of TrP's:

Simons et al (1998), describe an integrated trigger point hypothesis (Chaitow and Delaney, 2000: p65). Factors such as stress, strain or overload cause endplate activity to become dysfunctional. This results in the release of large amounts of ACh at the synapse and this is associated with excess calcium. Persistent large quantities of calcium keep the calcium gates open which causes further release of ACh resulting in ischemia (oxygen and nutrient deficit). The ischemia causes a local energy crisis and owing to this, there is inadequate production of ATP (Chaitow and Delaney, 2000: p67).

A deficiency in ATP prevents the local tissue from removing the excess calcium ions that are keeping the calcium gates open. Owing to the fact that it requires more energy to remove the high concentrations of calcium than to sustain the contracture, the contracture persists. This contracture is involuntary and is sustained by chemistry at the innervation site rather the action potentials (Chaitow and Delaney, 2000: p68). During this process, the more ACh produced, the more the actin and myosin filaments slide to a fully shortened position thereby weakening the muscle. This causes the sarcomeres to shorten and bunch forming a knot. While those sarcomeres bunch, the others that are part of that fiber stretch, eventually creating a palpable taut band (Chaitow and Delaney, 2000: p68).

2.5.3 Eitiology of MPS:

The etiology of TrP's is a focal muscular dysfunction which can exert a strong influence on all major parts of the nervous system, and can cause spinal level neuroplastic changes. These changes can convert an acute pain problem into a chronic one (Travell and Simons, 1999: p38). Rosen (1993) suggests that the primary cause of skeletal imbalance is a muscle imbalance that occurs between the agonist and antagonist muscles which become susceptible to overload. Dysfunction can result from improper use or abnormal loads placed on the muscle, thereby exceeding the critical load of those muscles leading to overload and fatigue (Rosen, 1993).

MPS has been suggested to have multi-factorial etiologies and the development of TrP's can be divided into two basic groups, namely:

- Factors causing direct trauma either through repetitive micro-trauma or direct injury,
- Factors that cause muscle weakness such as: structural disharmony, joint disorders, nutritional deficiencies, lack of exercise and sleep disturbances.

(Fricton et al, 1985: p621)

Owing to the fact that there seems to be no positive predictive values for any one combination of etiological factors, there is still some uncertainty over the etiology of MPS. Despite this, Chaitow and Delany (2002: p20) and Travell, Simons and Simons (1999 1: p19), all agree that several primary factors lead to the development or activation of TrP's:

2.5.3.1 Primary etiological factors:

- Trauma
- Nerve compression
- Adverse environmental conditions (excessive cold, heat or dampness)
- Leaving the muscle in a shortened position for prolonged periods
- Systemic biochemical imbalances (i.e. hormonal disturbances)
- Mechanical abuse (Acute sustained or repetitive overload such as prolonged muscle contraction)

2.5.3.2 Secondary etiological factors:

- Satellite TrP's (arise in pain reference zone of primary trigger points),
- Low oxygenation of tissues,
- Compensating synergistic or antagonistic muscles of muscles already containing TrP's may develop TrP's.

According to Travell, Simons and Simons (1999: p110), once- off traumatic events can activate TrP's but are not responsible for perpetuating them, there are other factors that maintain TrP activity. Situations that cause repeated or chronic overload can activate trigger points as well as perpetuate them. These two different onsets need to be differentiated as they require different therapeutic approaches.

2.5.4 Perpetuating factors: as discussed by Travell, Simons and Simons (1999: p178-p179):

- Metabolic and Endocrine inadequacies (e.g. Hypometabolism),
- Nutritional inadequacies (e.g. thiamine, ascorbic acid),
- Mechanical stress (e.g. Structural inadequacies, muscle constriction, postural stress),
- Psychological factors (e.g. depression),
- Chronic infection and infestation (e.g. viral disease),
- Miscellaneous factors (e.g. allergy, fatigue, cold / damp),

2.5.5 Diagnosis of MPS:

It appears that the most reliable diagnostic criteria of TrP's on examination of the muscle is the presence of exquisite tenderness at a nodule in a palpable taut band (Travell, Simons and Simons, 1999: p117). The diagnostic physical signs of a trigger point according to travel and Simons (1983: p12-16), are discussed in chapter 3.

2.5.6 TrP's causing muscle weakness:

Travell, Simons and Simons (1999: p21), states that the weakness is from reflex motor inhibition and occurs without atrophy of the affected muscle (Travell, Simons and Simons 1999: p22). The weakness may be a type of guarding mechanism, in which the muscle is reflexly inhibited from full contraction because of pain (Schneider, 1995: p74).This weakness is most often found in muscles with active TrP's, however the magnitude is variable from muscle to muscle and patient to patient.

In muscles with active TrP's, the muscle starts out fatigued, fatigues at a faster rate and becomes exhausted before normal muscles would and there is also delayed recovery (Travell, Simons and Simons 1999: p22-24). Not only can a TrP cause weakness of the muscle in which it is found, but it can also cause referred inhibition of other muscles, which can lead to major disruption of normal muscle function (Travell, Simons and Simons 1999: p26-27). For example, Headley discovered that TrP's in the infraspinatus muscle could inhibit movements of the anterior deltoid in various directions (Travell, Simons and Simons 1999: p27).

A muscle containing a TrP is prevented by pain from reaching its full stretch range of motion, and is also restricted in its strength and/or endurance (Travell, Simons and Simons 1999: p21). When one attempts to passively stretch the muscle beyond its limit, an increase in the amount of pain results, as the involved muscle fibers are already under increased tension at there rest length (Travell, Simons and Simons 1999: p22).

A change in the resting length of a muscle (the best connection or bonding between actin or myosin, which is usually at 90% of its maximum length) can alter the available force. Therefore, if the muscle is already shortened at the time of contraction the muscle will be weakened and the force of contraction will be less then normal (Souza, 1994: p41-43). When the TrP is inactivated and its taut band released i.e. by needling it, its range of motion and therefore its contraction strength will return to normal (Travell, Simons and Simons 1999: p22).

It is possible that the weakness could also be as a result of arthrogenic muscle inhibition (AMI). AMI is a natural response designed to protect the joint or structure from further damage (Hopkins and Ingersoll, 2000). Without other means of protecting a joint, AMI is the body’s method of choice to protect injured extremities (Ingersoll, Palmieri and Hopkins, 2003). If AMI is not resolved after the initial injury has occurred, mechanoreceptor activity will continue to alter muscle activity surrounding the joint. The patient will replace normal muscle patterning with an adopted functional motor program (Ingersoll, Palmieri and Hopkins, 2003).

2.5.7 Management of MPS:

Fomby and Mellion (1997: p3) believe that a large part of patient management is recognizing the underlying problems by influencing the patients pain, and this can be done by increasing the tension and irritability of the involved muscle. Therefore, when treating MPS, a treatment protocol must take into account both the contributing and perpetuating factors, so long term relief may be obtained (Esenyl, et al, 2000: p51).

There are many different forms of treatment for MPS and these include: exercise, massage, medication and spray and stretch (Rosen, 1993), myofascial trigger point injection, dry needling and transcutaneos electrical nerve stimulation (TENS) (Han and Harrison, 1997: p95 and Hubbard, 1998: p23). However, for the purposes of this research, only the dry needling and injection treatment protocols will be discussed further.

2.5.8 Injection and Dry needling of TrP's:

Effective treatment using either the injection or dry needling depends on mechanical disruption and inactivation of the active loci in the TrP. TrP injections are commonly used in the management of MPS as this form of treatment is to a large extent clinically accepted (Alvarez, 2002: p657). Although Han and Harrison (1997: p96) prefer TrP injection to dry needling, because of its analgesic effect, it was found by Garvey et al (1989) in a randomized double-blind clinical study that dry needling and acupressure were more effective then transcutaneous injection of either local anesthetic or local anesthetic and steroids.

In a study performed by Hong, comparing dry needling to injection of lidocaine into TrP's, both groups experienced the same amount of improvement. These results suggest that the critical therapeutic factor in both of these cases is mechanical disruption by the needle of nerve endings or contractile elements of the muscle. This relates to the fact that disruption of the TrP contraction, terminates the basis for a local energy crisis and its sensitization of nearby nerves (Hong, 1994: p256-263,).

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

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

2.6 Summary:

The shoulder is placed at risk of sustaining a micro-traumatic injury while performing a variety of activities which include throwing, tennis, swimming, baseball (Andrews and Wilk, 1994:p524). When a dynamic activity such as repetitive throwing occurs, it places a large amount of stress on the athletes shoulder. During throwing, extremely high forces are generated by the RC muscles, specifically during the deceleration phase, in order to slow the rapidly moving shoulder (Andrews, 1994: 113). Therefore, owing to the small muscle mass of the external rotators and the lack of strength / endurance training of these muscles, overuse syndromes are commonly seen (Andrews and Wilk, 1994: 418).

A consistent pattern of relative external rotation peak torque and total work imbalance has been observed in the dominant shoulder of competitive overhead athletes (Koziris, et-al, 1991: p253, Ellenbeker, 1992, and Chandler et-al, 1992). High demands placed on the shoulder muscles during throwing may result in subsequent muscle fatigue, eccentric overload, inflammation and eventual tendon failure (Andrews and Wilks, 1994: p370), which could result in micro-trauma leading to posterior shoulder injuries and the formation of overuse syndromes (Andrews and Wilk, 1994: p418 and Atwater, 1979: 63). These overuse syndromes can become more severe eventually resulting in a “Repetitive Stress Injury” (RSI), (Hinton, 1988: p278 and Jacobson et-al, 1989: 1037).

In respect of the above it would therefore seem that there is some degree of mechanical abuse of the muscle in the form of muscle overload prior to the onset of RSI syndromes. This is supported by (Sola et al, 1955: p588 and Hains 2002: p192), who found that the incidence of TrP’s in various muscles can be accounted for on the basis of mechanical stress, which activates the TrP resulting in a Myofascial Pain Syndrome (Lee et-al, 1997: p81-89).

Myofascial trigger points can cause motor dysfunctions in a muscle such as: spasm, weakness of the involved muscle function, loss of co-ordination and decreased work tolerance of the involved muscle (Travell, Simons and Simons, 1999: p5 and p 21) and this may alter the co-ordinated shoulder complex motion and the peak torque and total work of the shoulder myotatic unit (Andrews and Wilk, 1994: p15 and Lawrence et-al, 1996: p73-74).

This research aims to provide greater insight into the role of TrP's as an etiological factor and to assess the effectiveness of dry needling of TrP's on restoring the balance within the myotatic unit. Any weakness remaining after balance is restored between the agonists and antagonists within a myotatic unit can be addressed by therapeutic strengthening exercises (Lawrence et-al, 1996: p74).

CHAPTER 3

MATERIALS AND METHODS

3.0 INTRODUCTION:

This chapter gives a description of the primary and secondary data, the subjects, the design and the intervention used.

Statistical analysis as well as each measurement parameter will be discussed and an overview of the myofascial diagnostic scale will be given.

3.1 THE DATA:

The data included primary and secondary data.

3.1.1 Primary data:

- Case history (Appendix A)
- Physical examination (Appendix B)
- Thoracic regional examinations (Appendix D)
- Cervical regional examinations (Appendix C)
- Shoulder regional examination(Appendix E)
- Myofascial diagnostic scale(Appendix K)
- Location of Shoulder External Rotator Myotatic Unit TrP’s
- Cybex Isokinetic 700 Dynamometer (at King’s Park Medical Centre)

3.1.2 Secondary data:

This particular data came from many different sources which included:

- Textbooks,
- Journal articles and
- Internet search engines.

3.2 Study Design:

This study was a pilot intervention clinical assessment study.

3.3 The subjects:

The study included volunteers who were classified as overhead throwing athletes that suffered from active TrP's in the shoulder muscles and resided in the KwaZulu- Natal area.

3.4 Sampling procedure:

A non-probability convenience sampling technique was used. The study was limited to patients residing in the KwaZulu- Natal province. A minimum sample group of thirty competitive overhead throwing athletes was required, in order to remain within the budget constraints and to attain statistically viable results within this parameter.

3.5 Advertisements for subject recruitment:

Advertisements placed at gymnasia, sports clubs, and in teaching institutions i.e. DIT campus informed the public of the study (Appendix F). The advert was aimed at participants between the age of 18 and 40 years of age that were suffering from shoulder pain. Patients that responded to the advert were required to undergo a cursory telephonic interview with the examiner to exclude subjects that did not fit the criteria for the study.

3.6 Clinical assessment procedure:

All those who responded to the study underwent a cursory telephonic discussion with the examiner to exclude subjects that obviously do not fit the criteria for the study (Appendix G). Thirty participants, who had to meet the inclusion and exclusion criteria in order to be part of the study, were chosen to participate and all of them underwent an initial consultation at the Durban Institute of Technology Chiropractic Day Clinic.

During their initial consultation, the participants underwent a case history, relevant physical examination and Cervical, Thoracic and Shoulder regional examinations. Prior to being accepted into the study all subjects received a letter of information (Appendix H), completed an informed consent form (Appendix I) and were provided with an opportunity to ask questions. These participants were evaluated accordingly and the trigger points in the shoulder rotator myotatic units mapped out and their severity recorded. 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).

3.6.1 Inclusion criteria:

- Participants had to be between the ages of 18-40 years, to allow for greater sample uniformity (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 were given a letter of information to read and signed an informed consent form, which outlines the benefits and potential risks of the testing procedures.
- The subjects participating in this study were required to be male.
- Criteria to identify the asymptomatic group:
    - ➢ Subjects must have had both upper extremities free from a significant musculoskeletal injury in the past year. A significant musculoskeletal injury is one that required a cessation of activity or altered activities of daily living for three consecutive days or more (Ellenbecker, 1991: p9).
- Criteria to identify the symptomatic group (Travell and Simons, 1983: p557-820):

➢ Restricted shoulder range of motion

➢ Referred pain in and about the shoulder

➢ Shoulder pain during activity

➢ Shoulder girdle fatigue

➢ Perceived stiffness about the shoulder

3.6.2 Exclusion Criteria:

- If there was a history of traumatic shoulder dislocation or if there was a positive drop arm test which could indicate a rupture of the rotator cuff (see shoulder regional – Appendix E).
- If there was a history of shoulder surgery (see Appendix A).
- If subjects had, or if the physical examination (Appendix B) suggested that they had, cardiac, pulmonary or systemic diseases which may refer pain to the shoulder.
- If subjects 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 (See Appendix B, C, D and E).
- If pain was as a result of Nerve Root Entrapment (See cervical regional - Appendix C).
- If subjects met any of the contra-indications for dynamometer testing.
- Any subject who failed to sign the informed consent form was excluded immediately from the study (Appendix I).
- Participants who had any contraindications to dry needling e.g., systemic illness, fever, high anxiety or emotional stress, feeling of faintness or bleeding disorders (Han and Harrison, 1997: p96).
- Participants who had been diagnosed with blood dyscrasias or those that were on any form of anticoagulant therapy (Liggins, 1999 and Han and Harrison, 1997: p96).
- Individuals who had a history of epilepsy or those that were prone to convulsions (Foster and Palastanga, 1985).

All the patients received a letter of information and were required to sign an informed consent form before treatment commenced.

3.7 Clinical treatment plan:

After all the relevant data was accumulated from the initial consultation, two free treatments were given. The participants were asked to refrain from any other treatment protocol for myofascial pain syndrome such as drugs or manual interventions (Poul et al, 1993).

3.8 Intervention type:

In a previous clinical trial conducted by Rowley (2000) and Wilks (2003) patients were treated twice in a one week period, with at least a 2 day break in between treatments and then had a one week follow up consultation. The above treatment period was chosen such that any extraneous variables could be reduced as much as possible.

Therefore, the participants in this study were treated on two occasions with a 2 day break in between each treatment. The needles used for the treatment process were 0.25mm by 25mm in size. One TrP site has a highly variable number of active loci that must be inactivated, Travell, Simons and Simons (1999: p150). Therefore, once the needle was inserted into the TrP, a fanning technique was used as this would help de-activate as many loci as possible.

Once the treatment was complete, the participants had a follow up consultation which enabled the researcher to asses the treatment given and to take the final reading on the Cybex 700 Isokinetic Dynamometer at Kings Park Medical Centre (Davies 1992: p43-44). This follow up consultation was conducted at the Kings Park Medical centre just before the final reading on the Cybex 700 Isokinetic Dynamometer is taken.

3.9 Study Assessments:

3.9.1 Diagnosis and assessment readings related to the myofascial trigger points:

Participants were screened for active myofascial trigger points once they were found to be viable candidates for the study. Chaitow and Delaney (2002: p18-19) and Travell, Simons and Simons (1999: p35) suggest that the essential criteria for the identification of myofascial trigger points (MTrp) and the confirmatory observations include:

3.9.2 Essential Criteria:

1) Taut band palpable (if muscle accessible)
2) Exquisite spot tenderness of a nodule in a taut band.
3) Patient's recognition of current pain complaint by pressure on the tender nodule (identifies active TrP's)
4) Painful limit to full stretch range of motion.

For the diagnosis of myofascial TrP's all 4 essential criteria must be present (Travell, Simons and Simons (1999: p35) and Murphy (1989), and this protocol was utilized in this study.

3.9.3 Confirmatory Observations:

1) Visible or tactile identification of a local twitch response
2) Imaging of a local twitch response induced by needle penetration of a tender nodule
3) Pain or altered sensation (in the distribution expected from a TrPt in that muscle) on compression of a tender nodule
4) Electromyographic demonstration of spontaneous electrical activity characteristic of active loci in the tender nodule of a taut band.

The presence of the confirmatory signs serve to reinforce the diagnosis that was made from the essential criteria (Travell, Simons and Simons (1999:35) and Murphy (1989).

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), Gerwin et al. (1997) and Banks et al. (1998) all reported to using these criteria to identify trigger points.

3.10 Objective measurements:

Location of the trigger points: (Appendix J)

a) Antagonistic muscles of external rotation.

- Subscapularis - There are two common lateral TrP's locations and a medial trigger area in this muscle. The lateral TrP's lie inside the lateral border of the scapula on the ventral aspect. The medial area is located along the vertebral border of the scapula. (Travell and Simons,1983: p601)

- Pectoralis Major - Trigger points can be located in the clavicular section, three central TrP's locations of the intermediate sternal section and two central TrP's in the lateral free margin (Travell and Simons,1983: p820).

- Anterior Deltoid - TrP's are found close to midmuscle section (Travell and Simons,1983: p625).

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 (Travell and Simons,1983: p557).

- 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 (Travell and Simons,1983: p567).

- Posterior Deltoid – TrP's are found close to midmuscle section (Travell and Simons,1983: p625).

The infraspinatus functions synergistically with the supraspinatus and other rotator cuff 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 (Travell and Simons, 1983: p543).

3.11 The Myofascial Diagnostic Scale: (Chettiar 2001) (Appendix K)

The purpose of this scale is to determine the extent to which a patient suffers from myofascial Pain syndrome. It 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 scale is rated out of 17 points. A score of 9 or above is considered indicative of active trigger points. A score of less than 9 is considered indicative of latent trigger points. It 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.

This scale is utilized as a standardization tool to increase reliability when used as an intra-examiner tool however, there is no inter-examiner reliability and therefore the use of a second examiner in this study is inappropriate. 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 for this study’s purposes (Chettiar, 2001).

3.12 The Cybex 700 Isokinetic Dynamometer:

One needs dynamic muscular stabilization when throwing in order to throw successfully and avoid injury. This creates a need to asses the throwing shoulder's muscular performance in an objective manner. Isokinetic testing provides dynamic, objective, reliable and valid data to asses the functional status of throwing athletes (Wilk, et-al, 1991: p69).

The Cybex 700 Isokinetic dynamometer at Kings Park Medicine Centre 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: p63-69). The first ratio to be evaluated was concentric contraction of the internal rotators vs concentric contraction of the external rotators. The second ratio evaluated was eccentric contraction of the internal rotators vs eccentric contraction of the external rotators. These values were compared to established norms (Wright, 2003 and Alderink and Kluck, 1986: 163 and Ivy et al. 1984: p127).

It is necessary to test the uninvolved side first and the shoulder in a position that closely resembles its position of function during activity, while isolating the specific muscle groups desired. In these types of patients (the overhead athlete or worker), Wilk et al (1991: p524) recommends testing in the 90-degree abducted 90-degree elbow flexed position for shoulder external and internal rotation.

Testing the uninvolved side (non-dominant shoulder) first, serves three important functions (Wilk, 1990 and Davies, 1987):

1) establishes a baseline of data for the involved side,
2) it evaluates the client's willingness to be tested and
3) it serves to decrease patient apprehension by allowing exposure to an isokinetic movement in the contralateral extremity first.

3.12.1 Reliability of an Isokinetic Dynamometer.

Muscle capability and injury assessment can be accurately evaluated from an isokinetic dynamometer as it provides reliable and precise values for maximal strength and endurance. 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 (Pincivero, Lephart and Karunakara, 1997).

Over 20 years of independent clinical research has 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 Dynomometer (no p-value stated). Davies (1992: p35) states that several studies have been conducted confirming the reliability and validity of the Cybex (no p-value stated).

The Cybex "NORM"TM Isokinetic dynamometer : Declaration of Conformity (Appendix L), at Kings Park Medicine Centre was 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 and accepted normative values attained on similar machinery. Normative data can be used as guidelines for testing and rehabilitation when used relative to a specific population (Davies, 1992: p63).

The Cybex 700 machine to be used will be calibrated weekly for the duration of the study (Wright, 2003).

3.12.2 The use of isokinetic testing:

One of the most important aspects of dynamometry is clinical testing. Isokinetic testing provides an effective way to attain objective measures and the primary function of an isokinetic dynamometer is to provide some form of quantitative measure of muscular force of a limb at any given moment or position (Rothstein, 1985; Montgomery et al., 1989, p315-322; Kendall and McCrearey, 1983). Isokinetic dynamometry has also been used in injury rehabilitation and muscle training (Perrin, 1993: p120-4; Chan and Maffulli, 1996: p10; and Davies, 1992: p125-134 and Deans, 2001).

3.12.3 Advantages of isokinetics: (Davies, 1992: p19-20)

- It accommodates resistance
- Provides maximum resistance throughout the velocity spectrum
- Validity and reliability of the equipment
- Minimal risk to patients owing to accommodating resistance
- Exercise through velocity spectrum
- Minimal post exercise soreness
- Isokinetic dynamometers and recording systems (computers)
- Specificity of movements
- Develops force control accuracy.
- Decreases reciprocal innervation time of agonist/antagonist contractions.
- Efficiency of muscular contractions.
- Accommodation to pain.
- Accommodation to fatigue.
- Decreases joint compressive forces at high speed and
- Neurophysiological patterning for functional speeds and movements

3.12.4 Limitations of isokinetic exercise: (Perrin, 1993: p7)

- Non-specific functional training for the lower extremity in the closed kinetic chain fashion.
- Angular velocity movements that do not approach functional speeds.

3.12.5 Measurable values and their definitions:

These include: peak torque, work and total work and are defined in the glossary. There is little scientific evidence regarding the reliability and validity of these values. The peak torque value is the only value that is both valid and reliable. This reduces the clinical application of several of these performance measures, thus limiting the utilization of isokinetic dynamometry as an effective measurement device (Deans, 2001).

3.12.6 Contraindications to isokinetic sessions:

3.12.6.1 Absolute contraindications:

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

3.12.6.2 Relative contraindications:

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

(Davies, 1992: p37)

3.12.7 Isokinetic testing of the shoulder:

It is important to determine the functional positions of the shoulder that are most commonly involved in overuse injuries when assessing muscular performance of the shoulder. Most micro-traumatic injuries occur when the shoulder is in an elevated and abducted position for prolonged periods while performing a wide variety of activities such as throwing, tennis, swimming, volleyball etc. It is important to assess the shoulder in an objective manner, before strenuous activity is resumed because of the nature of micro-traumatic injuries and complex biomechanics of this region (Davies, 1992: p392).

Owing to these factors, a standardized isokinetic testing protocol for the throwing shoulder has been developed and is known as 'The Throwers Series'. This testing protocol serves to fulfill three goals:

1. To improve reproducibility in testing,
2. to test throwers in the position that is specific to their throwing motion and
3. to allow clinicians to share data.

(Wilk, 1991: p64).

The series is composed of fifteen variables, each of which can effect the reliability and validity of the measures obtained during isokinetic testing. The more important variables are explained in more detail:

1. Planes of motion to evaluate.
2. Axis of joint motion. Any unnatural joint movements should be avoided.
3. Client education. It is important to familiarize the subject with the testing procedure. The use of practice sessions and patient comfort has shown to increase the maximum voluntary effort of the subject.
4. Active warm up. To ensure a safer and more effective muscle contraction.
5. Gravity compensation. The gravity effect torque is the torque produced by the tested limb and attachment. Gravity correction allows for the measurement of the torque value of the tested limb only.

6. Rest intervals.
7. Test collateral extremity first.
8. Standardize verbal commands. The use of verbal encouragement has shown to increase the maximum voluntary force output.
9. Standardize visual feedback.
10. Testing velocities utilized.
11. Test repetitions.
12. System level/stabilized.
13. Use of window data/semi-hard end stop.
14. System calibration. The equipment should be calibrated once a month.
15. Testing position/stabilization. Stabilization is needed to prevent excessive movements during testing. It is very important to test the thrower in the position that closely resembles the throwing act as well as isolating the muscle groups that need to be tested. Therefore testing is done in the seated position. This will allow for natural gravitational stabilization of the trunk and lower extremities. Owing to this, testing of the shoulder internal and external rotators should be performed in 90 degrees of shoulder abduction and 90 degrees of elbow flexion (90deg/90deg position). This position ensures muscle isolation and closely resembles the normal throwing position and therefore optimizes the length-tension relationships of both the external and internal rotators and creates the greatest torque values for the external rotators.

(Wilk, 1991: p64-p68)

3.12.8 The Cybex 700 Isokinetic Assessment:

3.12.8.1 Test Protocol:

Participants performed a concentric/ concentric shoulder internal/external isokinetic test at a test velocity of 60° per second and an 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).

3.12.8.2 Test Procedure:

The testing was done in such a way so that the test position closely resembles that of the normal throwing motion while ensuring muscle isolation (Wilk et al., 1991: p63-69). Therefore, subjects were tested in a comfortable seated position with their arm in 90 degrees of shoulder abduction and 90 degrees elbow flexion. Owing to the fact that internal/external rotation of the shoulder was being tested, the axis of rotation was aligned through the center of the olecranon and the shaft of the humerus (Wilk et al., 1991: p63-69). Participants 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).

Participants received the isokinetic assessment one week after the treatment of the TrP's and were told not to perform any sporting activities, which may alter the state of the shoulder during this interim period.

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.

The machine was calibrated weekly for the duration of the study.

3.12.8.3 Patient Positioning:

- Participants 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.
- Participants were instructed to grip the handle of the machine at all times.
- Participants were allowed to see the computer screen during testing.
- Participants were given standardized, scripted verbal encouragement while performing the test.

- All data with regard to participant position and machine set up was recorded.

3.12.8.4 Patient Procedure:

Subjects completed a 5 minute warm up cycle and the uninvolved shoulder was tested 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).

3.12.8.5 Isokinetic Data

Isokinetic data was recorded recorded at the Kings Park Sports Medicine Centre 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. Owing to the fact that the body of normative data is extremely limited, only certain parameters could be compared with the available normative values. Those parameters for which no norms could be found were recorded for future use.

3.13 Demographic Data:

Demographic data recorded included the following:

1) average age,
2) weight,
3) 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.

3.14 Statistical Analysis:

The SPSS statistical package (as supplied by the SPSS Inc., Marketing Department, 444 North Michigan Avenue, Chicago Illinois, 606611) was used for data entry and analysis.

Pre and post quantitative measurements were compared using paired t-tests for normally distributed data or Wilcoxon sign rank tests for non- parametrically distributed variables. Pre and post categorical measurements were compared with McNemar's chi square tests. Pearson and Spearman correlation was used to assess correlation between measurements on the same individual.
Mann-Whitney tests were used to compare medians in two independent groups.

Hypothesis testing and decision rule:

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.

3.15 Ethics:

The Durban Institute of Technology provided ethical guidelines which were strictly adhered to. Each participant was required to sign and complete an informed consent form and was given a letter of information about the study. All information was treated as confidential and the study only involved a minimal amount of risk.

CHAPTER 4
THE RESULTS

4.0 Statistical Methods

Data were captured in MS Excel and exported to SPSS version 12.0 (SPSS Inc. Chicago, Ill) for analysis.

Pre and post quantitative measurements were compared using paired t-tests for normally distributed data or Wilcoxon sign rank tests for non- parametrically distributed variables. Pre and post categorical measurements were compared with McNemar's chi square tests.
Pearson and Spearman correlation was used to assess correlation between measurements on the same individual.
Mann-Whitney tests were used to compare medians in two independent groups.
Hypothesis testing and decision rule
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.

Abbreviations

n = number
% = percentage
CI = Confidence interval
SD = standard deviation
p = probability value
df = degrees of freedom
IQR = inter-quartile range

4. 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, for non-parametric data, medians and ranges are presented. Frequencies for categorical variables are displayed as number and percentage. There was no missing data.

4.2 Demographics

Thirty male athletes participated in this study. Their ages ranged from 18 to 40 years, with a mean age of 24.8 yrs (SD 5.1). Ninety percent of the participants were right shoulder dominant (n=27), while 10% (n=3) were left shoulder dominant. The athlete's dominant shoulder was assessed in this study. The main sporting activity the subjects took part in was water polo, followed by baseball. This is shown in Figure A. The Cybex machine at Kings Park Sports Medicine Centre was capable of testing right and left shoulders with no alteration in the procedure.

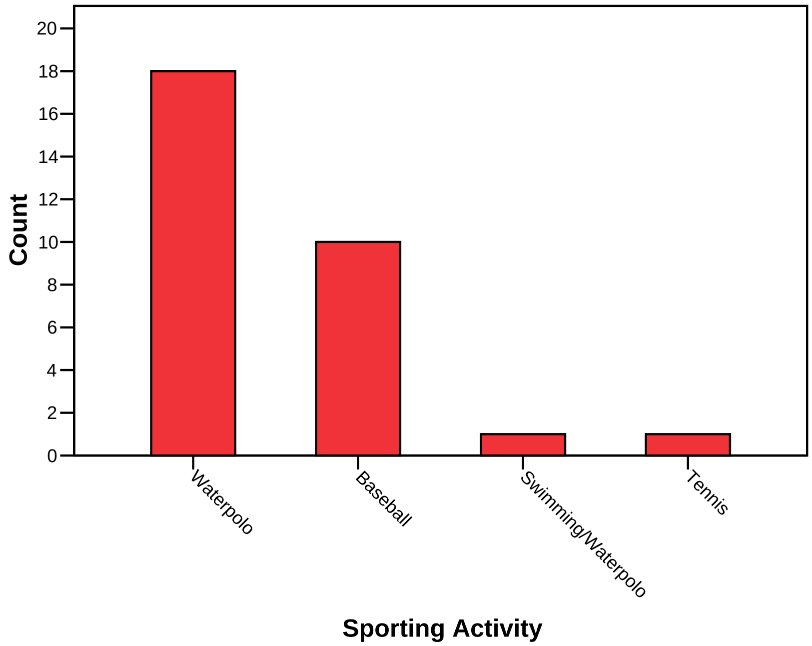


Figure A: Sporting activities of participants (n=30)

4.3 Descriptive statistics and comparisons of trigger points pre and post intervention:

4.3.1 Number of trigger points:

Wilcoxon signed ranks tests were used to assess changes in median number of trigger points pre and post intervention. There was a significant change in number of antagonistic ($p = 0.034$), agonistic ($p < 0.005$) and total trigger points ($p<0.001$). Figure B shows the median number of trigger points pre and post intervention. For agonistic and total trigger points, there was a decrease in the number of trigger points after the intervention.

Table 1 shows that the mean ranks for the negative ranks (where the number post was less than the number pre intervention) are far greater than those for the positive ranks, thus we can conclude that there was a significant decrease in number overall after the intervention.

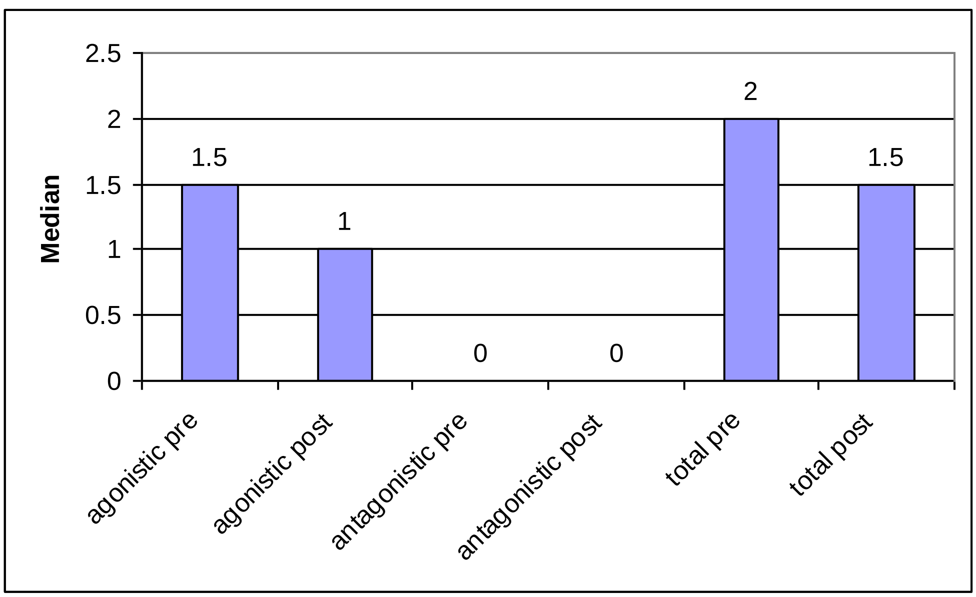


Figure B: median number of trigger points by location pre and post intervention

Table 1: Results of Wilcoxon signed ranks tests for comparison of number of trigger points pre and post intervention

		N	Mean Rank	Sum of Ranks	z	p
number of agonistic trigger points post - number of agonistic trigger points present pre	Negative Ranks	11(a)	6.55	72.00	-2.840	0.005
	Positive Ranks	1(b)	6.00	6.00		
	Ties	18(c)				
	Total	30				
number of antagonistic trigger points post - Number of antagonistic trigger points present pre	Negative Ranks	7	4.50	31.50	-2.121	0.034
	Positive Ranks	1	4.50	4.50		
	Ties	22				
	Total	30				
total number of trigger points post - number of trigger points present pre	Negative Ranks	16	9.06	145.00	-3.532	<0.001
	Positive Ranks	1	8.00	8.00		
	Ties	13				
	Total	30				

a number of trigger points post < number of trigger points pre

b number of trigger points post > number of trigger points pre

c number of trigger points post = number of trigger points pre

4.3.2 Severity of trigger points:

Wilcoxon signed ranks tests were used to assess changes in median severity score pre and post intervention. There was a significant change in severity scores for antagonistic ($p = 0.003$), agonistic ($p < 0.001$) and total trigger points score ($p < 0.001$). Examination of Table 2 shows that the sum of ranks for the negative ranks (where the score post was < the score pre intervention) are far greater than those for the positive ranks, thus we can conclude that there was a highly significant decrease in severity score overall after the intervention. This is reflected in Figure C, where the severity scores dropped markedly for agonistic and total trigger points after the intervention.

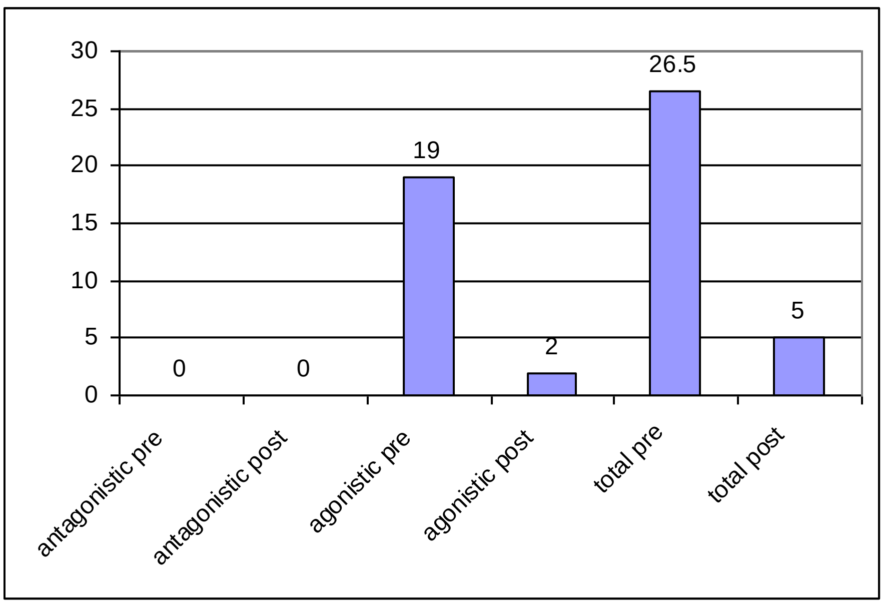


Figure C: median severity scores for trigger points by distribution pre and post intervention

Table 2: Results of Wilcoxon signed ranks tests for comparison of trigger point severity scores pre and post intervention.

		N	Mean Rank	Sum of Ranks	Z	p
total trigger point severity score post - Total severity score pre	Negative Ranks	30(a)	15.50	465.00	-4.783	<0.001
	Positive Ranks	0(b)	.00	.00		
	Ties	0(c)				
	Total	30				
Severity score for agonistic trigger points post - Severity score for agonistic trigger points pre	Negative Ranks	30	15.50	465.00	-4.784	<0.001
	Positive Ranks	0	.00	.00		
	Ties	0				
	Total	30				
Severity score for antagonistic trigger points post - Severity score for antagonistic trigger points pre	Negative Ranks	11	8.00	88.00	-2.977	0.003
	Positive Ranks	2	1.50	3.00		
	Ties	17				
	Total	30				

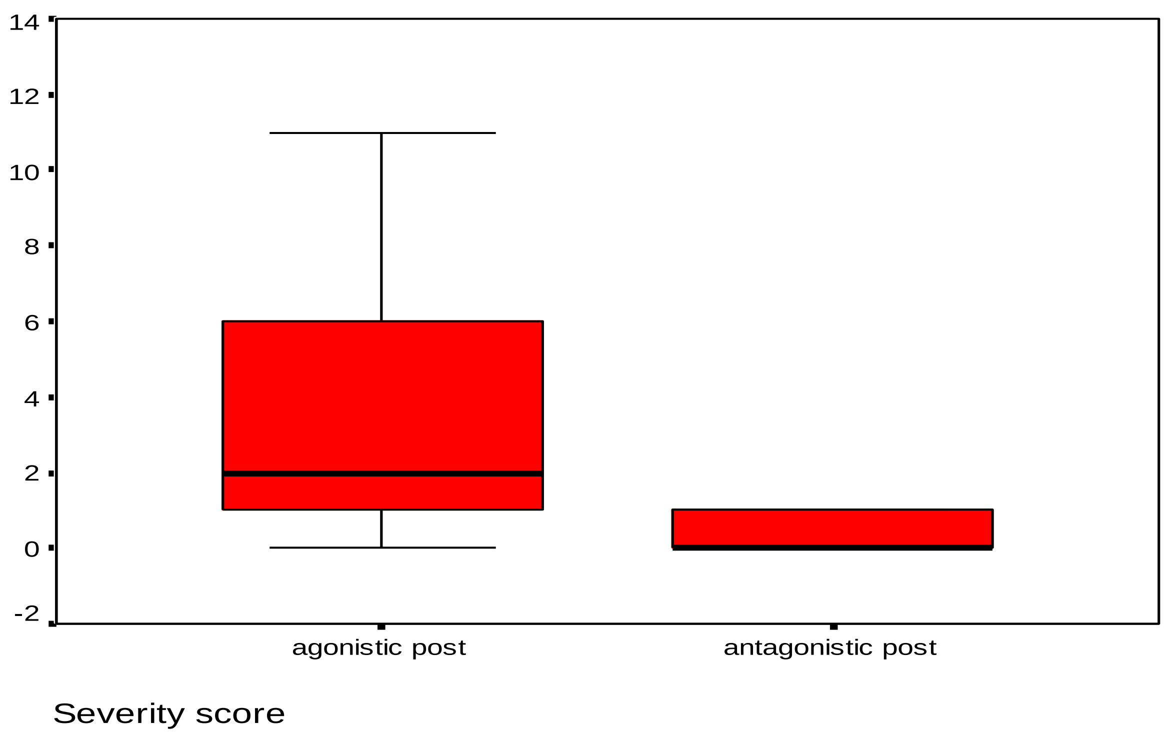
a total trigger point severity score post < Total severity score pre

b total trigger point severity score post > Total severity score pre

c total trigger point severity score post = Total severity score pre

4.3.2.1 Comparison of severity scores for agonistic and antagonistic trigger points post-intervention

There was a significant difference between the severity scores for agonistic and antagonistic trigger points post -intervention (p=0.015). The severity score for agonistic trigger points was higher than those for antagonistic trigger points, since in Table 3, the sum of ranks for negative ranks was higher than that for positive ranks. It can be seen from Figure D below that the distribution of severity scores for agonistic trigger points and for antagonistic trigger points post -intervention were significantly different. The severity of agonistic trigger points was higher than that for antagonistic trigger points.



<u>Figure D: boxplot of the distribution of severity scores for agonistic and antagonistic trigger points post intervention</u>

Table 3: Wilcoxon signed ranks test for comparison of severity scores for agonisitic and antagonistic trigger points post- intervention

-

		N	Mean Rank	Sum of Ranks	p
severity score for antagonistic trigger points post and severity score for agonistic trigger points post	Negative Ranks	22(a)	14.05	309.00	Z=-2.424, p=0.015
	Positive Ranks	6(b)	16.17	97.00	
	Ties	2(c)			
	Total	30			

a severity score for antagonistic trigger points post < severity score for agonistic trigger points post

b severity score for antagonistic trigger points post > severity score for agonistic trigger points post

c severity score for antagonistic trigger points post = severity score for agonistic trigger points post

4.3.3 Distribution of trigger points:

There was no significant difference in the distribution of trigger points pre and post intervention (p=1.00). Table 4 shows the distributions at the two time points. The distribution of trigger points had changed in 10 of the 30 participants. 18.2% of those who had mainly agonistic trigger points pre intervention, had equal trigger points post intervention. The participant who had mainly antagonistic trigger points pre intervention had equal trigger points post intervention. 57.1% of those who had equal trigger points pre intervention changed to mainly agonistic post intervention, and one with equal pre -intervention became mainly antagonistic post -intervention.

Table 4: comparison of distribution of trigger points pre and post intervention

			Distribution of trigger points post intervention			Total
			mainly agonistic	mainly antagonistic	equal	
Distribution of trigger points pre intervention	mainly agonistic	Count	18	0	4	22
		Row %	81.8%	.0%	18.2%	100.0%
	mainly antagonistic	Count	0	0	1	1
		Row %	.0%	.0%	100.0%	100.0%
	equal	Count	4	1	2	7
		Row %	57.1%	14.3%	28.6%	100.0%
Total		Count	22	1	7	30
		Row %	73.3%	3.3%	23.3%	100.0%

McNemar-Bowker test statistic=0.00, p = 1.00

4.4 Descriptive statistics of trigger points post intervention

4.4.1 Number of trigger points observed post intervention:

The median number of trigger points in the 30 subjects post intervention was 1 agonistic point, 0 antagonistic points, and 1.5 median total trigger points. The ranges are shown in Table 5. The maximum number of trigger points a participant had after the intervention was 3 and the minimum was 0.

Table 5: Statistics for number of agonistic, antagonistic and total trigger points post intervention

	number of agonistic trigger points post	number of antagonistic trigger points post	total number of trigger points post
N	30	30	30
Median	1.00	.00	1.50
Minimum	0	0	0
Maximum	2	1	3

4.4.2 Severity of trigger points post intervention:

The severity was measured utilizing the myofascial diagnostic scale, (Appendix K). When measured on this scale, if a TrP has a severity score of 9 and above, it is active and anything below 9 indicates that it is a latent TrP.

The median severity score for agonistic trigger points post intervention was 2, for antagonistic trigger points was 0 and for total trigger points was 5. The ranges are shown in Table 6. The maximum severity score was 18.

Table 6: Statistics for severity score for agonistic, antagonistic and total trigger points post intervention (n=30)

	severity score for agonistic trigger points post	severity score for antagonistic trigger points post	total trigger point severity score post
N	30	30	30
Median	2.00	.00	5.00
Minimum	0	0	0
Maximum	11	12	18

4.4.3 Distribution of trigger points post intervention:

Trigger points were categorized as to whether they occurred mainly agonistically, antagonistically or equally in both in each participant post intervention. The distribution of trigger points was tabulated in Table 7. They mainly occurred agonistically. There was only one participant with more antagonistic than agonistic trigger points in the study. Seven participants (23.3%) had equal numbers of agonistic and antagonistic trigger points post intervention.

Table 7: Distribution of trigger points post intervention (n=30)

	Frequency	Percent
mainly agonistic	22	73.3
mainly antagonistic	1	3.3
Equally agonistic and antagonistic	7	23.3
Total	30	100.0

4.5 Association between trigger points and ratios

4.5.1 Comparison of median number of trigger points between subjects with altered and normal ratios pre and post- intervention.

Altered internal/external ratios for peak torque and work were defined as a ratio value >150 and normal was <=150.

Mann Whitney tests were used to compare median number of trigger points in each of the two groups (normal and abnormal) for each type of ratio pre and post -treatment.

For each of the ratios, there were only 5 subjects with normal ratios pre and post -treatment. There was no significant difference in median number of trigger points post treatment between those containing agonist or antagonist TrP's for any of the ratios at any of the time points.

Pre- intervention the higher mean ranks in the abnormal groups suggest that there was actually more trigger points in the those with abnormal ratios, however this was not statistically significant. Post- intervention the higher mean ranks in the normal groups suggested that there were more trigger points in the normal subjects.

Figures E and F show the median numbers of trigger points by each category of normal or abnormal ratio for pre and post- intervention. Pre- intervention the abnormal group showed higher median number of trigger points than the normal group, while post- intervention it's the reverse. The statistical analysis is shown in Tables 8 and 9.

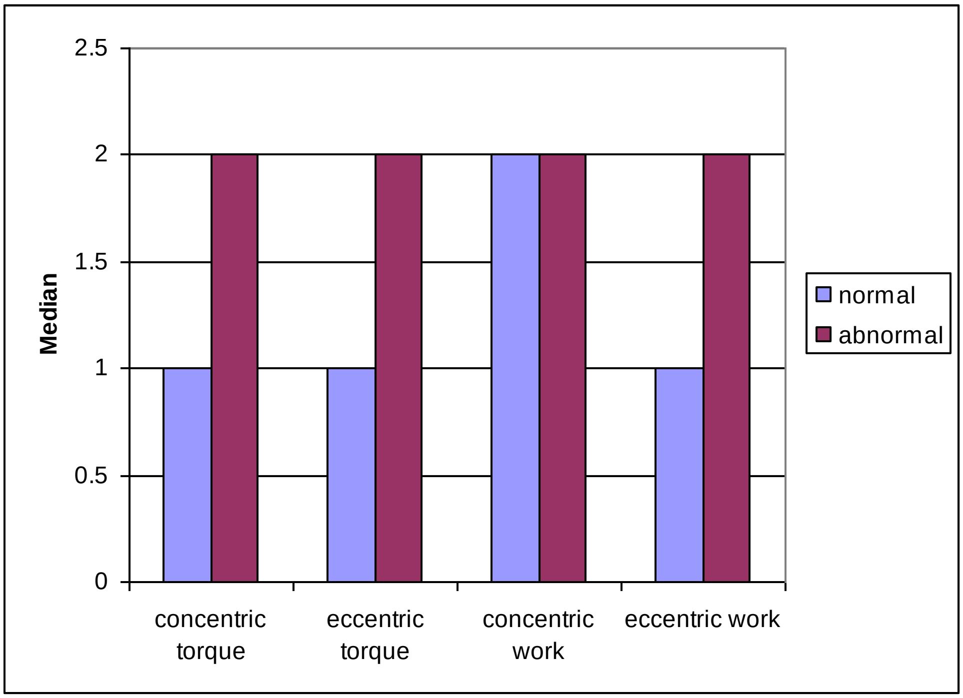


Figure E: Pre intervention median number of trigger points by ratio category

Table 8: Mann-Whitney tests for the comparison of median number of trigger points by ratio categories pre- intervention

ratio concentric torque pre	N	Mean Rank	Sum of Ranks	p
normal	5	10.90	54.5	0.208
abnormal	25	16.42	410.5	
Total	30			
ratio eccentric torque pre	N	Mean Rank	Sum of Ranks	
normal	5	10.90	54.5	0.208
abnormal	25	16.42	410.5	
Total	30			
ratio concentric work pre	N	Mean Rank	Sum of Ranks	
normal	5	13.10	65.5	0.516
abnormal	25	15.98	399.5	
Total	30			
ratio eccentric work pre	N	Mean Rank	Sum of Ranks	
normal	5	10.90	54.5	0.208
abnormal	25	16.42	410.5	
Total	30			

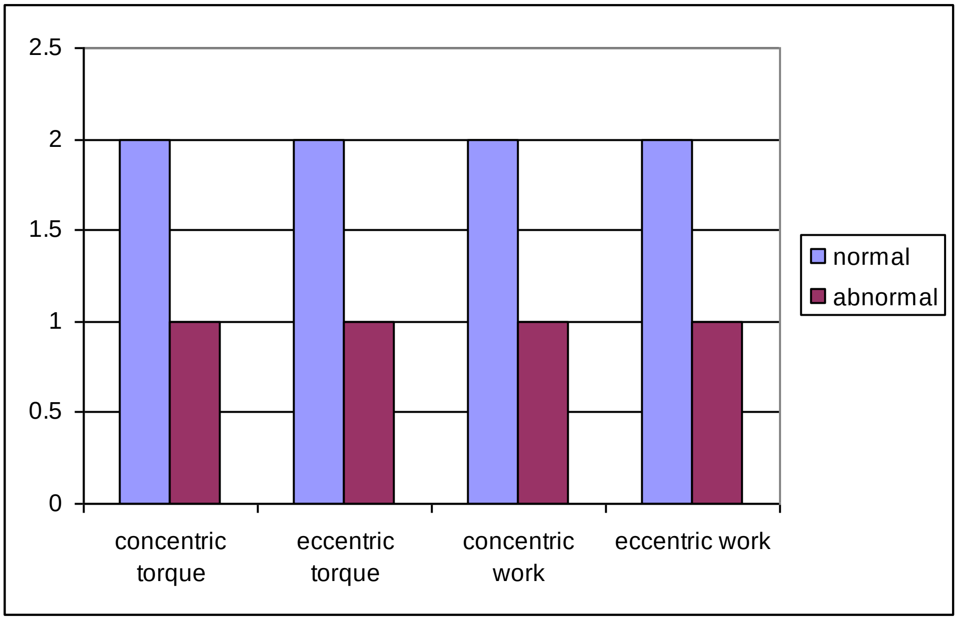


Figure F: Post- intervention median number of trigger points by ratio category

Table 9: Mann-Whitney tests for the comparison of median number of trigger points by ratio categories post- intervention

ratio concentric torque post	N	Mean Rank	Sum of Ranks	p
normal	5	16.60	83.00	0.787
abnormal	25	15.28	382.00	
Total	30			
ratio eccentric torque post	N	Mean Rank	Sum of Ranks	
normal	5	16.60	83.00	0.787
abnormal	25	15.28	382.00	
Total	30			
ratio concentric work post	N	Mean Rank	Sum of Ranks	
normal	5	19.30	96.50	0.300
abnormal	25	14.74	368.50	
Total	30			
ratio eccentric work post	N	Mean Rank	Sum of Ranks	
normal	5	16.60	83.00	0.787
abnormal	25	15.28	382.00	
Total	30			

4.6 Comparison of pre and post Cybex readings

4.6.1 Cybex readings pre and post intervention:

Since the Cybex measurements and their ratios were normally distributed, parametric paired t-tests were used to compare pre and post- measurements. Table 10 shows that most of the mean differences were negative, thus the pre readings were lower than the post readings (the readings had increased post- intervention). This increase was statistically significant in concentric internal rotation for work (p=0.022) and eccentric external rotation for work (p = 0.001). Figure G shows the mean cybex readings pre and post- intervention. Only eccentric external peak torque did not increase from pre to post -intervention.

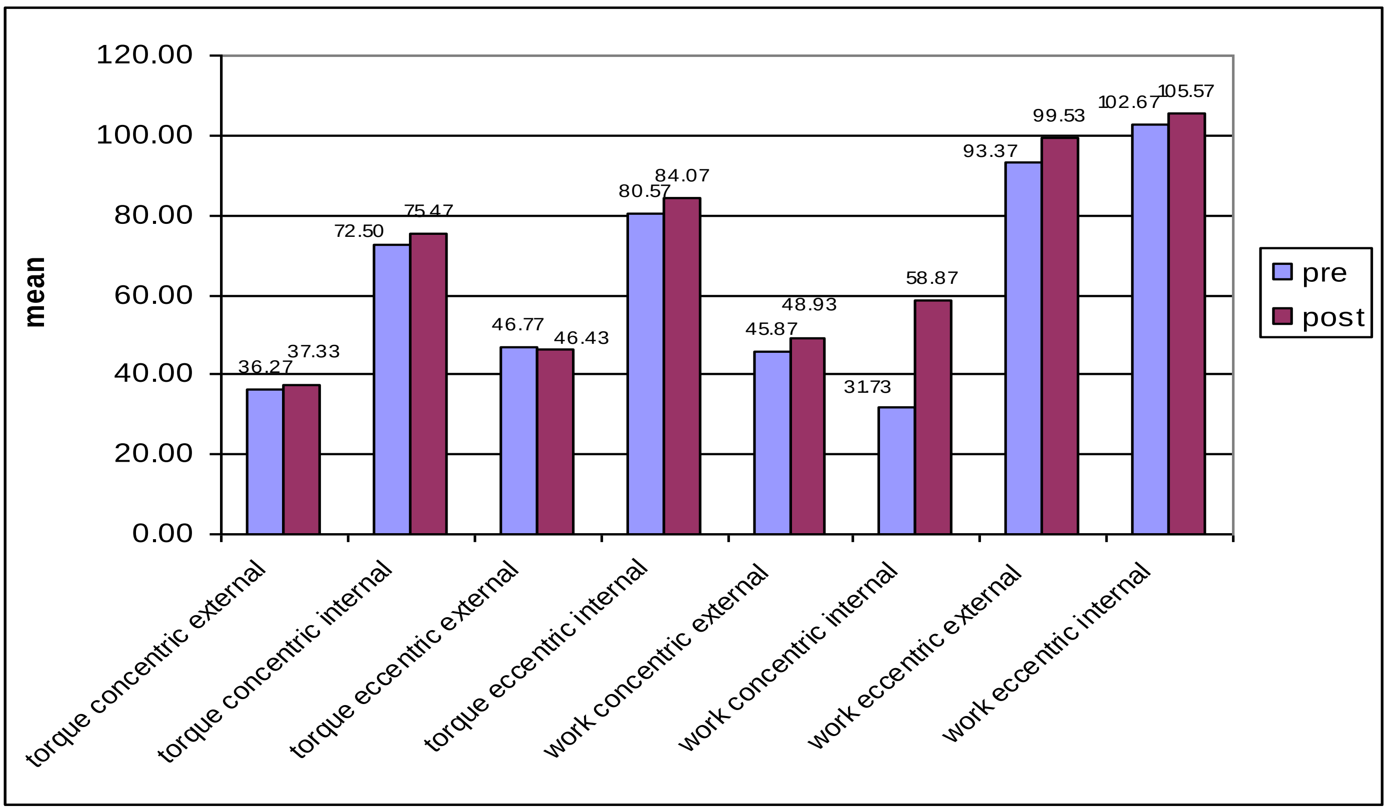


Figure G: mean Cybex readings pre and post- intervention

Table 10: Paired t-tests for the comparison of Cybex measurements pre and post-intervention

	Paired Differences					t	df	p (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Concentric external rotation torque	-1.067	4.884	.892	-2.891	.757	-1.196	29	.241
concentric internal rotation torque	-2.967	10.015	1.829	-6.706	.773	-1.622	29	.116
Eccentric external rotation torque	.333	7.179	1.311	-2.347	3.014	.254	29	.801
eccentric internal rotation torque	-3.500	12.495	2.281	-8.166	1.166	-1.534	29	.136
Concentric external rotation work	-3.067	9.262	1.691	-6.525	.392	-1.813	29	.080
concentric internal rotation work	-6.167	13.948	2.547	-11.375	-.958	-2.422	29	.022
Eccentric external rotation work	-27.133	41.839	7.639	-42.756	-11.510	-3.552	29	.001
eccentric internal rotation work	-2.900	15.659	2.859	-8.747	2.947	-1.014	29	.319

4.6.2 internal/external ratios pre and post- intervention:

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 (Davies, 1992: p53).

The ratios pre and post are compared in Table 11 by paired t-tests. None of the ratios were significantly different pre and post- intervention, although the mean differences were all negative indicating that the internal/external ratios had increased slightly from pre to post. This is shown in Figure H where the ratios were slightly higher post- intervention.

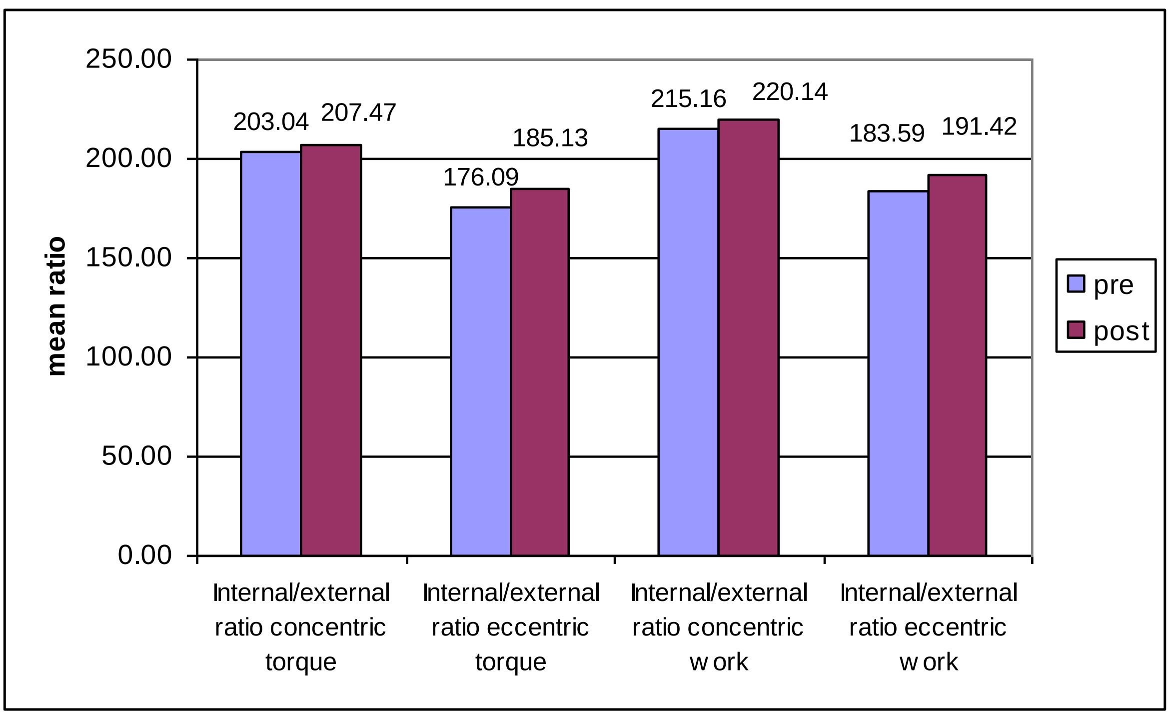


Figure H: mean internal/external ratios pre and post- intervention

Table 11: Paired t-tests for the comparison of Cybex ratios pre and post- intervention

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Internal/external ratio concentric torque	-4.433	26.865	4.905	-14.465	5.598	-.904	29	.374
Internal/external ratio eccentric torque	-9.044	28.991	5.293	-19.870	1.781	-1.709	29	.098
Internal/external ratio concentric work	-4.977	32.541	5.941	-17.128	7.175	-.838	29	.409
Internal/external ratio eccentric work	-7.838	33.546	6.125	-20.364	4.689	-1.280	29	.211

4.7 Comparison of concentric and eccentric ratios post- intervention

Concentric and eccentric ratios were compared by paired t-tests. There was a highly significant difference between concentric and eccentric ratios for both peak torque and for work ($p<0.001$). The mean differences were positive, thus the eccentric ratios were significantly lower than the concentric ratios (see Table 12).

Table 12: Comparison of concentric and eccentric ratios for peak torque and work post- intervention

	Paired Differences					t	df	p (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
-INT/EXT ratio concentric torque post - INT/EXT ratio eccentric torque post	22.340	29.690	5.421	11.253	33.426	4.121	29	<0.001
-INT/ext ratio concentric work post - INT/ext ratio eccentric work post	28.714	35.278	6.441	15.541	41.888	4.458	29	<0.001

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 measures (Myofascial Diagnostic Scale scores, location of TrP's and isokinetic ratio readings) and correlation tests. The discussion will follow relevant findings.

In order to avoid confusion, the following muscle groups have been defined for the purposes of this study.

Agonists of external rotation:

- Infraspinatus
- Posterior Deltoid
- Teres Minor

Antagonists of external rotation:

- Pectoralis Major
- Anterior Deltoid
- Subscapularis

(Travell and Simons, 1983: 555-556 and Moore, 1999: 710-711 and David,J.Magee, p235-236).

Various results and outcomes of the study indicate that a cycle may occur in overhead throwing athletes. This cycle can be explained as follows: the athlete starts out with a naturally occurring agonist strength deficit when compared to the antagonist as there are fewer agonist muscle and they are smaller (Cook et al, 1987: p456-457 and Andrews and Wilks, 1994: p418-643). This places large amounts of stress on the agonist muscles during overhead throwing as they have to counter the force produced by the antagonists and decelerate the throwing arm (Davies, p390).

This leads to muscle fatigue, and after continuous overhead throwing an overuse syndrome may result. This syndrome involves micro-trauma of the involved muscles resulting in the formation of TrP's within the agonists. This would cause altered shoulder motion (Baldry and Thompson, 1993: p76). TrP's found in one muscle group such as the shoulder external rotators can cause inhibition of their antagonists. In this case the shoulder internal rotators would be inhibited (Lawrence et al, 1996: p73-74).

After treatment of the MPS and elimination of the TrP's, the shoulders mechanics are restored and the shoulder can function normally. This allows the antagonist muscle to perform more work because of the absence of the inhibitory effect of the external rotators and improved stretch range of motion. This will eventually lead to an increase in stress and fatigue on the internal rotators and the formation of TrP's in the internal rotators. As discussed above this will upset the shoulder mechanics and place greater strain on the external rotators causing overuse of these muscles and completing the vicious cycle. This cycle will be referred to during the discussion of various results.

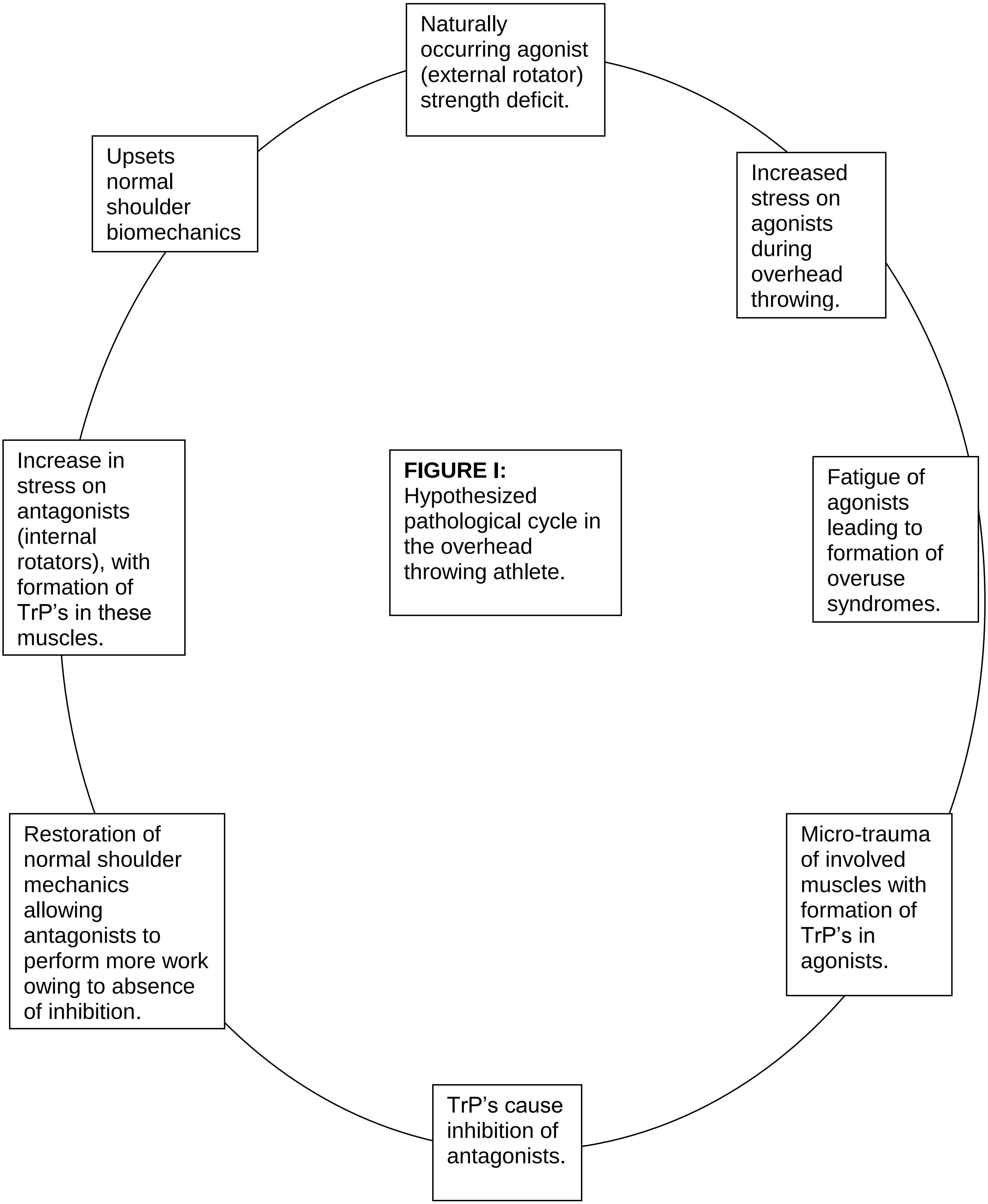


FIGURE I: Hypothesized pathological cycle in the overhead throwing athlete.

5.2 Demographics

5.2.1 Age Distribution:

Thirty male athletes participated in this study. Their ages ranged from 18 to 40 years, with a mean age of 24.8 yrs (SD 5.1).

Discussion:

Current literature indicates that the age of the athlete and their level of performance can be classified as predisposing factors to shoulder injuries, (Arroyo et al, 1997: p69 and Jobe and Kvitne, 1989: p963). One can categorize shoulder injuries into two groups, namely:

1. The young overhead athlete (18 to 35 years of age),
2. The older overhead athlete (older then 35 years of age)

The young athlete is susceptible to problems involving micro-trauma to the glenohumeral joint static stabilizers which may lead to instability and subluxation, secondary impingement and eventually rotator cuff tears. The older athlete suffers more from degenerative processes which can result in mechanical impingement on the coracoacromial arch and associated coracoacromial ligament thickening and spur formation which can cause narrowing of the subacromial space. Owing to this process, this age group is more susceptible to rotator cuff tears than the younger age group (Arroyo et al, 1997: p69). The above information tells us that although the ages of the participants in the study ranged from 18 to 40, the mean age was 24.8 yrs. It is therefore likely that most of the individuals in this study would have had shoulder pain from micro-traumatic injury because the mean age was below 35 years of age.

5.2.2 Sporting Distribution:

The main sporting activity the subjects took part in was waterpolo, followed by baseball. This is shown in Figure A (pg50). The Cybex machine at Kings Park Sports Medicine Centre was capable of testing right and left shouldered athletes with no alteration in the procedure.

Discussion:

Athletes involved in sporting activities such as: swimming (waterpolo), baseball, tennis and javelin require repetitive overhead use of the arm (Kennedy,and Hawkins, 1980: p151-158). Owing to the high demands placed on the shoulder muscles during such activities, they may develop a painful shoulder (Kennedy, 1980), which can result in subsequent muscle fatigue, eccentric overload, inflammation, tendon failure (Andrews and Wilks, 1994: p370) and eventually the formation of an overuse syndrome (Andrews and Wilk, 1994: p418).

The relatively high number of baseball players in the study (seen in figure A), may be related to the fact that the players were well into the season at the time of the study and that they participated in a provincial selection tournament prior to the time of the study. This would suggest that they had already performed a high level of repetitions which would have placed high demands on the athletes shoulder as discussed above, therefore making them susceptible to overuse injuries and shoulder pain.

Swimming requires repetitive internal rotation of the shoulder. This involves a high-resistance pull-through phase evident in most strokes which leads to strengthening of the internal rotators without specific training of the external rotators. This creates an imbalance between these two groups of muscles and results in early fatigue of the external rotators. This fatigue may become chronic and the athlete then becomes susceptible to an overuse injury such as impingent as a result of the dysfunctional scapular musculature (Souza, 1994: p118).

Similar to the baseball players the waterpolo players had just participated in their annual Currie Cup Waterpolo Tournament prior to the study. These waterpolo players would have had to perform fitness training in the form of swimming, which would involve repetitive internal rotation of the shoulder. A large amount of swimming training combined with overhead throwing during their games may lead to micro-traumatic injury as discussed above. This could possibly explain the high incidence of waterpolo players that took part in the study (see figure A).

5.3 Descriptive statistics and comparisons of trigger points pre and post intervention:

5.3.1 Number of trigger points:

Wilcoxon signed ranks tests were used to assess changes in median number of trigger points pre and post intervention. There was a significant change in number of antagonistic ($p = 0.034$), agonistic ($p < 0.005$) and total trigger points ($p<0.001$). Figure B (pg51) shows the median number of trigger points pre and post intervention. For agonistic and total trigger points, there was a decrease in the number of trigger points after the intervention.

Table 1 (pg52) shows that the mean ranks for the negative ranks (where the number post was less than the number pre intervention) are far greater than those for the positive ranks, thus we can conclude that there was a significant decrease in number overall after the intervention.

5.3.2 Severity of trigger points:

Wilcoxon signed ranks tests were used to assess changes in median severity score pre and post intervention. There was a significant change in severity scores for antagonistic ($p = 0.003$), agonistic ($p < 0.001$) and total trigger points score ($p<0.001$). Examination of Table 2 (pg54) shows that the sum of ranks for the negative ranks (where the score post was less than the score pre intervention) are far greater than those for the positive ranks, thus we can conclude that there was a highly significant decrease in severity score overall after the intervention. This is reflected in Figure C (pg53), where the severity scores dropped markedly for agonistic and total trigger points after the intervention.

Discussion:

Effective treatment using either the injection or dry needling depends on mechanical disruption and inactivation of the active loci in the TrP. Dry needling can be very effective and one must remember that one well-performed injection can fully inactivate a TrP immediately, whereas manual methods (spray and stretch, ischaemic compression, soft tissue therapy, e.t.c.) require several treatments (Travell, Simons and Simons 1999:p150-151).

Hong (1994: p256-263) performed a study that compared dry needling to injection of lidocaine into TrP's and he found that both groups experienced the same amount of improvement.

In a randomized double-blind clinical study conducted by Garvey et al (1989), it was found that dry needling and acupressure were more effective then transcutaneous injection of either local anesthetic or local anesthetic and steroids.

These results suggest that when there is mechanical disruption by the needle of nerve endings or contractile elements of the muscle this contributes to the de-activation and elimination of TrP's. This is evident as the signs of a trigger point according to Travell and Simons (1983:12-16) i.e. (referred pain in the zone of reference, local twitch response, palpable taut band and focal tenderness), as well as the TrP's, will have disappeared or become less severe.

This explains the decrease in the number of TrP's and their severity scores as seen in table 1 (pg52) and table 2 (pg54).

5.3.2.1 Comparison of severity scores for agonistic and antagonistic trigger points post-intervention:

There was a significant difference between the severity scores for agonistic and antagonistic trigger points post -intervention (p=0.015). The severity score for agonistic trigger points was higher than those for antagonistic trigger points, since in Table 3 (pg56), the sum of ranks for negative ranks was higher than that for positive ranks. It can be seen from Figure D (pg55) below that the distribution of severity scores for agonistic trigger points and for antagonistic trigger points post -intervention were significantly different. The severity of agonistic trigger points was higher than that for antagonistic trigger points.

Discussion:

There are a number of reasons that could have contributed to the severity of agonistic trigger points being higher than that for antagonistic trigger points.The first one being that of post needling soreness that may have occurred. In some cases patients have been known to be sore after a TrP is needled during a treatment protocol (Hong, 1994: p256-263 and Travell, Simons and Simons 1999:p150).

Another contributing factor may have been perpetuating factors that may have placed some form of stress on the agonistic muscles. This abuse may be as a result of a number of factors with a few being; mechanical stress, irritation by the dry needling, infections etc (Chaitow and Delaney, 2000: p80 and Travell, Simons and Simons, 1999: p178-p179).

The fact that the agonist muscles contained more trigger points and had higher severity scores then the antagonists initially, as seen in Figure B (pg51) and C (pg53), indicates that it may have been more difficult to completely de-activate and eliminate the TrPs in the agonists, and easier to eliminate the TrPs in the antagonists thereby producing the outcome in figure D (pg55).

A remaining factor could be related to the stage in the cycle, discussed in the introduction, that the athlete might be in.

5.3.3 Distribution of trigger points:

There was no significant difference in the distribution of trigger points pre and post intervention (p=1.00). Table 4 (pg57) shows the distributions at the two time points. The distribution of trigger points had changed in 10 of the 30 participants. 18.2% of those who had mainly agonistic trigger points pre intervention, had equal trigger points post intervention. The participant who had mainly antagonistic trigger points pre intervention had equal trigger points post intervention. 57.1% of those who had equal trigger points pre intervention changed to mainly agonistic post intervention, and one with equal pre -intervention became mainly antagonistic post -intervention.

Discussion:

The results seen in table 4 (pg57) are consistent with the cycle explained in the introduction. It is evident that the number and severity of the agonist and antagonist TrP's in various participants did not decrease consistently with treatment. Several participants had a changed from agonistic to antagonistic TrP's and visa versa, during the research study, indicating that different stages of the cycle may result in the formation of TrP's in different muscle groups.

It was found that 18.2% of those who had mainly agonistic trigger points pre- intervention, had equal trigger points post -intervention. Therefore agonists improved but not more so than the antagonists. A noticeable difference may have resulted as the condition in the agonists was more severe or the muscles contained a greater number of TrP's, as seen above in tables 1 to 3. However this may have prevented complete elimination of the TrP's. The greater severity and number of TrP's in the agonists may also have prevented complete elimination of the TrP's in the antagonists because of the inhibitory effect that the agonists had on them as discussed in the introduction.

One participant mentioned above who initially had more antagonistic trigger points pre-intervention ended up with equal trigger points post-intervention. This suggests that the antagonist improved but not more so than the agonists. This may have occurred owing to the fact that the participant may have been an active individual and performed activities that may have overworked and placed added stress on their antagonists such as gym or paddling. This may have perpetuated the TrP's, (Chaitow and Delaney, 2000, p80 and Travell, Simons and Simons 1999, p178-p179).

Of those participants who had equal trigger points pre- intervention, 57.1% changed to mainly agonistic post –intervention and one changed mainly to antagonistic post-intervention. This signifies that there was a greater improvement in the antagonists then the agonists with the exception of 1 participant. This may have resulted as the antagonists contained less TrP's and they were less severe. Another contributing factor may have been that the agonist muscles in these participants contained fewer TrP's which therefore may have had less of an inhibitory effect on the antagonists.

The one participant who had a change to mainly antagonistic TrP's post- intervention, may have been an active individual and performed activities that may have overworked and placed added stress on their antagonists such as gym or paddling. This may have perpetuated the TrP's, (Travell, Simons and Simons 1999, p178-p179).

5.4 Descriptive statistics of trigger points post intervention

5.4.1 Number of trigger points observed post intervention:

The median number of trigger points in the 30 subjects post intervention was 1 agonistic point, 0 antagonistic points, and 1.5 median total trigger points. The ranges are shown in Table 5. The maximum number of trigger points a participant had after the intervention was 3 and the minimum was 0.

After analysis of table 5 (pg58) it is evident that dry needling of the TrP's was effective as the number of TrP's in both the agonist muscles of external rotation and antagonist muscles of external rotation were reduced. It can be seen from table 5 above, that more TrP's remained in the agonist muscles then antagonist muscles and there are a number of explanations for this which are explained in the discussion below 5.4.3.

5.4.2 Severity of trigger points post intervention:

The severity was measured utilizing the myofascial diagnostic scale, (Appendix K). When measured on this scale, if a TrP has a severity score of 9 and above, it is active and anything below 9 indicates that it is a latent TrP.

The median severity score for agonistic trigger points post intervention was 2, for antagonistic trigger points was 0 and for total trigger points was 5. The ranges are shown in Table 6. The maximum severity score was 18.

Table 6 indicates that the severity score of the TrP's post treatment was worse for the agonists then antagonists. It shows us that there was no severity score for the antagonistic muscles as all their TrP's had been eliminated, however, there was a severity score for the agonists suggesting that the agonists still contained TrP's post treatment, however these TrP's were less severe than before the treatment. This suggests that the dry needling was successful, as discussed below table 5.3.2. The fact that the agonists had a greater severity score post treatment then the antagonists can be explained using a number of reasons discussed below 5.4.3.

5.4.3 Distribution of trigger points post intervention:

Trigger points were categorized as to whether they occurred mainly agonistically, antagonistically or equally in both in each participant post intervention. The distribution of trigger points was tabulated in Table 7 (pg60). They mainly occurred agonistically. There was only one participant with more antagonistic than agonistic trigger points in the study. Seven participants (23.3%) had equal numbers of agonistic and antagonistic trigger points post intervention.

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, mainly antagonistic, or equally agonistic and antagonistic. Most subjects had mainly agonistic.

Discussion:

After analysis of tables 5 to 7 (pg58-60) it is evident that dry needling of the TrP's was effective. Both the number of TrP's and the severity scores were reduced indicating that the TrP's were either eliminated or de-activated. The explanations for the changes seen in tables 5 to 7 are as follows:

1) The agonists may have initially contained more TrP's then the antagonists and their MPS may have been more severe. This can be explained from the premise that the agonists have a much smaller muscle bulk then the antagonists. This results in a naturally occurring muscle imbalance which is exaggerated in overhead athletes. The external rotators have a relative strength deficit when compared to the antagonists because of the small muscle bulk and therefore have to perform more work (Cook et al, 1987: p456 and Andrews and Wilks, 1994: 643).

This would cause the agonists to fatigue faster then the antagonists resulting in the development of an overuse syndrome from overhead activity (Andrews and Wilk, 1994: 418 and Baldry and Thompson, 1993: p76). This overuse syndrome could precipitate the formation of MPS (Sola et al, 1955: p588 and Hains 2002: p192), resulting in the formation of TrP's that are greater in number and more severe then in the antagonists because of the premature fatigue.

2) Early fatigue and weakness of the external rotators could also precipitate the formation of an overuse syndrome causing pain (Souza, 1994: p118). There are a number of factors that could have contributed to the weakening or inhibition of the external rotators:

- If the agonists had more TrP's than the antagonists initially, this would decrease their stretch range of motion and weaken them, which would reflexively inhibit their antagonists, thereby weakening them further (Lawrence et al, 1996: 73-74).
- The weakness may also be a type of guarding mechanism, in which the muscle is reflexly inhibited from full contraction because of pain i.e. arthrogenic muscle inhibition (AMI), (Hopkins and Ingersoll, 2000 and Schneider, 1995: p74).

3) Decreased muscular efficiency can lead to uncoordinated joint motion (Lawrence et-al, 1996:p73-p74). Musculoskeletal impairment can significantly alter the coordinated shoulder complex motion (Andrews and Wilk, 1994:p15).The patient will replace normal muscle patterning with an adopted functional motor programme (Ingersoll, Palmieri and Hopkins, 2003). This would place added strain on the external rotators thereby leading to the formation of TrP's in these muscles.

5.5 Association between trigger points and ratios

5.5.1 Comparison of median number of trigger points between subjects with altered and normal ratios pre and post- intervention:

Altered internal/external ratios for peak torque and work were defined as a ratio value >150 and normal was <=150.

Mann Whitney tests were used to compare median number of trigger points in each of the two groups (normal and abnormal) for each type of ratio pre and post -treatment.

For each of the ratios, there were only 5 subjects with normal ratios pre and post -treatment. There was no significant difference in median number of trigger points post treatment between those containing agonist or antagonist TrP's for any of the ratios at any of the time points.

Pre- intervention the higher mean ranks in the abnormal groups suggest that there was actually more trigger points in the those with abnormal ratios, however this was not statistically significant. Post- intervention the higher mean ranks in the normal groups suggested that there were more trigger points in the normal subjects.

Figures E (pg62) and F (pg64) show the median numbers of trigger points by each category of normal or abnormal ratio for pre and post- intervention. Pre- intervention the abnormal group showed higher median number of trigger points than the normal group, while post-intervention it's the other way around. The statistical analysis is shown in Tables 8 (pg63) and 9 (pg65).

Discussion:

Figure E (pg62) and Table 8 (pg63) show that the participants with abnormal ratios (greater then 150%) have more TrP's then the participants with normal ratios (smaller then or equal to 150%). This could be as a result of muscle inhibition owing to pain, AMI and stretch range of motion (Schneider, 1995: p74 and Hopkins and Ingersoll, 2000 and Lawrence et al, 1996: 73-74). 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. This will also result in biomechanical changes and abnormal shoulder movement in order to avoid the pain. This abnormal shoulder movement results in recruitment of other muscle groups and leads to further muscle imbalance, thus perpetuating the dysfunction cycle.

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.

Figure F (pg64) and Table 9 (pg65) indicate that after treatment the TrP's in the participants with normal ratios increased but decreased in those with abnormal ratios.

This suggests that dry needling was effective in those participants with abnormal ratios by eliminating or de-activating their TrP's. However the TrP's in those with normal ratios may have increased for three reasons individually or in combination:

1. The TrP's may have been irritated by the needling, mechanical stress, (Travell, Simons and Simons 1999, p111 and p178-p179) or the initial reading on the Cybex machine.

2. The needling may have eliminated the TrP's thereby restoring normal function of the agonists and antagonists and stopping the inhibitory effect of the agonists, allowing for the antagonists to function normally (Lawrence et al, 1996: 73-74), and for restoration of normal biomechanics of the shoulder joint (Ingersoll, Palmieri and Hopkins, 2003). The shoulder pain caused by the TrP's would also have been reduced. The

antagonists will then be able to perform more work, leading to a greater amount of stress placed on them resulting in fatigue and an eventual overuse syndrome with the formation of TrP's (Andrews and Wilk, 1994: 418 and Baldry and Thompson, 1987: p76). This supports the cycle discussed above in the introduction.

3. The participants may have been suffering from post needling soreness. One of the objective measurement tools used to assess the improvement of the TrP's was the Myofascial Diagnostic scale. This tool involved palpating the TrP's in order to assess their tenderness. The post needling soreness could have influenced the severity scores and contributed to increased sensitivity and/or re-activation of the TrP's during palpation.

5.6 Comparison of pre and post Cybex readings

5.6.1 Cybex readings pre and post intervention:

Since the Cybex measurements and their ratios were normally distributed, parametric paired t-tests were used to compare pre and post- measurements. Table 10 (pg67) shows that most of the mean differences were negative, thus the pre readings were lower than the post readings (the readings had increased post- intervention). This increase was statistically significant in concentric internal rotation for work (p=0.022) and eccentric external rotation for work (p = 0.001). Figure G (pg66) shows the mean cybex readings pre and post-intervention. Only eccentric external peak torque did not increase from pre to post - intervention.

Discussion:

The fact that the peak torque and work readings increased post- treatment indicates that the dry needling was successful (Travell, Simons and Simons 1999:p150-151 and Hong, 1994: p256-263). The explanations for the increase in readings are as follows:

1. The de-activation and elimination of the TrP's would have stopped the inhibitory effect that the agonists may have had on the antagonists thereby allowing them to function normally with increased strength and restoring normal shoulder mechanics (Lawrence et al, 1996: p73-74).

2. Treatment of these TrP's may also have stopped the AMI and decreased pain also contributing to normal and smooth co-ordinated shoulder motion thereby increasing shoulder strength for all measurements (M.J. Schneider, p74; Travell, Simons and Simons; 1999: p21-22 and Ingersoll, Palmieri and Hopkins, 2003).

3. With elimination of the TrP's that were found within the muscles, the muscles elongate and return to their normal length. This will allow them to contract at optimal strength and will therefore contribute to the improved values (Travell, Simons and Simons 1999: p21-p22 and Souza, 1994: p41-43).

The fact that both concentric internal rotation for work and eccentric external rotation for work had a statistically significant increase can be explained as above. With the inhibitory effect of the agonists, AMI and pain resolved with the resolution of the TrP's, the antagonists (internal rotators), can function normally and would therefore have more strength when contracting concentrically to perform internal rotation (M.J. Schneider, p74; Travell, Simons and Simons (1999: p21-22 and Ingersoll, Palmieri and Hopkins, 2003), and because they are now functioning normally, they would be more accommodating and could stretch more thereby allowing a greater increase in eccentric external rotation (Ingersoll, Palmieri and Hopkins, 2003; Davies, p26-p27 and Travell, Simons and Simons 1999: p21).

It is evident from the above information (table 1 – pg52)) that the agonists contained more TrP's then the antagonists. Therefore by reducing the TrP's in the agonists this would stop the weakening effect that the TrP's have on the muscles containing the TrP's thereby allowing them to function normally and regain strength (Travell, Simons and Simons 1999: p22).

5.6.2 internal/external ratios pre and post- intervention:

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 (Davies, 1992: p53).

The ratios pre and post are compared in Table 11 (pg69) by paired t-tests. None of the ratios were significantly different pre and post- intervention, although the mean differences were all negative indicating that the internal/external ratios had increased slightly from pre to post. This is shown in Figure H (pg68) where the ratios were slightly higher post- intervention.

Discussion:

A study by Audie (2005) correlated the peak torque values of overhead athletes with established normative values. His mean values were the following:

- Concentric contractions for peak torque = 204.9%.
- Eccentric contractions for peak torque = 179.2 %.

When compared it can be seen that these values are significantly higher then the current normative values, and he suggested the following reason. The Cybex Isokinetic Dynomometer used at the Kings Park Medicine Centre, 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. Audie (2005) believes that this factor could be eliminated in the future if one established normative ratios in non-athletes on this machine which could be used as a control group.

The fact that the ratios were larger than normal, especially with regard to concentric contractions, could be due to the over training of the internal rotators with repetitive concentric contracting of those muscles with very limited concentric contraction of the external rotators (Miller, 1984: p68-83).

As seen above in figure H (pg68), the ratios have increased, instead of decreasing as was initially hypothesized in this study. This may have occurred for the following reasons:

1) From the explanations and results above, it was determined that the dry needling was effective in treating the TrP's. This may have lead to the cessation of inhibition from the agonists on the antagonists, AMI and pain thereby improving shoulder mechanics, restoring normal function and increasing strength of both the agonists and antagonists (M.J. Schneider, p74; Travell, Simons and Simons, 1999: p21-22 and Ingersoll, Palmieri and Hopkins, 2003).

2) Owing to the fact that the antagonist muscle are a larger group of muscle then the agonist muscles (Cook, 1987: p456 and Andrews and Wilks, 1994: 643), and that the antagonist muscles are much larger then the agonists (Souza, 1994: p41-43), the increased ability of the antagonists, with more strength, would have created a greater differential, thereby increasing the ratio instead of decreasing it.

3) The pain caused by the trigger points would have caused patient apprehension and prevented the patient from using the affected arm (Schneider, 1995: p74). After the treatment of the TrP's and elimination of pain, the participant may have had remaining psychological overlay/apprehension and would be reluctant to use his arm at its full capability especially in external rotation, and this would result in larger internal/external shoulder ratios.

4) Long term/chronic TrP's may have caused residual muscle weakness, even with the elimination of the TrP's thereby preventing the shoulder rotator unit from working at its full potential which could create enlarged ratios.

5) The formation of a neural scar from a chronic overuse condition could cause lasting muscle inhibition and also influence the ratios negatively (Leach, 1994: p101).

6) The small sample size could also have affected the outcome of results as they were not statistically significant.

7) The Cybex Isokinetic Dynomometer used at the Kings Park Medicine Centre, does not offer gravity correction for this specific test position (Wright, 2003).

8) 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.

9) The fact that the ratios were larger than normal especially with regard to concentric contractions, could be due to the over training of the internal rotators (Miller, 1984: p68-83), and repetitive concentric contracting of those muscles with very limited concentric contraction of the external rotators. Therefore, once the TrP's were eliminated, the internal rotators could function normally and would have a greater improvement in strength then the external rotators.

10) This cycle discussed in the introduction may affect the normative peak torque and total work values of overhead throwing athletes. These normal values were taken as an arbitrary cut off from the current literature, but could just be related to a specific point in this cycle that an athlete may be in.

5.7 Comparison of concentric and eccentric ratios post- intervention

Concentric and eccentric ratios were compared by paired t-tests. There was a highly significant difference between concentric and eccentric ratios for both peak torque and for work ($p<0.001$). The mean differences were positive, thus the eccentric ratios were significantly lower than the concentric ratios (see Table 12 pg70).

Discussion:

During the acceleration phase of overhead throwing, the internal rotators contract concentrically to accelerate the arm. The external rotators contract eccentrically during the deceleration phase to slow the arm down. The large forces needed by the small muscle mass of the external rotators to slow the arm down can lead to the formation of an overuse injury which may manifest as a repetitive strain injury which involves inflammation and muscular weakness (Andrews and Wilk, 1994: p418 and Hinton, 1988: p278 and Jacobson et-al, 1989: 1037).

However, the large amount of concentric contractions produced during the throwing motion causes the internal rotators to undergo a plyometric-type of training, and this type of training has been found to greatly enhance power in larger muscle groups (Miller, 1984: p68-83). Therefore, the differences between concentric and eccentric ratios for both peak torque and for work may be as a result of the altered muscle activity explained above. It is evident that there is a partial absence of concentric muscle training of the external rotators thereby creating the ratio differences between the two sets of values. And consequently should be considered in training programs and rehabilitation programmes for competitive overhead athletes.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The aim of this investigation was to evaluate the therapeutic effect of dry needling for active myofascial trigger points (TrP's), on the association between internal/external ratios of the shoulder rotator myotatic unit in overhead throwing athletes which might aid the clinician in treating the problem of RSI prior to definitive pathological changes in the muscle – such as actual muscle tearing. It was hypothesized that dry needling would decrease the adverse effects and the number of TrP's in the rotator unit of the shoulder thereby, increasing muscle strength and improving the internal-external ratio of the dominant shoulder in these athletes.

The first objective was to assess and quantify the number, severity and specific location of the TrP's within the shoulder rotator muscle group. The second objective was to assess the internal-external ratio of the dominant shoulder in throwing athletes using a Cybex 700 dynamometer, after intervention and the third objective was to establish a comparable clinical profile of the participants.

The intervention significantly reduced the number and severity of trigger points, but did not change the distribution of these points. The TrP's were predominantly found in the agonist muscles of external rotation, although a small number were present in the antagonists. The fact that the agonists are involved in decelerating the arm at the end of the overhead throw places them under a large amount of stress. The small muscle mass of the agonists means that they will have difficulty in coping with this stress over long periods of time, and are therefore more susceptible to forming TrP's then the antagonists.

There was no association between number or distribution of trigger points, and Cybex ratios.

The Cybex readings increased post- intervention, with work concentric internal and eccentric external readings increasing significantly.

This study failed to show a significant improvement in the peak torque and work ratios of the dominant arm in the overhead throwing athletes. The ratios all increased, but none showed statistical significance. However, this may have been skewed due to a small sample size.

Concentric and eccentric ratios were significantly different post -intervention with concentric ratios being higher then eccentric ratios.

The results in this study confirm that dry needling was very successful in the treatment of MPS. They also suggests that a consistent pattern of relative external rotation peak torque and total repetition work imbalance exists in the dominant shoulder of competitive overhead athletes and is therefore consistent with current literature (Koziris et al, 1991; Ellenbeker, 1991 and Chandler et-al, 1992).

It appears that MPS is related to the shoulder rotator muscle imbalance which can alter the coordinated shoulder complex motion and the peak torque and total work ratios of the shoulder myotatic unit (Andrews and Wilk, 1994: p15 and Lawrence et-al, 1996: p73-74). However the extent of the impact that these TrP's have on the ratios is unclear. This study was unable to determine whether they were perpetuating, causative or concomitant factors. The fact that the ratios were enlarged post-treatment, although not significantly, confirms that an external rotation imbalance exists and indicates that when the shoulder rotator unit is functioning correctly and coordinated shoulder complex motion is regained, the internal rotators over power the external rotators to a greater extent.

This suggests that trainers, athletes and clinicians should concentrate on strengthening the external rotators (especially using concentric strengthening exercises) in overhead athletes in order to achieve and maintain a favorable internal/external strength balance which may prevent or reduce the severity of repetitive overload injuries. This study indicates that eccentric and concentric strength ratios and their association with MPS needs to be investigated further.

RECOMMENDATIONS:

To improve the statistical significance, the following recommendations can be made:

- A larger sample size would increase the validity of the study and limit the possibility of incorrectly accepting the null hypothesis. However, budget considerations and the cost of using outside facilities was a limiting factor in this study.
- The sample population could exhibit uniformity with respect to the clinical presentation of MPS. Participants should all either have TrP's in the external rotators or the internal rotators.
- The sample population should be limited to specific type of activity.
- Stricter inclusion and exclusion criteria should be applied in order to get a more uniform sample group.

Currently, the data for isokinetic testing is very limited and difficult to access and it is therefore very difficult to make accurate comparisons. It is very important that a greater resource of normative data for over head throwing athletes and non -athletes is determined from other studies. These normative values should be determined at all testing speeds and for all isokinetic parameters made.

The sample group should be isolated to a specific population group. This may help to determine specific data for specific population groups. It also helps to eliminate variables that may be present in some groups and not others that have a bearing on the formation of overuse syndromes and the outcome of the study.

Similarly, studies should be conducted separately in participants that suffer from both acute and chronic overuse syndromes. These two groups may have characteristics that differ from one another, inclusive of their baseline normative values.

Participants should be monitored for a third week and retested to determine further changes in the shoulder myotatic unit which may confirm or refute the hypothesized cycle discussed in chapter 5. Any changes may influence future treatment and rehabilitative programs.

A future study should be conducted in which the agonist / antagonist cycle is analyzed over a lengthy period of time as this study only encountered glimpses of it. This may provide a better understanding of the pathological process that exists in the dominant shoulder of overhead throwing athletes and contribute to formulating optimal conditioning programs for injury prevention.

A longer treatment protocol could be adopted in order to completely eliminate all TrP's which may have a greater effect on the shoulder internal-external ratios.

A weakness in the study was the technique used to diagnose and assess the MPS in the participants. The methods used were subjective (e.g. Myofascial Diagnostic Scale) and therefore may not have been entirely accurate. Future studies should include objective diagnostic methods in order to establish a more precise diagnosis.

A study needs to be performed on a non- athletic population group suffering from MPS in the shoulder rotator unit to establish normative data. This will allow a comparison to be made of the ratios post- treatment and contribute to a greater understanding of the relationship between MPS and the shoulder rotator unit ratios.

It is difficult to determine to what extent the external rotators need to be strengthened in order to cope with the demands placed on them during overhead throwing and how much difference it will actually make because of the existing muscle imbalance. This should be determined in a concurrent study involving strengthening of the external rotators, especially using concentric exercises, which may help determine an ideal ratio for optimal shoulder function in overhead athletes. This is important as the role of muscular control in the shoulder is yet to be properly evaluated.

It is important that studies in the future compare and analyze the eccentric action of the rotator cuff. This information seems to be missing from current literature as most of the available isokinetic data relates to the concentric component of the rotator cuff (especially concentric external rotation), even though the RC muscles act predominantly eccentrically (Andrews and Wilk, 1994: p574).

Different treatment protocols for MPS could be used in order to determine which one was more successful and whether there may be a different outcome with regard to the shoulder internal/external ratios.

Questionnaires should be designed and incorporated into the study to give it more strength in terms of subjective data.

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APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX F

APPENDIX G

APPENDIX H

APPENDIX I

APPENDIX J

APPENDIX K

APPENDIX L