The Acute Effect of a Myofascial Release Intervention on Resting Scapular Position

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A thesis submitted to the faculty of The University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Arts in the Department of Exercise and Sport Science (Athletic Training)

Chapel Hill
2007

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ABSTRACT

MICHELLE M. MCLEOD: The Acute Effect of a Myofascial Release Intervention on Resting Scapular Position
(Under the direction of Dr. William E. Prentice)

This study examined the acute effect of utilizing a self myofascial release technique (MRT) intervention on resting scapular position. Resting postural and kinematic data were collected using an electromagnetic motion analysis system on twenty-nine subjects (15 experimental, 14 control) using a pretest-posttest design. Posture was determined through measures of scapular upward/downward rotation, scapular internal/external rotation, and scapular anterior/posterior tipping. Measures were compared between groups prior to and immediately following the MRT intervention using a foam roller or rest period lasting the duration required to complete the MRT. Statistical analyses revealed no significant differences in posture for group, or for test by group interaction. A main effect was observed for test in anterior/posterior tipping, suggesting the scapula was more posteriorly tipped in posttest measures.

ACKNOWLEDGEMENTS

Many thanks are due to my committee members for helping me achieve this. Ms. Shana Harrington, Dr. Darin Padua, Dr. Bill Prentice, and Ms. Terri Jo Rucinski: Thank you for your guidance, time, commitment, and patience with this project and your contribution to the Tar Heel experience! Special thanks to Dr. Chuck Thigpen for helping me to strive for what I am capable. While two quick years have come and gone since my days as a Panther, I must extend my thanks to Dr. Todd Evans at the University of Northern Iowa for inspiring me to take this path. I cannot express how grateful I am for your continued encouragement and words of wisdom.

To my classmates of 2007…we made it! I couldn't have asked for a better group of people to spend the last two years with; it's been incredibly fun and I will cherish the memories of these days and nights that have flown by! I've learned so much with and from all of you. .Will, without you I don't know that I would have made it through the waiting, and waiting, and waiting…but we did and I thank you for all or your help! I am privileged to have worked alongside you; your ambition is amazing!

Last, but most definitely not least, thank you to my family and friends for your never-ending support. To my brothers; my heroes, there's no better word. To my parents: Mom and Rob, Dad and Judy, for always being there. To Sean, for your never-ending encouragement and insight—you kept me on my feet through this year. To "the girls," for helping me to see the light at the end of the tunnel and to run towards it!

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Chapter One: Introduction

The glenohumeral joint is the most mobile joint in the body allowing the greatest range of motion at the expense of stability. In the overhead athlete, the balance between mobility and stability is challenged for optimal performance and to prevent injury to the shoulder complex.(Cavallo RJ 1998) Overhead athletic activities involve excessive external rotation while requiring a simultaneous stabilization against subluxations of the humeral head, referred to as the “thrower’s paradox.”(Wilk, Meister et al. 2002)

Overhead athletes have been shown to exhibit altered resting scapular position and altered range of motion when compared to the non-throwing limb and to non overhead athletes.(Myers JB 2005) This change is thought to be a result of chronic adaptations to the stresses placed on the shoulder during repeated overhead activity. (Myers JB 2005; Downar JM 2005) Adaptations include attenuation of the anterior-inferior capsule, loss of scapular upward rotation, increased posterior shoulder tightness possibly attributed to muscular adhesions, and alterations in rotational ranges of motion, all of which are thought to be related to common shoulder pathologies such as subacromial impingement. However, clear relationships between these factors and injury have not been clearly demonstrated. (Downar JM 2005)

Increased posterior shoulder tightness may influence resting scapular position.(Leahy DC 1991; Buchberger 1993) Inflammation due to repeated micro-traumas associated with overhead activity within soft tissue may result in fibrotic scapulothoracic adhesions that have the potential to alter muscle length and thus disrupt optimal length-tension relationships necessary to maintain proper kinematics. This kinematic compromise places the shoulder at increase risk of sustaining an injury. Scapulothoracic adhesions within the serratus anterior and subscapularis may result in weakened musculature and thus atrophy, resulting in force couple imbalances between dynamic and static stabilizers. This limited scapular rotation about the thorax may produce an anatomical block of acromial lift of the scapula.

Without adequate dynamic stabilization of the humeral head, abnormal superior displacement of the humerus into the subacromial space may lead to bony changes of the acromion.(Deutsch A 1996) Such disturbance prevents necessary scapular upward rotation and creates a mechanical block of humeral elevation. Consequent of such adaptations, these subacromial structures become irritated due to shearing forces of the humerus on the inferior side of the acromion, resulting in overuse injuries such as subacromial impingement syndrome, rotator cuff pathology, glenohumeral instability, suprascapular neuropathy, and ulnar collateral ligament sprains of the elbow.(Meister 2000; Wilk, Meister et al. 2002; Borsa PA 2003; Lewis, Wright et al. 2005)

Myofascial tightness and muscular adhesions that may contribute to the disruptions described above are frequently addressed in the clinical setting through utilization of myofascial release techniques, yet little research addresses its use in shoulder rehabilitation protocols. The evidence of the success of myofascial release techniques remain anecdotal with reports of “feeling better” or “looser” after stretching on a foam roller. (Leahy DC 1991; Buchberger 1993; Lewis, Wright et al. 2005) In theory, the use of a myofascial intervention aids to restore of proper muscle length. This restoration would ideally allow the muscles to fire in balance with each other to ensure appropriate posture and kinematics through a full range of motion without dysfunction and minimal predisposition to injury.

Statement of Problem

The purpose of this study was to observe the acute effect of a myofascial release technique (MRT) on resting scapular position in overhead athletes. The MRT consisted of the athlete using a foam roller over the pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature.

Dependent Variables

1. Resting scapular position at 0^{o} of humeral flexion and abduction
    a. Scapular Upward rotation
    b. Scapular Downward rotation
    c. Scapular Internal Rotation
    d. Scapular External Rotation
    e. Anterior tipping
    f. Posterior tipping
2. Group
    a. Fifteen subjects were randomly assigned to an experimental group where they used a foam roll to perform a MRT over the pectoralis minor, latissimus dorsi and posterior rotator cuff musculature.
    b. Fourteen subjects were randomly assigned to a control group that sat at rest for the same period of time as if they performed the MRT (six minutes). This was to control for differences observed by the

experimental group and to rule out changes in scapular position that may have been a result of stretching during range of motion measures.

Independent Variables

1. Time of testing: resting scapular position was tested prior to and following the MRT or the resting period, dependant on group assignment.

Research Questions

Is there an immediate change in resting scapular position following a myofascial release intervention on the pectoralis minor, latissimus dorsi and posterior rotator cuff musculature?

Null Hypothesis

1. Immediately following a myofascial release intervention over the pectoralis minor, latissimus dorsi, and posterior rotator cuff, there will not be significant changes observed in resting scapular position.

Research Hypothesis

1. Immediately following a myofascial release intervention over the pectoralis minor, latissimus dorsi, and posterior rotator cuff, there will be significant changes observed in resting scapular position.

Definition of Terms

1. Overhead athlete: Division I varsity or recreational club volleyball, softball, baseball and tennis athletes at the University of North Carolina at Chapel Hill that participated in overhead activity for at least 30 minutes, three times a week.

2. Myofascial release technique: self release of pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature with a foam roller.

Assumptions

a. The athlete had myofascial tightness that may contribute to altered scapular position
b. The myofascial release technique was performed properly and over the appropriate musculature.
c. Instrumentation used was reliable and valid.
d. All scapular position measurements were precise and accurate
e. The athletes stood at their normal standing posture during resting scapular measurement.

Chapter Two: Review of Literature

Introduction

This review of literature is provided to give background in basic and relevant shoulder anatomy and function, as well as the specific role of the scapula in the overhead athlete including the relationship between resting scapular position and myofascial tightness. The literature will evolve into an original research question investigating the relevance of a self myofascial release technique and its effectiveness in restoring proper muscle alignment and function of the shoulder.

Shoulder Anatomy and Biomechanics

The shoulder joint allows the greatest range of motion of any joint in the body and is demonstrated in the shoulder of the overhead athlete.(Terry and Chopp 2000) The articulations of the shoulder include the sternoclavicular, acromioclavicular, and glenohumeral joints, and a scapulothoracic articulation of the scapula on the thoracic wall. Because of a lack in bony stability at these joints, and the stresses on the shoulder during overhead motion, an extensive and balanced stabilization is required through dynamic and static forces. These include the glenoid labrum, the joint capsule, ligaments, the rotator cuff and deltoid musculature, and scapular stabilizers (Terry and Chopp 2000). It is believed that resting scapular position may be altered due to chronic adaptations such as attenuation of the anterior-inferior capsule; decreased scapular upward rotation, posterior capsule tightness, muscle adhesions; and decreased rotational ranges of motion result from repetitive stresses demanded of the overhead athlete. (Downar and Sauers 2005; Myers JB 2005)

Sternoclavicular Joint

The sternoclavicular (SC) joint is the lone articulation of the upper extremity with the axial skeleton. It is a saddle joint, consisting of the medial portion of the clavicle and the manubrium of the sternum. This is a weak joint with ligamentous support anchoring the clavicle to the medial end of the sternum. The SC joint may translate superiorly, inferiorly, anteriorly, posteriorly, and in axial rotation.(Prentice 2004)

Acromioclavicular Joint

The distal portion of the clavicle and medial edge of the acromion form the acromioclavicular (AC) joint. The AC joint is stabilized via static structures including a thin joint capsule, an intra-articular disk and several ligaments. The AC ligament prevents excessive posterior translation of the acromion and clavicle relative to each other, while the trapezoid and conoid portions of the coracoclavicular ligament prevent excessive superior/inferior movement. (Terry and Chopp 2000; Prentice 2004)

Glenohumeral Joint

The glenohumeral joint allows for the greatest amount of movement due largely in part to the incongruency between the articulating surfaces.(Terry and Chopp 2000) A ball-and-socket joint, the large head of the humerus does not contact well within the small glenoid fossa of the scapula, which contributes to laxity. Thus, the glenohumeral joint relies strongly upon the delicate balance of static and dynamic forces for proper positioning and smooth movement. (Terry and Chopp 2000)

Scapulothoracic articulation

While it is not considered a true joint due to a lack of bone on bone articulation, the scapulothoracic articulation is a critical component in shoulder movement as it allows for movement beyond the 120° of elevation allowed by the glenohumeral joint. Soft tissue structures on the anterior side of the scapula provide for smooth movement about the thorax. The scapula also serves as the attachment or origin site for seventeen muscles that provide stability and movement of the scapula and humerus including: trapezius, deltoid (3), coracobrachialis, short head of the biceps, pectoralis minor and major, supraspinatus, infraspinatus, teres major and minor, triceps, rhomboid major and minor, serratus anterior, and levator scapula. (Terry and Chopp 2000)

Dynamic Stabilization

The rotator cuff plays a large role in dynamic stabilization of the glenohumeral joint. Comprised of the subscapularis, infraspinatus, supraspinatus, and teres minor muscles, the rotator cuff acts as the primary steering joint of the glenohumeral joint. (Terry and Chopp 2000) Based on size and location, the rotator cuff provides stability during shoulder abduction in addition to rotation and depression of the humeral head.

The subscapularis muscle is the anterior portion of the rotator cuff. Originating from the subscapular fossa, it inserts into the lesser tuberosity of the humerus. Its primary functions are to internally rotate the humerus, and also serves to depress the humeral head and provide anterior stabilization .(Leahy PM 1991; Terry and Chopp 2000)

The infraspinatus originates from the infraspinous fossa on the scapula and inserts onto the medial lip of the greater tuberosity. The teres minor originates on the upper half of the lateral boarder of the scapula and inserts superiorly on the greater tuberosity. These muscles work alongside each other to externally rotate the humerus and prevent posterior subluxation of the glenohumeral joint. (Terry and Chopp 2000)

The supraspinatus originates from the supraspinous fossa on the scapula and inserts on the greater tuberosity of the humerus. Its function is to stabilize the glenohumeral joint as the tendon blends into the joint capsule and infraspinatus tendon. It also serves to abduct the arm, working along with the middle deltoid. (Terry and Chopp 2000)

While it is not part of the previously described rotator cuff, the long head of the biceps plays an important role with the rotator cuff to depress the humeral head and providing anterior stability to the glenohumeral joint.

Static Stabilization

Static stabilization is provided to the glenohumeral joint via the glenoid labrum, the joint capsule, and glenohumeral joint ligaments. These structures do not require active contraction to provide stability in contrast to the shoulder musculature. The static and dynamic stabilizers work in concert to constrain the humerus towards the center of the glenoid fossa.

The glenoid labrum is a dense fibrocartilaginous ring located at the outer portion of the glenoid fossa. Its purpose is to deepen the glenoid fossa, increasing stability of the glenohumeral joint as it increases the contact area available to the head of the humerus.

Ligaments that support the glenohumeral joint include the coracohumeral ligament and the three glenohumeral ligaments: superior, middle and inferior. The coracohumeral ligament is described as a thick band of capsular tissue originating from the coracoid and inserting into the lesser and greater tuberosities. It is taut in adduction, positioning the humeral head on the glenoid. This ligament also aids in preventing inferior translation in adduction, as well as posterior translation in forward flexion, adduction and internal rotation. (Terry and Chopp 2000) The superior glenohumeral ligament runs from the superior portion of the glenoid to the superior portion of the greater tuberosity and functions similarly to the coracohumeral ligament.

The middle glenohumeral ligament extends from the superior labrum on the glenoid to the lesser tuberosity on the humerus. It stabilizes the joint by limiting both anterior translation and inferior translation. The inferior glenohumeral ligament is the thickest of the three ligaments. It is also subdivided into an anterior band, axillary pouch, and posterior band. The anterior band extends from the anteroinferior labrum to the lesser tuberosity and primarily checks humeral anterior translation. Injury to this ligament contributes significantly to instability of the glenohumeral joint.(Terry and Chopp 2000)

Scapular Stabilization

Many muscles originate or attach onto the scapula, including the trapezius, rhomboid major and minor, levator scapulae, serratus anterior and the deltoid muscle group contribute to scapulothoracic stability. The contribution of these muscles to shoulder stability are more grossly observable than that of the glenohumeral joint   The scapulothoracic joint serves as a stable base on which the head of the humerus may move.

The trapezius is a flat triangular muscle that can be divided into three parts: upper, middle, and lower. It originates from the occiput and ligamentum nuchae, as well as from the spinous processes of C7 and T1-T12 and inserts onto the lateral acromion and spine of the scapula. Its primary function is to retract the scapula and elevate the lateral angle of the scapula in addition to serving as a stabilizer during arm flexion(Terry and Chopp 2000; Hislop HJ 2002).

The rhomboids major and minor originate from spinous processes C1-T5 and insert onto the medial border of the scapula. These muscles are responsible for scapular retraction and elevation. The levator scapulae originate on cervical transverse processes and inserts on the superior angle of the scapula. As its name implies, it elevates and rotates the scapula downward. (Terry and Chopp 2000; Hislop HJ 2002).

The serratus anterior originates from rib bodies 1 through 9, and inserts in 3 different points on the anterior scapula from the superior to inferior angles. The function of the serratus anterior is scapular protraction and upward rotation. Weakness of this muscle or damage to the thoracic nerve often presents clinically as scapular winging. The pectoralis minor originates from ribs 2-5 and inserts onto the base of the coracoid of the scapula. It is a scapular protractor, working with the serratus anterior. (Terry and Chopp 2000; Hislop HJ 2002)

The deltoid muscle can be divided into three parts: anterior, middle and posterior. The anterior portion originates from the lateral portion of the clavicle, the middle from the acromion and the posterior from the spine of the scapula. The three portions have a common insertion on the deltoid tuberosity of the humerus. Shoulder abduction is achieved through activation of the middle and anterior portions, forward flexion and internal rotation through the anterior portion, and extension and external rotation by the posterior portion of the deltoid. (Terry and Chopp 2000; Hislop HJ 2002)

Several additional muscles play an integral role in the function of the shoulder complex. The latissimus dorsi serves to adduct, extend and internally rotate the shoulder. It originates from spinous processes T6-T12 and the thoracolumbar fascia and inserts into the intertubercular groove of the humerus. The latissimus dorsi is particularly active during overhead movements (Terry and Chopp 2000; Hislop HJ 2002).

The teres major originates at the inferior angle of the dorsal scapula, and inserts into the medial lip of the intertubercular groove of the humerus. The teres major internally rotates, adducts, and extends the shoulder. (Terry and Chopp 2000; Hislop HJ 2002) The coracobrachialis originates on coracoid of the scapula and inserts on the anteromedial shaft of the humerus. It functions with the short head of the biceps to flex and adduct the shoulder. The pectoralis major originates from the medial aspect of the clavicle, the sternum, and ribs 5 and 6, and runs laterally to insert onto the lateral lip of the intertubercular groove. This muscle also adducts the shoulder and assists with internal rotation. (Terry and Chopp 2000)

Force Couples

Balance must exist between force couples and static stabilizers for the shoulder to function properly during the overhead motion. A force couple is the resultant effect of equal parallel forces acting in opposite directions(Hamilton N 2002).

The intact rotator cuff muscles compress and center the humeral head on the glenoid fossa. The supraspinatus and infraspinatus work together with the deltoid to abduct the arm, and to elevate the arm in the scapular plane. The rotator cuff muscles collectively counteract the upward pull of the deltoid during abduction, depressing the humeral head to maintain contact within the glenoid fossa. (Deutsch A 1996)

The serratus anterior and trapezius muscles form a force couple for upward rotation of the scapula. The rhomboids and middle trapezius are active in scapular stabilization during abduction.(Hamilton N 2002)

Role of the Scapula

The scapula is a flat bone, referred to as a “blade,” that lies along the posterior thoracic wall. The shape and orientation of the scapula provides a large surface area for muscular attachment. The scapula is allowed smooth movement along the thoracic wall with assistance from other soft tissue structures such as nervous tissue and bursae. Because of multiple muscular attachments on the scapula, it is capable of rotation and translation.(Kibler 1998)

In the overhead athlete, the scapula must be appropriately positioned for normal movement to occur at the shoulder. Inefficient movement at the shoulder predisposes it to injury. The scapula’s primary role is to stabilize the glenohumeral joint. It is critical that the scapula move in concert with the glenohumeral joint to position the center of rotation of the humeral head with the glenoid fossa throughout the range of motion. (Kibler 1998)

Secondly the scapula retracts and protracts along the thoracic wall. Retraction is important in the overhead athlete in facilitating glenohumeral movement during the cocking phase in the tennis serve, swimming recovery, and the baseball throw(Kibler 1998). Efficient scapular motion allows for transitioning between eccentric and concentric contractions on the anterior side, and opposite effects for the posterior musculature. During the acceleration phase of these motions, it is necessary for the scapula to protract laterally and anteriorly around the thoracic wall to maintain its position relative to the humerus(Kibler 1998).

The third role of the scapula in overhead motions is acromial elevation. The scapula must rotate to avoid compression and impingement of structures underlying the acromion. The fourth role of the scapula is to serve as a site for muscle attachment. The extrinsic muscles consisting of the deltoid, biceps, and triceps attach laterally on the scapula. The rotator cuff attaches along the entire surface of the scapula and compresses the humeral head into the glenoid fossa during glenohumeral movement. Lastly, the scapula serves as a link in the kinetic chain in transferring force from the lower extremity and trunk through the shoulder and upper extremity(Kibler 1998).

<u>The Overhead Athlete's Shoulder</u>

During repetitive overhead activity, extreme stresses are placed on the athletic shoulder. It is believed that chronic adaptations evolve that result in observable differences in resting scapular position when compared to the general population(Myers

JB 2005). These adaptations include attenuation of the anterior-inferior capsule, loss of scapular upward rotation, increased posterior shoulder tightness which may be attributed to muscular adhesions, and alterations in rotational ranges of motion, all of which contribute to common shoulder pathologies. However, clear relationships between these factors and injury have not been demonstrated. (Downar JM 2005)

Common Injuries Associated With the Overhead Athlete

Subacromial Impingement Syndrome

Subacromial impingement syndrome is due to compression of the tissues underlying the acromion. These tissues include specifically, the rotator cuff, the subacromial bursa, and the biceps tendon.(McClure PW 2004) This compression is the result of a repetitive force overload to underlying structures during abduction, flexion, and internal rotation which eventually results in inflammation, weakness and pain(Anderson MK 2000; Prentice WE 2000). This weakness and pain may also result in muscular imbalances thus placing proper scapular kinematics at risk and furthering the degree of injury. Subacromial impingement is common due to the repetitive nature of this movement seen in the overhead athlete. When muscular weaknesses of the rotator cuff lead to force couple imbalances, the result is impaired glenohumeral movement that may result in rotator cuff damage due to its failure to depress the humeral head in the glenoid fossa. (Ludewig and Cook 2002)

Common signs and symptoms of shoulder impingement include pain deep in the shoulder that may be felt at night. Overhead activity will increase the level of pain as the shoulder is placed in a position of impingement. With shoulder impingement, external rotators of the glenohumeral joint tend to be weaker than internal rotators (Prentice WE 2000). Positive signs will be elicited with provocative impingement tests and atrophy may be apparent depending on the severity and duration of symptoms (Anderson MK 2000). Management of this condition should include restoring normal biomechanics of the shoulder complex to maintain sufficient subacromial space to allow clearance of subacromial structures. Exercises should include rotator cuff and scapular stabilizer strengthening in addition to range of motion restoration(Anderson MK 2000; Prentice WE 2000). Scapular stabilizers are important in the rehabilitation process. It has been shown that individuals with impingement syndrome presented with a decrease in upward rotation and posterior tipping of the scapula, closing off the subacromial space. This decrease can be attributed to weakness of the trapezius muscles (Ludewig and Cook 2000).

Movement Impairment Syndromes

Myofascial pain syndrome (MFPS) is one of many terms used in conjunction with painful musculoskeletal conditions.(Sahrmann 2002) While origins of syndromes such as MFPS are unknown, they are thought to arise from irritation of myofascial, periarticular or articular tissues as a result of microtrauma. This microtrauma occurs from overuse, where a repetitive use or excessive load exceeds stresses that the tissue is able to withstand.(Sahrmann 2002) In addition to overuse conditions, poor posture and stress are thought to be contributors to MFPS.(Cantu RI 2001)

Myofascial pain is more specifically characterized by a taut palpable band of muscle that is tender and may elicit a twitch response and "jump response" of the individual, reflexive in response to associated tenderness. This taut band of tissue is commonly referred to as a trigger point, and may also refer pain to areas away from the taut band itself. A trigger point, however, may not elicit a jump response and in such a scenario is considered to be a “latent” trigger point, versus an “active” trigger point. However, both active and latent trigger points may result in dysfunction of tissue.(Cantu RI 2001)

Restrictions can include range of motion deficits due to shortening of muscle fibers and pain. Chronic cases can result in soft tissue and joint adhesions that may further contribute to decreased range of motion. Muscle weakness is frequently present.

Myofascial pain syndrome can often go undiagnosed. Altered biomechanics may not present until there is associated pain. The proposed alignment-impairment model, by Borstad, proposes that alignment deviations lead to structural alterations, pathomechanical alteration and thus impairment, including pain and function loss.(Borstad 2006)

Myofascial Release Intervention

The primary goal in the treatment of MFPS is restoration of normal tissue mobility. This may possibly be achieved through deactivating trigger points to allow return of function.(Cantu RI 2001) As with many conditions encountered clinically, pain management is of initial concern. While there are numerous invasive options such as dry needling, basic and less invasive techniques including manual therapy are appropriate to address pain associated with MFPS. Such manual techniques include myofascial manipulation, massage therapy, trigger point release or overpressure of the trigger point, spray and stretch techniques and muscle energy.

Conclusion

Myofascial tightness is commonly treated in the clinical setting through using a foam roll to achieve manual release. However, the success of using this technique remains highly anecdotal, as evidence based literature is lacking regarding the effectiveness of myofascial release techniques on restoring muscle length, and proper alignment and function.

This brings to question: what acute effect does a myofascial release technique intervention have on resting scapular position? This question will be addressed by measuring resting scapular position and implementing a foam roller intervention over the pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature. Measurements will be repeated following the intervention to assess whether any changes in resting scapular position may have occurred.

Chapter Three: Methods

Subjects

Subjects consisted of twenty-nine (15 male and 14 female) individuals who were participants of Division I varsity volleyball (3 female), recreational club volleyball (6 male, 4 female), recreational club softball (6 female), recreational club baseball (6 male), and recreational tennis (3 male, 1 female) teams at the University of North Carolina at Chapel Hill. Subjects were randomly divided into an intervention group (N=15, 9 male, 6 female, age= 20.5 ± 2.53yrs, height= 171.64 ± 13.11cm, weight= 72.30 ± 12.59kg) and a control group (N=14, 6 male, 8 female, age= 20.0 ± 2.27yrs, height= 173.87 ± 11.76cm, weight= 73.68 ± 12.99kg). Assignment was determined by drawing a stick from a cup with the group assignment "control" or "intervention" written on it. Subjects were included if they were not currently experiencing shoulder pain and had participated in any formal shoulder rehabilitation program during the previous six months. Prior to participation in the study, all participants signed an informed consent form approved by the University of North Carolina –Chapel Hill Medical School IRB as well as completed a short medical history questionnaire to determine that they fit the study's inclusion criteria (Appendix A). In the case that "yes" was answered to any of the questions, they subject was not eligible to participate in the study. Compensation was not awarded to the subject for his or her participation.

Instrumentation/Equipment

1. Shoulder range of motion was measured using a digital inclinometer (The Saunders Group, Inc). Measures included forward flexion, internal rotation, external rotation, abduction, horizontal adduction, and sleeper stretch (sidelying internal rotation). Procedures for positioning were followed as directed by Norkin and White (1995) for goniometric measurements. Horizontal adduction was measured using a method outlined by Laudner. Each measure was taken three times and the average was used as the final reported value.
2. Laboratory measures of resting scapular position were taken using the Flock of Birds electromagnetic tracking system (Ascension Technology Corporation, Burlington VT), and the Motion Monitor electromagnetic tracking system (Innovative Sports Training, Inc., Chicago, Illinois) to build a skeletal model of the upper extremity on the Motion Monitor. Sensors were placed on landmarks over the spinous process of C7; the angle of acromion process of the scapula bilaterally, and the posterior aspect of the distal humerus bilaterally. The Flock of Birds consists of a standard direct current transmitter containing three orthogonal coils which generates an electromagnetic field. The Motion Monitor receives the signal from the electromagnetic sensors and calculates the sensors position and is saved to a hard drive.
3. A 6” diameter dense foam construction foam roll (Power Systems, Inc.) was used to implement the myofascial release technique. Subjects in the experimental group used a foam roll on the pectoralis minor, latissimus dorsi and posterior rotator cuff musculature for duration of 2 minutes each on the dominant limb only. Subjects in

the control group sat at rest in a comfortable position, with their arms at their sides for a duration of time 6 minutes, the same amount of time it took to complete the MRT. During this time, sensors remained attached to the skin to ensure measurement accuracy.

4. Each measure using the Flock of Birds was repeated following the MRT or the rest duration.

Procedures

A convenience sample of 15 male and 14 female subjects were tested on the dependent variables of scapular upward/downward rotation, protraction/retraction, anterior/posterior tipping, elevation, depression, and pectoralis minor length using the Flock of Birds motion analysis system.

Subjects reported to the Sports Medicine Research Lab in athletic attire including a sports bra or tank top for women so that the shoulders may be appropriately exposed for accurate measurements. Testers of the same sex as the subject were present during the testing sessions. Prior to testing, each subject was educated on the study and testing procedures, and asked to sign an informed consent form. The testing consisted of a one-time session lasting approximately 75 minutes.

Glenohumeral Range of Motion Measures

Subjects underwent baseline glenohumeral (GH) range of motion measurements performed by the principal investigator (PI) using a digital inclinometer. Measures of GH flexion, internal rotation, external rotation, abduction, horizontal adduction, and sleeper stretch (sidelying internal rotation) were taken. The order of the measurements was chosen at random prior to each testing session by drawing a stick out of a cup with the specific glenohumeral measure written on it. Each measure was taken three times and the average was used as the final reported value.

Shoulder Flexion

Subjects started in standing position with his or her back against the wall to limit excessive trunk extension. The shoulder was placed in a position of 0 degrees abduction, adduction and rotation. The forearm was in neutral position, with the palm facing the side of the body. The subject was then asked to actively flex his or her shoulder until he or she cannot flex any further, or until trunk extension was initiated. The subject held this position until the digital inclinometer was placed parallel to the long axis of the posterior humerus and displayed the angle of flexion.

Internal Rotation

Subjects were positioned supine with knees flexed. The arm being tested was placed in a position of 90 degrees of shoulder abduction. The forearm was placed perpendicular to the testing table, in 0 degrees of supination and pronation, so that the palm was facing inferiorly toward the feet. The subject was passively moved into internal rotation, moving the palm towards the floor, until a firm end feel was felt or until the scapula began to move from its stabilized position on the table. The digital inclinometer was placed parallel to the long axis of the posterior forearm in line with the distal ulna and displayed the angle of internal rotation.

External Rotation

Subjects were positioned supine with knees flexed. The arm tested was placed in a position of 90 degrees of shoulder abduction. The forearm was placed in a position perpendicular to the testing table, in 0 degrees of supination and pronation, so that the palm faced inferiorly toward the feet. The digital inclinometer was placed parallel to the long axis of the forearm in line with the distal ulna, using the styloid process as a reference point. The subject was passively moved into external rotation until a firm end feel was felt or until the scapula began to move from its stabilized position on the table.

Abduction

Subjects were in standing position with the opposite shoulder and foot against a wall to prevent side bending in attempt to increase the range of motion. The shoulder was placed in a position of 0 degrees of flexion and extension, with the shoulder in external rotation so that the palm faced anteriorly. This external rotation is necessary for the head of the humerus to clear the glenoid fossa through the motion. The elbow was positioned in extension to eliminate tension from the triceps tendon and the digital inclinometer was placed parallel to the long axis of the humerus. The subject was then asked to actively abduct the shoulder until a firm end feel was felt.

Horizontal Adduction

To measure horizontal adduction, we implemented a method described by Laudner et al (2006). Subjects were placed in a supine position with his or her knees bent and both shoulders flat on the table. The subject's arm was placed in 90 degrees of abduction, 0 degrees of humeral rotation and 90 degrees of elbow flexion in the beginning position. The tester grasped the forearm just distal to the elbow with one hand while the scapula was grasped by the lateral border with the other hand, and stabilized against the table with a posteriorly directed force. The tester then passively moved the shoulder into horizontal adduction with the forearm hand while still continuing to stabilize the scapula and maintaining neutral humeral rotation. At the end of this range of motion, a second tester placed the digital goniometer on the posterior midline of the humerus. Full posterior capsule range of motion has been defined as maximal humeral horizontal adduction or the initiation of scapular motion. The angle of the humerus is considered the degrees of horizontal adduction.

Flock of Birds Motion Analysis

A Flock of Birds® (Ascension Technologies, Inc., Burlington, VT) electromagnetic motion analysis system controlled by the Motion Monitor® (Innovative Sports Training, Inc. Chicago, IL) software was used to assess scapular position at a sampling rate of 50 Hz. Electromagnetic tracking sensors were placed on bony segments using double sided tape. A global reference system was set up using X, Y, and Z axes which corresponded with the three cardinal planes of the body. The Motion Monitor system uses a stylus connected to a sensor to digitize, analyze, and visualize, the selected body segments in space. Sensors were placed on participants' thorax over the spinous process of T3, and the involved shoulder over the broad flat surface of the scapular acromion process and the posterior one third of the upper arm with the sensor over the area of least muscle mass to minimize potential sensor movement. The sensors were secured to the skin using double stick tape and pre-wrap which will be used to additionally secure the sensor over the posterior humerus (Figure 1.). In order to assess the position of the shoulder, reconstruction of the bony landmarks will be performed following the recommendations by the International Society of Biomechanics-Shoulder Group Recommendations which has been used in previous studies (International Society of Biomechanics Shoulder Group, 2002).

The following bony landmarks were digitized: the spinous processes of C12, C7, T8, the distal point of the xiphoid process, suprasternal notch, medial and lateral epicondyle, the inferior angle of the acromion, the root of the scapular spine, and the inferior angle of the scapula at the most inferior point of the scapula. The sensors remained taped onto the subject's skin during the intervention protocol to ensure accurate post-intervention measures.

Subjects stood facing forward with both arms at rest at his or her side. Three consecutive static trials were measured for duration of five seconds each in this resting position. Following the static measures, additional measures were taken at 90 degrees of abduction with a weight equal to 3% of the subject's body weight. These measures were also held for duration of 5 seconds and measured bilaterally. Lastly active movement task kinematics were recorded, consisting of the subject moving through his or her full abduction range of motion and forward flexion motion. Order of this task was the same as the order during range of motion measures with the digital inclinometer. Five repetitions of this movement task were recorded as the subject moved through the range of motion at a pace that was most comfortable for him or her.

Myofascial Release Intervention

Subjects were randomly assigned to one of two groups. The intervention group was given instruction and demonstration how to perform inhibition techniques using a foam roller addressing the pectoralis major, latissimus dorsi, and the posterior rotator cuff musculature (Figure 2, Figure 3, and Figure 4.) The techniques utilized were followed as suggested by the National Academy of Sport Medicine for integrated flexibility training protocol to improve soft tissue extensibility and correct muscle imbalances via autogenic inhibition, where this prolonged stimulus to the Golgi tendon organs results in an inhibition of the muscle spindles within the contracted agonist muscle. This inhibition technique was performed in this same order for 2 minutes over each muscle group on the dominant limb and was performed once without a rest period in between the target muscle group. Thus, the total treatment time for all muscle groups was 6 minutes. The control group remained in a relaxed, seated position for 6 minutes and were then re-measured following the same protocol as the pretest measures. This was to control for differences observed with the intervention as well as to rule out possible position changes due to a stretch of the tissues during range of motion measures.

Pectoralis minor inhibition

The subject lied on his or her stomach with the foam roller placed underneath the pectoralis region over the chest and armpit area. The subject rolled over the foam roll until an area of restriction was felt, and held that position on the foam roller for 2 minutes.

Latissimus dorsi inhibition

Following the pectoralis inhibition, the subject slightly rolled backwards so that the foam roll was under the armpit region, over the latissimus dorsi musculature. The subject will rolled over the foam roll until an area of restriction was felt and held that position on the foam roll for 2 minutes while he or she actively extended his or her humerus overhead.

Posterior rotator cuff inhibition

Following the latissimus inhibition, the subject moved down slightly toward the feet so that the foam roller was on the back of the armpit with the arm in the same starting position as the latissimus inhibition. The subject rolled over the foam roll until an area of restriction was felt and held that position on the foam roll for 2 minutes while he or she actively internally and externally rotated his or her humerus with the elbow stabilized on the floor. At the completion of the myofascial intervention, resting scapular measurements were taken immediately.

Data Processing and Reduction

Three-dimensional coordinates of the digitized bony landmarks were calculated using the Motion Monitor® software (Innovative Sports Training, Inc. Chicago, IL). Segment reference frames were defined according to the recommendations set forth by the Shoulder Group of the International Society of Biomechanics (Wu et al., 2005). Humeral motions were calculated as the Euler angles of the humerus relative to the thorax reference frame in the following order of rotations: internal-external rotation about Y axis, elevation about the Z' axis, and internal-external rotation about the Y" axis (An, Browne, Korinek, Tanaka, & Morrey, 1991). Scapular motions were calculated as the Euler angles of the scapula relative to the thorax reference frames in the following order of rotations: internal/external rotation about the Y axis, upward-downward rotation about the Z' axis, and posterior-anterior tilting about the X" axis (Karduna, McClure, & Michener, 2000; Wu et al., 2005). Kinematic data were smoothed through a Butterworth a low pass digital-filter (4^{th} order, recursive, zero phase lag) at an estimated optimum cutoff frequency of 3.5 Hz. The estimated optimum cutoff was determined after performing a spectral analysis for each kinematic variable. All humeral and scapular rotation spectral plots were similar.

Data Analysis

A 2-way repeated measure ANOVA was be used to determine significance of change in resting scapular position, if any, following the use of the foam roller. Between subjects factors include group assignment (intervention versus control), and within subjects factors include resting scapular position measures (upward/downward rotation, anterior/posterior tipping, and scapular internal/external rotation). The alpha level was be set at $p < 0.05$ a priori. All statistics were analyzed using SPSS v 13.00.

Research Question	Description	Data Source	Comparison	Method
1	Is there an acute change in resting scapular position following a myofascial release intervention?	Dependent Variables: Upward/downward rotation, protraction/retraction, anterior/posterior tilt Independent Variable: Myofascial release	Intervention group: MRT; and Control group: no intervention, repeated measures on both groups.	2x2Repeated Measures ANOVA

Chapter 4: Results

Subject Characteristics

Twenty-nine subjects were included in this study. Fourteen were randomly assigned to a control group and 15 subjects were assigned to the experimental group, where the use of a foam roll was implemented for a self myofascial release on the dominant limb pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature. Demographic data for each of these groups is presented in Table 1.

Resting Scapular Position

Upward/Downward Rotation, Anterior/Posterior Tipping, Internal/External Rotation

Means and standard deviations for resting scapular position pre-test and post-test measures are presented in Table 2. A 2-way repeated measures ANOVA statistical analysis revealed no main effect for test in scapular internal/external rotation ($F(1, 27)=1.34$, $p=.256$), or for upward/downward rotation ($F(1,27)=.879$, $p=.357$). However, there was a main effect for test in anterior/posterior tipping of the shoulder ($F(1,27)=10.839$, $p=.003$). This indicates that following the myofascial release intervention, the involved scapula was in a more posteriorly tipped position. There was no main effect observed between groups in anterior/posterior (A/P) tipping ($F(1,27)=.047$, $p=.830$), IR/ER ($F(1,27)=.478$, $p=.495$), or U/D rotation ($F(1,27)=.447$, $p=.510$). There was no test by group interaction observed for IR/ER ($F(1,27)=.293$ $p=.593$), A/P tipping ($F(1,27)=.1.56$ $p=.223$), or U/D rotation ($F(1,27)=.071$ $p=.792$).

(Table 2.) These results suggest that the myofascial release intervention did not acutely change scapular resting position.

Glenohumeral Range of Motion

Glenohumeral ranges of motion measures were not repeated following the myofascial intervention due to time constraints.

Chapter Five: Discussion

The purpose of this study was to observe the acute affects of a myofascial release intervention technique using a foam roller on resting scapular position in overheard athletes. Results of this study suggest that there was no acute affect on measures of scapular internal/external rotation, upward/downward rotation, or anterior/posterior tipping following this intervention technique. While our results do not show evidence to support the theory behind this intervention technique, this study may serve as a stepping stone towards future research to further investigate the effects of a myofascial intervention.

The Overhead Athlete

Current research has shown there are expected resting postural differences in overhead athletes in regards to scapular position when compared to either their non-dominant limb or to non-overhead athletes (Myers JB 2005). Additional studies have suggested that this altered posture may contribute to injury as a result of altered kinematics through the range of motion demanded by overhead athletes (Myers JB 2005; Downar JM 2005). Factors influencing these adaptations may include soft tissue stiffness and adhesions within soft tissue that limits appropriate range of motion within the shoulder complex (Myers JB 2005; Downar JM 2005; Leahy DC 1991; Buchberger 1993).

The scapula serves as an attachment site for several muscles that contribute to shoulder motion. Because of this, optimal muscle length is crucial for proper scapular posture that influences the fluidity of shoulder kinematics and stability at the glenohumeral joint (Kibler 1998). In individuals who presented with shoulder impingement symptoms, decreased upward rotation and decreased posterior tipping of the involved scapula were exhibited (Ludwig and Cook 2001)

We hypothesized that using the myofascial intervention would restore proper muscle length in shortened musculature of the pectoralis minor, the latissimus dorsi, and the posterior rotator cuff. In theory, if these length tension relationships were restored, a more appropriate resting position of the scapula would result thus improving glenohumeral rhythm during overhead motion. To date, no published research has been found to support or refute this technique, as this study serves as a preliminary study for future lines of research.

Clinical Significance

While a majority of our mean findings were not statistically significant, our data indicates a range of several degrees difference in the standard deviations. This suggests that for several of the subjects in the study, there were differences of a few degrees in scapular posture following the myofascial intervention. However, it should be noted that there were differences observed regardless of group assignment. The control group was given a six minute rest period to control for changes that could potentially occur in the experimental group using the foam roller. However both groups underwent several abduction and movement tasks both during the pre-intervention and control measures that may have had an influence on shoulder range of motion. There may have also been a practice effect on the movement tasks they were asked to complete both prior to and following the intervention or rest period. To date we could not find studies that support or refute this theory on the effect of a myofascial intervention protocol.

The most important finding of our study was that we did observe a main effect for test in scapular anterior/posterior tipping. This indicates that following the intervention the scapula rested in a more posterior position which suggests that the myofascial intervention was an effective intervention on scapular tipping. Based on aforementioned literature, overhead athletes often exhibit restricted posterior tipping of the scapula resulting in a block of humeral elevation. This observed increase in posterior tipping may have had an influence in post intervention glenohumeral ranges of motion, however, we did not record these post-intervention measures.

Based on our study design and collective results, at this time we cannot suggest a one-time use of a foam roller in prevention and rehabilitation protocols for the upper extremity in a healthy recreational population. Because of the sample population used in the study, these findings cannot be generalized to all prevention and rehabilitation programs, but only to healthy, recreational athletes participating in overhead sports. The following discussion elaborates on limitations of this study and how future research may warrant the continued use of a foam roller as an effective tool in prevention and rehabilitation protocols. Our preliminary findings suggest that future advanced studies may warrant the continued use of a foam roller as an effective myofascial release technique in the upper extremity.

Limitations and Considerations for Future Research

There are several factors that may have contributed to the lack of significant findings in this particular study. Because we looked only at the acute effects of using a foam roller, it may be likely that differences were not observed because of the duration of the technique. This was a one session study looking at resting scapular position immediately prior to and immediately following the intervention task or rest period. Slight changes in rotational measures were observed. However these differences may be magnified if a similar study was completed over a longer period of time to determine if there are any long-term effects of implementing a myofascial release intervention.

Related to the duration of the study, due to the use of a convenience sample, we could not certainly say that muscles were short and tight in each of the subjects tested. Thus we are not able to assume that there was room for improvement of resting scapular position in these individuals. Furthering this limitation is that glenohumeral ranges of motion were not taken following the intervention due to time constraints and because they were not of specific interest in this study, although subjects verbally stated feeling “looser” following the intervention. Because there was a main effect observed for anterior/posterior tipping, glenohumeral ranges of motion may have been influenced, thus future research should seek to include these measurements both prior to and following the intervention.

Another limitation of our study was that it was assumed that there were alterations in scapular positioning of each subject. While it is possible that kinematics could be altered due to latent trigger points, the inclusion criteria required us to disqualify individuals who had outward symptoms of shoulder pain with overhead activity. Future research projects would benefit from including both healthy subjects and individuals who have pain with overhead movement patterns so that differences, if any, may be compared and given consideration. A thorough screening for myofascial trigger points or myofascial tightness should be conducted in future research to more accurately determine whether the restrictions are in an active or latent state.

The aim of our study was to look solely at resting scapular position. Future research should look at muscle activation patterns prior to and following a myofascial intervention to determine if attempting to restore proper scapular position and proper scapular muscle length has an acute influence on the muscles involved (the pectoralis minor, the latissimus dorsi, and the posterior rotator cuff).

Conclusion

The results of this study suggest that there is no acute difference in resting scapular position following a self myofascial release intervention using a foam roller. However, there was a wide range in standard deviations regardless of scapular position (scapular internal/external rotation, upward/downward rotation, anterior/posterior tipping) and regardless of group assignment. A main effect for test was observed in anterior/posterior tipping of the scapula that suggests that a foam roller may influence resting scapular position. Future studies should focus on long term effects of an exercise protocol including the foam roller as well as glenohumeral ranges of motion, and muscle activation patterns prior to and following a self myofascial release intervention. Scapular position at functional positions through a range of motions (i.e. 90 degrees of abduction) should be considered as well.

APPENDIX A

Abstract, Manuscript, Tables, Figures

The Acute Effects of a Myofascial Release Intervention on Resting Scapular Position

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Objective: The purpose of this study was to examine the acute effect of utilizing a self myofascial release technique (MRT) intervention on resting scapular position. Resting postural and kinematic data were collected using an electromagnetic motion analysis system on thirty individuals (15 experimental, 15 control) using a pretest-posttest design. Position of the scapula was determined through measurements of scapular upward and downward rotation, scapular internal and external rotation, and scapular anterior and posterior tilt. Measures were compared dominant to non-dominant limb as well as between groups (intervention versus control). The intervention comprised of a MRT utilizing a foam roller, while the control subjects remained at rest.

Design: A pretest, posttest design was used. Subjects reported for one seventy-five minute session where resting scapular position was measured prior to and immediately following a myofascial release intervention using a foam roller. A 2-way repeated measures ANOVA was used.

Setting: Sports Medicine Research Laboratory at the University of North Carolina at Chapel Hill

Subjects: Subjects consisted of twenty-nine (15 male and 14 female) Division I varsity or recreational club volleyball, softball, baseball, and tennis teams at the University of North Carolina at Chapel Hill. Subjects were randomly divided into an intervention group (15) and a control group (14). Subjects were included if they were not currently experiencing shoulder pain and had participated in any formal shoulder rehabilitation program during the previous six months. No subject received compensation for his or her participation.

Measurements: Bilateral resting scapular position of each subject was measured prior to and immediately following a myofascial release intervention using a foam roll, or immediately following a rest period, dependent on group assignment. Laboratory measures were taken using the Flock of Birds electromagnetic tracking system (Ascension Technology Corporation, Burlington VT), and the Motion Monitor electromagnetic tracking system (Innovative Sports Training, Inc., Chicago, Illinois) to build a skeletal model of the upper extremity on the Motion Monitor.

Results: There were no significant differences found regardless of group assignment in resting scapular position immediately following the self myofascial release intervention.

Conclusions: There is not an acute difference in resting scapular position following a self myofascial release intervention using a foam roll. At this time we cannot recommend the continued use of the foam roll as a myofascial release intervention in shoulder prevention and rehabilitation protocols, although success of the use of a foam roller remains anecdotal. Future research should focus on a multiple sessions observing long term effects, and muscle activation patterns prior to and following a myofascial release intervention.

Key Words: scapula, overhead athlete, myofascial release intervention, Flock of Birds electromagnetic tracking system, Motion Monitor.

Introduction:

The glenohumeral joint is the most mobile joint in the body allowing the greatest range of motion at the expense of stability. In the overhead athlete, the balance between mobility and stability is challenged for optimal performance and to prevent injury to the shoulder complex.(Cavallo RJ 1998) Overhead athletic activities involve excessive external rotation while requiring a simultaneous stabilization against subluxations of the humeral head, referred to as the “thrower’s paradox.”(Wilk, Meister et al. 2002)

Overhead athletes have been shown to exhibit altered resting scapular position and altered range of motion when compared to the non-throwing limb and to non overhead athletes.(Myers JB 2005) This change is thought to be a result of chronic adaptations to the stresses placed on the shoulder during repeated overhead activity. (Myers JB 2005; Downar JM 2005) Adaptations include attenuation of the anterior-inferior capsule, loss of scapular upward rotation, increased posterior shoulder tightness possibly attributed to muscular adhesions, and alterations in rotational ranges of motion, all of which are thought to be related to common shoulder pathologies such as subacromial impingement. However, clear relationships between these factors and injury have not been clearly demonstrated. (Downar JM 2005)

Increased posterior shoulder tightness may influence resting scapular position.(Leahy DC 1991; Buchberger 1993) Inflammation due to repeated micro-traumas associated with overhead activity within soft tissue may result in fibrotic scapulothoracic adhesions that have the potential to alter muscle length and thus disrupt optimal length-tension relationships necessary to maintain proper kinematics. This kinematic compromise places the shoulder at increase risk of sustaining an injury. Scapulothoracic adhesions within the serratus anterior and subscapularis may result in weakened musculature and thus atrophy, resulting in force couple imbalances between dynamic and static stabilizers. This limited scapular rotation about the thorax may produce an anatomical block of acromial lift of the scapula.

Without adequate dynamic stabilization of the humeral head, abnormal superior displacement of the humerus into the subacromial space may lead to bony changes of the acromion.(Deutsch A 1996) Such disturbance prevents necessary scapular upward rotation and creates a mechanical block of humeral elevation. Consequent of such adaptations, these subacromial structures become irritated due to shearing forces of the humerus on the inferior side of the acromion, resulting in overuse injuries such as subacromial impingement syndrome, rotator cuff pathology, glenohumeral instability, suprascapular neuropathy, and ulnar collateral ligament sprains of the elbow.(Meister 2000; Wilk, Meister et al. 2002; Borsa PA 2003; Lewis, Wright et al. 2005)

Myofascial tightness and muscular adhesions that may contribute to the disruptions described above are frequently addressed in the clinical setting through utilization of myofascial release techniques, yet little research addresses its use in shoulder rehabilitation protocols. The evidence of the success of myofascial release techniques remain anecdotal with reports of “feeling better” or “looser” after stretching on a foam roller. (Leahy DC 1991; Buchberger 1993; Lewis, Wright et al. 2005) In theory, the use of a myofascial intervention aids to restore of proper muscle length. This restoration would ideally allow the muscles to fire in balance with each other to ensure appropriate posture and kinematics through a full range of motion without dysfunction and minimal predisposition to injury.

Statement of Problem

The purpose of this study was to observe the acute effect of a myofascial release technique (MRT) on resting scapular position in overhead athletes. The MRT consisted of the athlete using a foam roller over the pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature.

Methods:

Subjects

Subjects consisted of twenty-nine (15 male and 14 female) individuals who were participants of Division I varsity volleyball (3 female), recreational club volleyball (6 male, 4 female), recreational club softball (6 female), recreational club baseball (6 male), and recreational tennis (3 male, 1 female) teams at the University of North Carolina at Chapel Hill. Subjects were randomly divided into an intervention group (N=15, 9 male, 6 female, age= 20.5 ± 2.53yrs, height= 171.64 ± 13.11cm, weight= 72.30 ± 12.59kg) and a control group (N=14,6 male, 8 female, age= 20.0 ± 2.27yrs, height= 173.87 ± 11.76cm, weight= 73.68 ± 12.99kg). Assignment was determined by drawing a stick from a cup with the group assignment "control" or "intervention" written on it. Subjects were included if they were not currently experiencing shoulder pain and had participated in any formal shoulder rehabilitation program during the previous six months. Prior to participation in the study, all participants signed an informed consent form approved by the University of North Carolina –Chapel Hill Medical School IRB as well as completed a short medical history questionnaire to determine that they fit the study's inclusion criteria (Appendix A). In the case that "yes" was answered to any of the questions, they subject was not eligible to participate in the study. Compensation was not awarded to the subject for his or her participation.

Instrumentation/Equipment

Shoulder range of motion was measured using a digital inclinometer (The Saunders Group, Inc). Measures included forward flexion, internal rotation, external rotation, abduction, horizontal adduction, and sleeper stretch (sidelying internal rotation). Procedures for positioning were followed as directed by Norkin and White (1995) for goniometric measurements. Horizontal adduction was measured using a method outlined by Laudner. Each measure was taken three times and the average was used as the final reported value.

Laboratory measures of resting scapular position were taken using the Flock of Birds electromagnetic tracking system (Ascension Technology Corporation, Burlington VT), and the Motion Monitor electromagnetic tracking system (Innovative Sports Training, Inc., Chicago, Illinois) to build a skeletal model of the upper extremity on the Motion Monitor. Sensors were placed on landmarks over the spinous process of C7; the angle of acromion process of the scapula bilaterally, and the posterior aspect of the distal humerus bilaterally. The Flock of Birds consists of a standard direct current transmitter containing three orthogonal coils which generates an electromagnetic field. The Motion Monitor receives the signal from the electromagnetic sensors and calculates the sensors position and is saved to a hard drive.

A 6” diameter dense foam construction foam roll (Power Systems, Inc.) was used to implement the myofascial release technique. Subjects in the experimental group used a foam roll on the pectoralis minor, latissimus dorsi and posterior rotator cuff musculature for duration of 2 minutes each on the dominant limb only. Subjects in the control group sat at rest in a comfortable position, with their arms at their sides for a duration of time 6 minutes, the same amount of time it took to complete the MRT. During this time, sensors remained attached to the skin to ensure measurement accuracy.

Each measure using the Flock of Birds was repeated following the MRT or the rest duration.

Procedures

A convenience sample of 15 male and 14 female subjects were tested on the dependent variables of scapular upward/downward rotation, protraction/retraction, anterior/posterior tipping, elevation, depression, and pectoralis minor length using the Flock of Birds motion analysis system.

Subjects reported to the Sports Medicine Research Lab in athletic attire including a sports bra or tank top for women so that the shoulders may be appropriately exposed for accurate measurements. Testers of the same sex as the subject were present during the testing sessions. Prior to testing, each subject was educated on the study and testing procedures, and asked to sign an informed consent form. The testing consisted of a one-time session lasting approximately 75 minutes.

Glenohumeral Range of Motion Measures

Subjects underwent baseline glenohumeral (GH) range of motion measurements performed by the principal investigator (PI) using a digital inclinometer. Measures of GH flexion, internal rotation, external rotation, abduction, horizontal adduction, and sleeper stretch (sidelying internal rotation) were taken. The order of the measurements was chosen at random prior to each testing session by drawing a stick out of a cup with the specific glenohumeral measure written on it. Each measure was taken three times and the average was used as the final reported value.

Shoulder Flexion

Subjects started in standing position with his or her back against the wall to limit excessive trunk extension. The shoulder was placed in a position of 0 degrees abduction, adduction and rotation. The forearm was in neutral position, with the palm facing the side of the body. The subject was then asked to actively flex his or her shoulder until he or she cannot flex any further, or until trunk extension was initiated. The subject held this position until the digital inclinometer was placed parallel to the long axis of the posterior humerus and displayed the angle of flexion.

Internal Rotation

Subjects were positioned supine with knees flexed. The arm being tested was placed in a position of 90 degrees of shoulder abduction. The forearm was placed perpendicular to the testing table, in 0 degrees of supination and pronation, so that the palm was facing inferiorly toward the feet. The subject was passively moved into internal rotation, moving the palm towards the floor, until a firm end feel was felt or until the scapula began to move from its stabilized position on the table. The digital inclinometer was placed parallel to the long axis of the posterior forearm in line with the distal ulna and displayed the angle of internal rotation.

External Rotation

Subjects were positioned supine with knees flexed. The arm tested was placed in a position of 90 degrees of shoulder abduction. The forearm was placed in a position perpendicular to the testing table, in 0 degrees of supination and pronation, so that the palm faced inferiorly toward the feet. The digital inclinometer was placed parallel to the long axis of the forearm in line with the distal ulna, using the styloid process as a reference point. The subject was passively moved into external rotation until a firm end feel was felt or until the scapula began to move from its stabilized position on the table.

Abduction

Subjects were in standing position with the opposite shoulder and foot against a wall to prevent side bending in attempt to increase the range of motion. The shoulder was placed in a position of 0 degrees of flexion and extension, with the shoulder in external rotation so that the palm faced anteriorly. This external rotation is necessary for the head of the humerus to clear the glenoid fossa through the motion. The elbow was positioned in extension to eliminate tension from the triceps tendon and the digital inclinometer was placed parallel to the long axis of the humerus. The subject was then asked to actively abduct the shoulder until a firm end feel was felt.

Horizontal Adduction

To measure horizontal adduction, we implemented a method described by Laudner et al (2006). Subjects were placed in a supine position with his or her knees bent and both shoulders flat on the table. The subject's arm was placed in 90 degrees of abduction, 0 degrees of humeral rotation and 90 degrees of elbow flexion in the beginning position. The tester grasped the forearm just distal to the elbow with one hand while the scapula was grasped by the lateral border with the other hand, and stabilized against the table with a posteriorly directed force. The tester then passively moved the shoulder into horizontal adduction with the forearm hand while still continuing to stabilize the scapula and maintaining neutral humeral rotation. At the end of this range of motion, a second tester placed the digital goniometer on the posterior midline of the humerus. Full posterior capsule range of motion has been defined as maximal humeral horizontal adduction or the initiation of scapular motion. The angle of the humerus is considered the degrees of horizontal adduction.

Flock of Birds Motion Analysis

A Flock of Birds® (Ascension Technologies, Inc., Burlington, VT) electromagnetic motion analysis system controlled by the Motion Monitor® (Innovative Sports Training, Inc. Chicago, IL) software was used to assess scapular position at a sampling rate of 50 Hz. Electromagnetic tracking sensors were placed on bony segments using double sided tape. A global reference system was set up using X, Y, and Z axes which corresponded with the three cardinal planes of the body. The Motion Monitor system uses a stylus connected to a sensor to digitize, analyze, and visualize, the selected body segments in space. Sensors were placed on participants' thorax over the spinous process of T3, and the involved shoulder over the broad flat surface of the scapular acromion process, and the posterior one third of the upper arm with the sensor over the area of least muscle mass to minimize potential sensor movement. The sensors were secured to the skin using double stick tape and pre-wrap which will be used to additionally secure the sensor over the posterior humerus (Figure 1.). In order to assess the position of the shoulder, reconstruction of the bony landmarks will be performed following the recommendations by the International Society of Biomechanics-Shoulder Group Recommendations which has been used in previous studies (International Society of Biomechanics Shoulder Group, 2002).

The following bony landmarks were digitized: the spinous processes of C12, C7, T8, the distal point of the xiphoid process, suprasternal notch, medial and lateral epicondyle, the inferior angle of the acromion, the root of the scapular spine, and the inferior angle of the scapula at the most inferior point of the scapula. The sensors remained taped onto the subject's skin during the intervention protocol to ensure accurate post-intervention measures.

Subjects stood facing forward with both arms at rest at his or her side. Three consecutive static trials were measured for a duration of five seconds each in this resting position. Following the static measures, additional measures were taken at 90 degrees of abduction with a weight equal to 3% of the subject's body weight. These measures were also held for a duration of 5 seconds and measured bilaterally. Lastly active movement task kinematics were recorded, consisting of the subject moving through his or her full abduction range of motion and forward flexion motion. Order of this task was the same as the order during range of motion measures with the digital inclinometer. Five repetitions of this movement task were recorded as the subject moved through the range of motion at a pace that was most comfortable for him or her.

Myofascial Release Intervention

Subjects were randomly assigned to one of two groups. The intervention group was given instruction and demonstration how to perform inhibition techniques using a foam roller addressing the pectoralis major, latissimus dorsi, and the posterior rotator cuff musculature (Figure 2., Figure 3., Figure 4.) The techniques utilized were followed as suggested by the National Academy of Sport Medicine for integrated flexibility training protocol to improve soft tissue extensibility and correct muscle imbalances via autogenic inhibition, where this prolonged stimulus to the Golgi tendon organs results in an inhibition of the muscle spindles within the contracted agonist muscle. This inhibition technique was performed in this same order for 2 minutes over each muscle group on the dominant limb and was performed once without a rest period in between the target muscle group. Thus, the total treatment time for all muscle groups was 6 minutes. The control group remained in a relaxed, seated position for 6 minutes and were then re-measured following the same protocol as the pretest measures. This was to control for differences observed with the intervention as well as to rule out possible position changes due to a stretch of the tissues during range of motion measures.

Pectoralis minor inhibition

The subject lied on his or her stomach with the foam roller placed underneath the pectoralis region over the chest and armpit area. The subject rolled over the foam roll until an area of restriction was felt, and held that position on the foam roller for 2 minutes.

Latissimus dorsi inhibition

Following the pectoralis inhibition, the subject slightly rolled backwards so that the foam roll was under the armpit region, over the latissimus dorsi musculature. The subject will rolled over the foam roll until an area of restriction was felt and held that position on the foam roll for 2 minutes while he or she actively extended his or her humerus overhead.

Posterior rotator cuff inhibition

Following the latissimus inhibition, the subject moved down slightly toward the feet so that the foam roller was on the back of the armpit with the arm in the same starting position as the latissimus inhibition. The subject rolled over the foam roll until an area of restriction was felt and held that position on the foam roll for 2 minutes while he or she actively internally and externally rotated his or her humerus with the elbow stabilized on the floor. At the completion of the myofascial intervention, resting scapular measurements were taken immediately.

Data Processing and Reduction:

Three-dimensional coordinates of the digitized bony landmarks were calculated using the Motion Monitor® software (Innovative Sports Training, Inc. Chicago, IL). Segment reference frames were defined according to the recommendations set forth by the Shoulder Group of the International Society of Biomechanics (Wu et al., 2005). Humeral motions were calculated as the Euler angles of the humerus relative to the thorax reference frame in the following order of rotations: internal-external rotation about Y axis, elevation about the Z' axis, and internal-external rotation about the Y" axis (An, Browne, Korinek, Tanaka, & Morrey, 1991). Scapular motions were calculated as the Euler angles of the scapula relative to the thorax reference frames in the following order of rotations: internal/external rotation about the Y axis, upward-downward rotation about the Z' axis, and posterior-anterior tilting about the X" axis (Karduna, McClure, &

Michener, 2000; Wu et al., 2005). Kinematic data were smoothed through a Butterworth a low pass digital-filter (4_{th} order, recursive, zero phase lag) at an estimated optimum cutoff frequency of 3.5 Hz. The estimated optimum cutoff was determined after performing a spectral analysis for each kinematic variable. All humeral and scapular rotation spectral plots were similar.

Data Analysis:

A 2-way repeated measure ANOVA was be used to determine significance of change in resting scapular position, if any, following the use of the foam roller. Between subjects factors include group assignment (intervention versus control), and within subjects factors include resting scapular position measures (upward/downward rotation, anterior/posterior tipping, and scapular internal/external rotation). The alpha level was be set at $p < 0.05$ a priori. All statistics were analyzed using SPSS v 13.00.

Results:

Subject Characteristics

Twenty-nine subjects were included in this study. Fourteen were randomly assigned to a control group and 15 subjects were randomly assigned to the experimental group, where the use of a foam roll was implemented for a self myofascial release on the dominant limb pectoralis minor, latissimus dorsi, and posterior rotator cuff musculature. Demographic data for each of these groups is presented in Table 1.

Resting Scapular Position

Upward/Downward Rotation, Anterior/Posterior Tipping, Internal/External Rotation

Means and standard deviations for resting scapular position pre-test and post-test measures are presented in Table 2. A 2-way repeated measures ANOVA statistical analysis revealed no main effect for test in scapular internal/external rotation ($F(1, 27)=1.34$, $p=.256$), or for upward/downward rotation ($F(1,27)=.879$, $p=.357$). However, there was a main effect for test in anterior/posterior tipping of the shoulder ($F(1,27)=10.839$, $p=.003$). This indicates that following the myofascial release intervention, the involved scapula was in a more posteriorly tipped position. There was no main effect observed between groups in anterior/posterior (A/P) tipping ($F(1,27)=.047$, $p=.830$), IR/ER ($F(1,27)=.478$, $p=.495$), or U/D rotation ($F(1,27)=.447$, $p=.510$). There was no test by group interaction observed for IR/ER ($F(1,27)=.293$ $p=.593$), A/P tipping ($F(1,27)=.1.56$ $p=.223$), or U/D rotation ($F(1,27)=.071$ $p=.792$). (Table 2.) These results suggest that the myofascial release intervention did not acutely change scapular resting position.

Glenohumeral Range of Motion

Glenohumeral ranges of motion measures were not repeated following the myofascial intervention due to time constraints.

Discussion:

The purpose of this study was to observe the acute affects of a myofascial release intervention technique using a foam roller on resting scapular position in overheard athletes. Results of this study suggest that there was no acute affect on measures of scapular internal/external rotation, upward/downward rotation, or anterior/posterior tipping following this intervention technique. While our results do not show evidence to support the theory behind this intervention technique, this study may serve as a stepping stone towards future research to further investigate the effects of a myofascial intervention.

The Overhead Athlete

Current research has shown there are expected resting postural differences in overhead athletes in regards to scapular position when compared to either their non-dominant limb or to non-overhead athletes (Myers JB 2005). Additional studies have suggested that this altered posture may contribute to injury as a result of altered kinematics through the range of motion demanded by overhead athletes (Myers JB 2005; Downar JM 2005). Factors influencing these adaptations may include soft tissue stiffness and adhesions within soft tissue that limits appropriate range of motion within the shoulder complex (Myers JB 2005; Downar JM 2005; Leahy DC 1991; Buchberger 1993).

The scapula serves as an attachment site for several muscles that contribute to shoulder motion. Because of this, optimal muscle length is crucial for proper scapular posture that influences the fluidity of shoulder kinematics and stability at the glenohumeral joint (Kibler 1998). In individuals who presented with shoulder impingement symptoms, decreased upward rotation and decreased posterior tipping of the involved scapula were exhibited (Ludwig and Cook 2001)

It was hypothesized that using the myofascial intervention would restore proper muscle length in shortened musculature of the pectoralis minor, the latissimus dorsi, and the posterior rotator cuff. In theory, if these length tension relationships were restored, a more appropriate resting position of the scapula would result thus improving glenohumeral rhythm during overhead motion. To date, no published research has been found to support or refute this technique, as this study serves as a preliminary study for future lines of research.

Clinical Significance:

While a majority of our mean findings were not statistically significant, our data indicates a range of several degrees difference in the standard deviations. This suggests that for several of the subjects in the study, there were differences of a few degrees in scapular posture following the myofascial intervention. However, it should be noted that there were differences observed regardless of group assignment. The control group was given a six minute rest period to control for changes that could potentially occur in the experimental group using the foam roller. However both groups underwent several abduction and movement tasks both during the pre-intervention and control measures that may have had an influence on shoulder range of motion. There may have also been a practice effect on the movement tasks they were asked to complete both prior to and following the intervention or rest period. To date there are no studies that support or refute this theory on the effect of a myofascial intervention protocol.

The most important finding of this study was that there was a main effect for test in scapular anterior/posterior tipping. This indicates that following the intervention the scapula rested in a more posterior position which suggests that the myofascial intervention was an effective intervention on scapular tipping. Based on aforementioned literature, overhead athletes often exhibit restricted posterior tipping of the scapula resulting in a block of humeral elevation. This observed increase in posterior tipping may have had an influence in post intervention glenohumeral ranges of motion, however, we did not record these post-intervention measures.

Based on this study design and collective results, a one-time use of a foam roller in prevention and rehabilitation protocols for the upper extremity in a healthy recreational population is not suggested. Because of the sample population used in the study, these findings should not be generalized to all prevention and rehabilitation programs, but only to healthy, recreational athletes participating in overhead sports. The following discussion elaborates on limitations of this study and how future research may warrant the continued use of a foam roller as an effective tool in prevention and rehabilitation protocols. The preliminary findings suggest that future advanced studies may warrant the continued use of a foam roller as an effective myofascial release technique in the upper extremity.

Limitations and Considerations for Future Research:

There are several factors that may have contributed to the lack of significant findings in this particular study. Because only the acute effects of using a foam roller were observed, it may be likely that differences were not evident because of the duration of the technique. This was a one session study looking at resting scapular position immediately prior to and immediately following the intervention task or rest period. Slight changes in scapular rotational measures were observed. However these differences may be magnified if a similar study was completed over a longer period of time to determine if there are any long-term effects of implementing a myofascial release intervention.

Related to the duration of the study, due to the use of a convenience sample, it is not certain that muscles were short and tight in each of the subjects tested. Thus it could not be assumed that there was room for improvement of resting scapular position in these individuals. Furthering this limitation is that glenohumeral ranges of motion were not taken following the intervention due to time constraints and because they were not of specific interest in this study, although subjects verbally stated feeling “looser” following the intervention. Because there was a main effect observed for anterior/posterior tipping, glenohumeral ranges of motion may have been influenced, thus future research should seek to include these measurements both prior to and following the intervention.

Another limitation of this study was that it assumed there were alterations in scapular positioning of each subject. While it is possible that kinematics could be altered due to latent trigger points, the inclusion criteria required to disqualify individuals who had outward symptoms of shoulder pain with overhead activity. Future research projects would benefit from including both healthy subjects and individuals who have pain with overhead movement patterns so that differences, if any, may be compared and given consideration. A thorough screening for myofascial trigger points or myofascial tightness should be conducted in future research to more accurately determine whether the restrictions are in an active or latent state.

The aim of this study was to look solely at resting scapular position. Future research should look at muscle activation patterns prior to and following a myofascial intervention to determine if attempting to restore proper scapular position and proper scapular muscle length has an acute influence on the muscles involved (the pectoralis minor, the latissimus dorsi, and the posterior rotator cuff).

Conclusion:

The results of this study suggest that there is no acute difference in resting scapular position following a self myofascial release intervention using a foam roller. However, there was a wide range in standard deviations regardless of scapular position (scapular internal/external rotation, upward/downward rotation, anterior/posterior tipping) and regardless of group assignment. A main effect for test was observed in anterior/posterior tipping of the scapula that suggests that a foam roller may influence resting scapular position. Future studies should focus on long term effects of an exercise protocol including the foam roller as well as glenohumeral ranges of motion, and muscle activation patterns prior to and following a self myofascial release intervention. Scapular position at functional positions through a range of motions (i.e. 90 degrees of abduction) should be considered as well.

Table 1: Demographic Data

Table 1: Demographic Data						
Group	**Age (Years)**		**Height (cm)**		**Weight (kg)**	
Control (n=15)	Mean	SD	Mean	SD	Mean	SD
	20.85	± 2.53	171.64	± 13.11	72.30	± 12.59
Intervention (n=14)	20.00	± 2.27	173.87	± 11.76	73.68	± 12.99

Table 2: Scapular Position (degrees) means (± SD), F, and p-values

Table 2: Scapular Position (degrees) means (± SD), F, and p-values

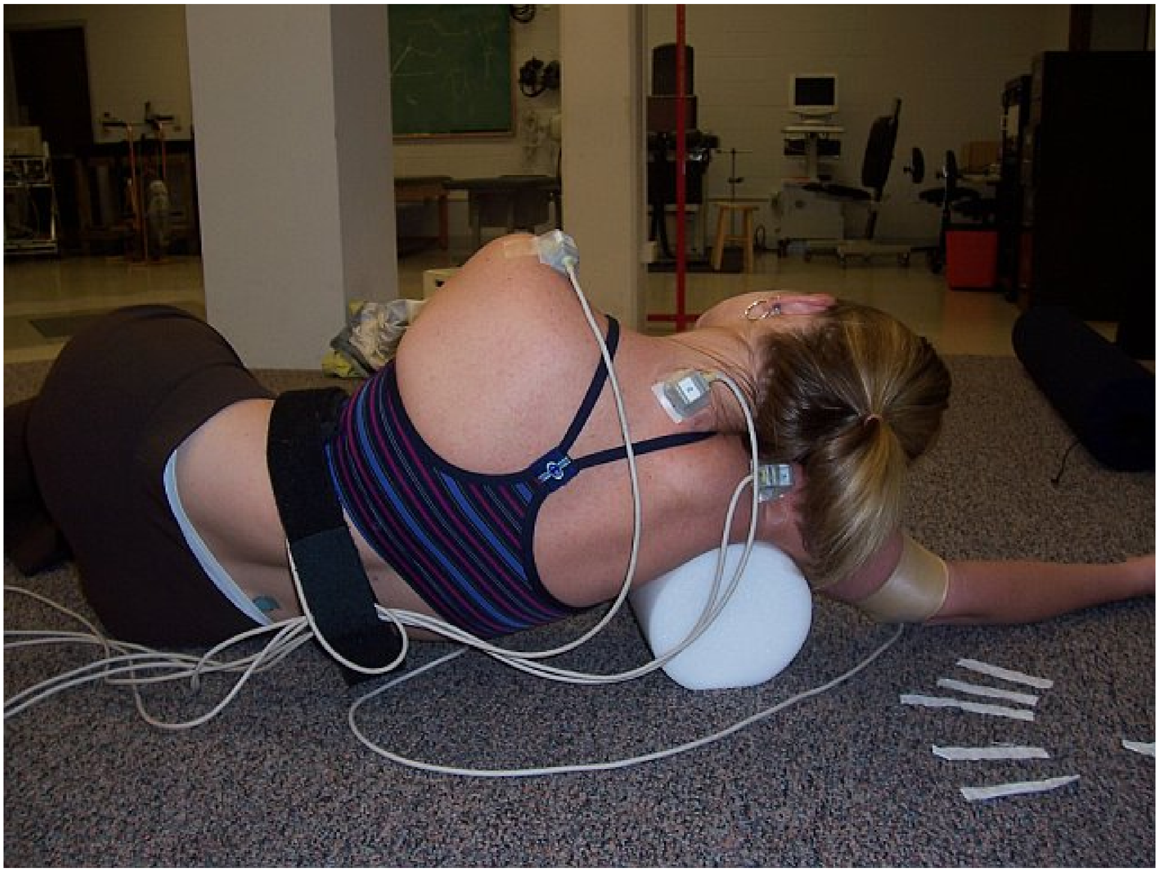
Scapular Position	**Group**	**Pretest**		**Posttest**		**Group Main Effect**	**Test Main Effect**	**Group x Test Interaction**
		Mean	**SD**	**Mean**	**SD**			
Internal/External Rotation	Control	-30.14	± 9.52	-30.03	± 9.10	[F(1,27)= 1.34, p=.256]	[F(1,27)= .478, p=.495]	[F(1,27)=.29, p=.593)
(-) denotes ER	Exp	-25.31	± 13.90	-27.64	± 15.02			
Upward/Downward Rotation	Control	13.63	± 8.34	13.32	± 7.68	[F(1,27)= .879, p=.357]	[F(1,27)= .447, p=.510]	[F(1,27)=.07, p=.792]
(-) denotes DR	Exp	11.11	± 8.61	10.39	± 7.72			
Anterior/Posterior Tipping	Control	-11.61	± 8.53	-12.78	± 9.40	[F(1,27)= .047, p=.830]	[F(1,27)= 10.839, p=.003]	[F(1,27)=1.5, p=.223]
(-) denotes PT	Exp	-11.63	± 9.52	-14.28	± 10.49			

Figure 1. Flock Set Up

Figure 2. Pectoralis Inhibition

Figure 3. Latissimus Inhibition

Figure 4. Posterior Cuff Inhibition



APPENDIX B

IRB Materials

University of North Carolina-Chapel Hill
Consent to Participate in a Research Study
Adult Subjects Biomedical Form

IRB Study #____________________
Consent Form Version Date: ______________
Title of Study: Comparison of Scapula Resting Position Using Different Assessment Instruments Before and After a Myofascial Release Intervention

Principal Investigator: Michelle M. McLeod, BA, ATC, LAT ; M. Will Rondeau LAT, ATC, CSCS
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Funding Source:

Study Contact telephone number: 919-962-2067
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What are some general things you should know about research studies?
You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

Research studies are designed to obtain new knowledge that may help other people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Deciding not to be in the study or leaving the study before it is done will not affect your relationship with the researcher, your health care provider, or the University of North Carolina-Chapel Hill. If you are a patient with an illness, you do not have to be in the research study in order to receive health care.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?
Position of the shoulder blade is believed to be an important factor that influences the risk of shoulder injury in people who regularly perform overhead activities (e.g. overhead

throwing, swinging a tennis racquet, striking a volleyball, etc…). Thus, it is important to establish valid and reliable measures of shoulder blade position that can be easily performed in a clinical setting. It is also important to identify effective treatments for changing shoulder blade position since individuals suffering from shoulder pain have been shown to display altered shoulder blade positioning when compared to healthy individuals. Therefore, the purpose of this study is to determine the reliability and validity of a novel clinical instrument (Palpation Meter device) to measure resting position of the shoulder blade in people who regularly perform overhead activities. We also will examine the effects of a myofascial release on resting shoulder blade position.

You are being asked to be in the study because you actively participate in repetitive overhead activities (throwing and striking) at least 3 times per week for a minimum of 45 minutes each session. It is believed that individuals participating in repetitive overhead activities are at greatest risk for exhibiting altered shoulder blade position and shoulder tightness which could possibly result in shoulder injury.

Are there any reasons you should not be in this study?

You should not be in this study if you currently experience shoulder pain, have undergone formal shoulder rehabilitation in the previous six (6) months, or are currently following a rehabilitation protocol that includes a myofascial release intervention (laying on a piece of foam or a small ball over areas of muscle tightness and tenderness) in the upper extremity.

How many people will take part in this study?

If you decide to be in this study, you will be one of approximately 30 people in this research study.

How long will your part in this study last?

If you participate in this study, you will spend approximately 90 minutes during one testing session. There is not a follow up session required.

What will happen if you take part in the study?

During the course of this study, the following will occur:
You will complete a short medical history questionnaire to determine if you have existing shoulder pain, have undergone formal rehabilitation in the previous six (6) months, or currently participate in a rehabilitation program that incorporates a myofascial release intervention. In the case that you answer "yes" to these questions, you will not be eligible to participate in this study. The purpose of the study and all procedures will be explained. Then you will have the opportunity to ask any questions. You may choose to not participate in the study at any time.

You will be randomly assigned into an intervention or a control group by drawing a stick from a cup with "intervention" or "control" showing your assignment. You will undergo baseline shoulder range of motion measurements performed by the principle investigator (PI) using a digital inclinometer. Measures of shoulder flexion, internal rotation, external rotation, abduction and posterior capsule tightness will be taken. Your shoulder blade position will be measured using the Palpation Meter and an electromagnetic motion analysis system. The Palpation Meter device is a clinical instrument that combines calipers and an inclinometer into one tool, and may be suitable for assessing shoulder blade position.

During the assessment of shoulder blade position, you will be asked to stand with your arms by your side, and points on your back, shoulder blade, and arm will be identified using a felt tip marker to assist in the measuring of shoulder blade position. Sensors from the electromagnetic motion analysis system will be attached at the base of your neck, the tip of your shoulder, and the end of your arm. Shoulder blade position will be measured with the Palpation Meter and electromagnetic motion analysis system of your dominant arm (arm used to throw or strike an object) and non-dominant arm (non-throwing or non-striking arm) in three different arm positions while holding a dumbbell in your hand that weighs 3% of your total body weight. The three different arm positions include: 1) arms by your side, 2) arms raised to 90-degrees away from the side of your body, and 3) arms raised to 90-degrees in front of your body. You will be asked to hold each arm position for approximately 5-seconds while your shoulder blade position is measured.

If you are assigned to the intervention group, you will be instructed on how to perform the self myofascial release intervention using a foam roller over the shoulder musculature. A myofascial release treatment using a foam roll involves the individual using a large, firm roll of foam placed underneath the area where tightness or trigger points are felt. The individual then places the body part that is tight on top of the roller and rolls over and around the area, and may maintain a steady position where the majority of the discomfort is felt. This exercise is typically performed for one to two minutes over a single area. Prior to performing the intervention, you will watch a video showing proper technique, and will also receive verbal cues from the tester during each intervention. Each intervention technique will last for approximately two (2) minutes for a total of approximately six (6) minutes. Immediately following the final intervention, you will be re-measured for shoulder flexion, internal and external rotation, abduction and posterior capsule tightness with the digital inclinometer,
as well as resting shoulder blade position using the Palpation Meter and electromagnetic motion analysis system.

If you are assigned to the control group, you will rest comfortably in a sitting position approximately 6 minutes and be re-measured for shoulder flexion, internal and external rotation, abduction and posterior capsule tightness with the digital inclinometer as well as resting shoulder blade position using the Palpation Meter and electromagnetic motion analysis system. This is to control for the intervention and possible gains in range of motion resulting from initial measurement.

During testing, male subjects will be required to take off their shirt; and female subjects will be in a tank top and wearing a sport bra. This is to allow exposure of your shoulder blade and arm for strength testing and sensor/ electrode placement. An individual who is the same sex as the participant will be present at all times during testing.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. Results from this study may potentially show the effectiveness of a commonly used rehabilitation tool in the clinical setting. This will allow the clinical population to more appropriately prevent and treat injuries encountered on a day to day basis. The benefits to you from being in this study include measurement of your shoulder blade position to determine if it is altered, and the possible relief of tightness and restored function of your dominant arm.

What are the possible risks or discomforts involved with being in this study?
If you are assigned to the intervention group, there is risk for common discomfort that may be experience during and following the intervention task. The discomfort typically subsides shortly following the completion of the intervention task. In addition, there may be uncommon or previously unknown risks that might occur. You should report any problems to the researchers.

What if we learn about new findings or information during the study?
You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

How will your privacy be protected?
No subjects will be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

A copy of this consent form will go in to your medical record. This will allow the doctors caring for you to know what study medications or tests you may be receiving as a part of the study and know how to take care of you if you have other health problems or needs during the study.

What will happen if you are injured by this research?
All research involves a risk of injury. This may include the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury from being in this study. If such problems occur, the researchers will help you seek medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

What if you want to stop before your part in the study is complete?
You can withdraw from this study at any time, without penalty. The investigators also have the right to stop your participation at any time. This could be because you have had

an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

Will you receive anything for being in this study?
You will not receive anything for taking part in this study.

Will it cost you anything to be in this study?
No cost will be required of the participants of this study.

What if you are a UNC student?
You may choose not to be in the study or to stop being in the study before it is over or at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research. You may choose not to participate or withdrawal from the study at any time or for any reason without jeopardizing your relationship with your coach, athletic trainer, or physician and without being penalized in any way. There will be no benefit or consequence to your standing on your athletic team in any way.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form.

What if you have questions about your rights as a research subject?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

- -

Subject's Agreement:

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

____________________________________ __________________
Signature of Research Subject Date

____
Printed Name of Research Subject

____________________________________ __________________
Signature of Person Obtaining Consent Date

Printed Name of Person Obtaining Consent

APPENDIX C

Subject Information Form

Subject Information Form

Subject Number: ________

Circle One: Right handed Left handed (Which hand do you throw with?)

Age: _______ Height: ________ Weight: _________
Sport: ______________

Experience:

Last time competed in an overhead sport: ______________ (Month/Year)

Medical History:

Are you currently being treated for any shoulder problems? Yes No

Do you currently have any pain when you lift your arm overhead? Yes No

Have you been to rehabilitation for your shoulder injury in the past 6 months?

Yes No

APPENDIX D

Statistical Analyses

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

test	Dependent Variable
1	d_pre_irer
2	d_post_irer

Between-Subjects Factors

		N
group	1	14
	2	15

Descriptive Statistics

	group	Mean	Std. Deviation	N
d_pre_irer	1	-30.1399	9.520113193	14
	2	-25.3111	13.903005825	15
	Total	-27.6422	12.031477544	29
d_post_irer	1	-30.0320	9.09916944	14
	2	-24.4276	15.01751960	15
	Total	-27.1332	12.62246371	29

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Pillai's Trace	.017	.478[b]	1.000	27.000	.495	.017	.478	.102
	Wilks' Lambda	.983	.478[b]	1.000	27.000	.495	.017	.478	.102
	Hotelling's Trace	.018	.478[b]	1.000	27.000	.495	.017	.478	.102
	Roy's Largest Root	.018	.478[b]	1.000	27.000	.495	.017	.478	.102
test * group	Pillai's Trace	.011	.293[b]	1.000	27.000	.593	.011	.293	.082
	Wilks' Lambda	.989	.293[b]	1.000	27.000	.593	.011	.293	.082
	Hotelling's Trace	.011	.293[b]	1.000	27.000	.593	.011	.293	.082
	Roy's Largest Root	.011	.293[b]	1.000	27.000	.593	.011	.293	.082

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+group
Within Subjects Design: test

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: test

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Sphericity Assumed	3.558	1	3.558	.478	.495	.017	.478	.102
	Greenhouse-Geisser	3.558	1.000	3.558	.478	.495	.017	.478	.102
	Huynh-Feldt	3.558	1.000	3.558	.478	.495	.017	.478	.102
	Lower-bound	3.558	1.000	3.558	.478	.495	.017	.478	.102
test * group	Sphericity Assumed	2.178	1	2.178	.293	.593	.011	.293	.082
	Greenhouse-Geisser	2.178	1.000	2.178	.293	.593	.011	.293	.082
	Huynh-Feldt	2.178	1.000	2.178	.293	.593	.011	.293	.082
	Lower-bound	2.178	1.000	2.178	.293	.593	.011	.293	.082
Error(test)	Sphericity Assumed	200.790	27	7.437					
	Greenhouse-Geisser	200.790	27.000	7.437					
	Huynh-Feldt	200.790	27.000	7.437					
	Lower-bound	200.790	27.000	7.437					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	test	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Linear	3.558	1	3.558	.478	.495	.017	.478	.102
test * group	Linear	2.178	1	2.178	.293	.593	.011	.293	.082
Error(test)	Linear	200.790	27	7.437					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	43739.164	1	43739.164	149.163	.000	.847	149.163	1.000
group	394.118	1	394.118	1.344	.256	.047	1.344	.201
Error	7917.240	27	293.231					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: MEASURE_1

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
-27.478	2.250	-32.094	-22.861

2. group

Measure: MEASURE_1

group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	-30.086	3.236	-36.726	-23.446
2	-24.869	3.126	-31.284	-18.455

3. test

Measure: MEASURE_1

test	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	-27.725	2.229	-32.298	-23.153
2	-27.230	2.327	-32.004	-22.456

4. group * test

Measure: MEASURE_1

group	test	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	-30.140	3.206	-36.717	-23.562
	2	-30.032	3.347	-36.899	-23.165
2	1	-25.311	3.097	-31.665	-18.957
	2	-24.428	3.233	-31.062	-17.794

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
d_pre_irer	29	46.994770	-48.8703	-1.875545	-27.6422	12.031477544
d_post_irer	29	57.81369	-51.76061	6.05308	-27.1332	12.62246371
Valid N (listwise)	29					

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

test	Dependent Variable
1	d_pre_ud
2	d_post_ud

Between-Subjects Factors

		N
group	1	14
	2	15

Descriptive Statistics

	group	Mean	Std. Deviation	N
d_pre_ud	1	13.63124	8.341653186	14
	2	11.10995	8.614150181	15
	Total	12.32712	8.429252451	29
d_post_ud	1	13.31956	7.680844521	14
	2	10.38683	7.716242430	15
	Total	11.80263	7.706184802	29

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Pillai's Trace	.016	.447[b]	1.000	27.000	.510	.016	.447	.099
	Wilks' Lambda	.984	.447[b]	1.000	27.000	.510	.016	.447	.099
	Hotelling's Trace	.017	.447[b]	1.000	27.000	.510	.016	.447	.099
	Roy's Largest Root	.017	.447[b]	1.000	27.000	.510	.016	.447	.099
test * group	Pillai's Trace	.003	.071[b]	1.000	27.000	.792	.003	.071	.058
	Wilks' Lambda	.997	.071[b]	1.000	27.000	.792	.003	.071	.058
	Hotelling's Trace	.003	.071[b]	1.000	27.000	.792	.003	.071	.058
	Roy's Largest Root	.003	.071[b]	1.000	27.000	.792	.003	.071	.058

a. Computed using alpha = .05

b. Exact statistic

c.

Design: Intercept+group
Within Subjects Design: test

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept+group
Within Subjects Design: test

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Sphericity Assumed	3.877	1	3.877	.447	.510	.016	.447	.099
	Greenhouse-Geisser	3.877	1.000	3.877	.447	.510	.016	.447	.099
	Huynh-Feldt	3.877	1.000	3.877	.447	.510	.016	.447	.099
	Lower-bound	3.877	1.000	3.877	.447	.510	.016	.447	.099
test * group	Sphericity Assumed	.613	1	.613	.071	.792	.003	.071	.058
	Greenhouse-Geisser	.613	1.000	.613	.071	.792	.003	.071	.058
	Huynh-Feldt	.613	1.000	.613	.071	.792	.003	.071	.058
	Lower-bound	.613	1.000	.613	.071	.792	.003	.071	.058
Error(test)	Sphericity Assumed	234.265	27	8.676					
	Greenhouse-Geisser	234.265	27.000	8.676					
	Huynh-Feldt	234.265	27.000	8.676					
	Lower-bound	234.265	27.000	8.676					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	test	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Linear	3.877	1	3.877	.447	.510	.016	.447	.099
test * group	Linear	.613	1	.613	.071	.792	.003	.071	.058
Error(test)	Linear	234.265	27	8.676					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	8498.363	1	8498.363	69.329	.000	.720	69.329	1.000
group	107.702	1	107.702	.879	.357	.032	.879	.148
Error	3309.672	27	122.580					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: MEASURE_1

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
12.112	1.455	9.127	15.097

2. group

Measure: MEASURE_1

group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	13.475	2.092	9.182	17.769
2	10.748	2.021	6.601	14.896

3. test

Measure: MEASURE_1

test	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	12.371	1.576	9.136	15.605
2	11.853	1.431	8.918	14.788

4. group * test

Measure: MEASURE_1

group	test	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	13.631	2.267	8.979	18.284
	2	13.320	2.058	9.098	17.542
2	1	11.110	2.191	6.615	15.605
	2	10.387	1.988	6.308	14.466

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

test	Dependent Variable
1	d_pre_ap
2	d_post_ap

Between-Subjects Factors

		N
group	1	14
	2	15

Descriptive Statistics

	group	Mean	Std. Deviation	N
d_pre_ap	1	-11.6084	8.533501840	14
	2	-11.6257	9.519840075	15
	Total	-11.6173	8.895130343	29
d_post_ap	1	-12.7838	9.395477348	14
	2	-14.2844	10.494857841	15
	Total	-13.5599	9.830472455	29

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Pillai's Trace	.278	10.389[b]	1.000	27.000	.003	.278	10.389	.874
	Wilks' Lambda	.722	10.389[b]	1.000	27.000	.003	.278	10.389	.874
	Hotelling's Trace	.385	10.389[b]	1.000	27.000	.003	.278	10.389	.874
	Roy's Largest Root	.385	10.389[b]	1.000	27.000	.003	.278	10.389	.874
test * group	Pillai's Trace	.054	1.555[b]	1.000	27.000	.223	.054	1.555	.225
	Wilks' Lambda	.946	1.555[b]	1.000	27.000	.223	.054	1.555	.225
	Hotelling's Trace	.058	1.555[b]	1.000	27.000	.223	.054	1.555	.225
	Roy's Largest Root	.058	1.555[b]	1.000	27.000	.223	.054	1.555	.225

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+group
Within Subjects Design: test

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+group
Within Subjects Design: test

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Sphericity Assumed	53.224	1	53.224	10.389	.003	.278	10.389	.874
	Greenhouse-Geisser	53.224	1.000	53.224	10.389	.003	.278	10.389	.874
	Huynh-Feldt	53.224	1.000	53.224	10.389	.003	.278	10.389	.874
	Lower-bound	53.224	1.000	53.224	10.389	.003	.278	10.389	.874
test * group	Sphericity Assumed	7.966	1	7.966	1.555	.223	.054	1.555	.225
	Greenhouse-Geisser	7.966	1.000	7.966	1.555	.223	.054	1.555	.225
	Huynh-Feldt	7.966	1.000	7.966	1.555	.223	.054	1.555	.225
	Lower-bound	7.966	1.000	7.966	1.555	.223	.054	1.555	.225
Error(test)	Sphericity Assumed	138.325	27	5.123					
	Greenhouse-Geisser	138.325	27.000	5.123					
	Huynh-Feldt	138.325	27.000	5.123					
	Lower-bound	138.325	27.000	5.123					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	test	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
test	Linear	53.224	1	53.224	10.389	.003	.278	10.389	.874
test * group	Linear	7.966	1	7.966	1.555	.223	.054	1.555	.225
Error(test)	Linear	138.325	27	5.123					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	9161.468	1	9161.468	51.893	.000	.658	51.893	1.000
group	8.342	1	8.342	.047	.830	.002	.047	.055
Error	4766.690	27	176.544					

a. Computed using alpha = .05

Estimated Marginal Means

1. Grand Mean

Measure: MEASURE_1

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
-12.576	1.746	-16.157	-8.994

2. group

Measure: MEASURE_1

group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	-12.196	2.511	-17.348	-7.044
2	-12.955	2.426	-17.932	-7.978

3. test

Measure: MEASURE_1

test	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	-11.617	1.683	-15.070	-8.164
2	-13.534	1.854	-17.339	-9.729

4. group * test

Measure: MEASURE_1

group	test	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	-11.608	2.421	-16.576	-6.641
	2	-12.784	2.667	-18.257	-7.311
2	1	-11.626	2.339	-16.425	-6.827
	2	-14.284	2.577	-19.572	-8.997

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