The Spine and Scapula Stabilizing (S3) Brace Has an Effect on Posture and Muscle
Activity in Overhead Athletes with Poor Posture

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ABSTRACT

Ashley K. Cole: The Spine and Scapula Stabilizing (S3) Brace Has an Effect on Posture and Muscle Activity in Overhead Athletes with Poor Posture
(Dr. Bill Prentice)

The purpose of this study was to determine whether or not the S3 scapular stabilizing brace corrects the posture of participants with FHRSP. In addition, this study determined whether or not wearing the S3 scapular stabilizing brace has an effect on the muscle activity of participants with FHRSP while performing six scapular stabilization exercises. Posture was measured using a digital camera and Adobe Photoshop to determine both the forward head and rounded shoulder angles. Muscle activity was measure for the upper trapezius, middle trapezius, lower trapezius, and serratus anterior using the average EMG recorded during Y's, T's, W's, shoulder extension, forward flexion, and scapular punches. This study found that there were significant changes in FSA and upper, middle, and lower trapezii EMG activity caused when wearing the S3 brace compared to not wearing it. However, this study did not find significant differences in the treatment group compared to the sham group for FHRSP or EMG activity in any muscles.

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LIST OF ABBREVIATIONS

C7	Seventh cervical vertebrae
FHA	Forward head angle
FHP	Forward head posture
FHRSP	Forward head, rounded shoulder posture
FSA	Forward shoulder angle
FSP	Forward shoudler posture
LT	Lower trapezius
MT	Middle trapezius
ROM	Range of motion
SA	Serratus anterior
UT	Upper trapezius

CHAPTER 1

Introduction

Shoulder injuries are a common and disabling condition among many athletes. Shoulder injuries account for 8-20% of all athletic injuries and many of these are classified as "overuse" (Terry & Chopp, 2000). Shoulder injuries are particularly common in overhead athletes. Nearly 50% of baseball pitchers experience shoulder or elbow pain significant enough to prevent participation at some point in their careers (Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). Recent NCAA injury surveillance system research has shown that shoulder injuries account for 39.4% of all injuries in baseball with shoulder injuries accounting for 28.3% of all injuries resulting in a time loss of 10 or more day. Similar studies were done for softball and women's volleyball with shoulder injuries accounting for 15.8% and 21.7% of overall injuries (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007; Dick et al., 2007; Marshall, Hamstra-Wright, Dick, Grove, & Agel, 2007). Thus finding ways to treat and prevent shoulder injuries are critical to the sports medicine profession. Research has shown that alterations in scapular motion occur in 68-100% of patients with shoulder injury (Terry & Chopp, 2000; Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). Many studies have looked at the relationship between altered scapulothoracic kinematics and one common overuse injury: impingement

syndrome. Studies have consistently shown that patients with shoulder impingement syndrome present with decreased scapular upward rotation, decreased posterior tipping/tilting (sometimes referred to as increased anterior tipping), and increased medial/internal rotation (Borstad & Ludewig, 2002; Ebaugh, McClure, & Karduna, 2006; Hebert, Moffet, McFadyen, & Dionne, 2002; Ludewig & Cook, 2000; Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999). It has been suggested that a decrease in the amount of scapular posterior tilt may reduce the size of the subacromial space which subjects the rotator cuff tendons to greater compressive forces (Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999)

A specific postural anomaly, forward head rounded shoulder posture, may also play a role in the development of shoulder pain. Forward head posture is defined as the tragus (ear lobe) being in front of the plumb line while the rest of the body remains in alignment (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005). Rounded/ forward shoulder posture is described as the acromion of the shoulder being located in front of the plumb line while the rest of the body remains in alignment (Lewis, Wright, & Green, 2005). These two postural abnormalities often occur in conjunction with one another and are thought to be related to many overuse injuries in the shoulder. One study found that when healthy patients adopted a slouched position this significantly increased scapular anterior tilt and upward rotation in neutral position, when compared to the neutral position during upright posture (Finley & Lee, 2003). These specific scapular alterations are believed to be related to the development of shoulder pathology. It may also be argued that repetitive humeral elevation in a slouched posture may increase the likelihood of

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encroachment of the supraspinatus tendon and the development of shoulder pathology (Finley & Lee, 2003). Furthermore, Greigel-Morris et al. found that the incidence of pain increased in subjects with more severe postural abnormalities including kyphosis and interscapular pain, FHP and right cervical pain, FHP and left cervical pain, FHP and headache, FHP and interscapular pain, left rounded shoulder posture (LRSP) and interscapular pain, and right rounded shoulder posture (RRSP) and interscapular pain (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992). Muscular balance plays a significant role in proper posture and normal scapular kinematics. Having muscular balance means that anterior and posterior, and medial and lateral muscles are equal in strength and move in an appropriate sequence with one another. One way to correct scapular positioning and FHRSP is to correct muscular imbalances surrounding the shoulder complex. Weakness of the scapulothoracic muscles has been shown to potentially lead to abnormal positioning of the scapula, disturbances in the scapulothoracic rhythm, and generalized shoulder dysfunction (Voight & Thomson, 2000). Several studies have examined muscle strength in the scapular muscles, balance between scapular muscles, and latent reaction times between muscles in overhead athletes with impingement. Results of these studies have shown that athletes with shoulder pathology showed decreased force output, decreased muscle activity during concentric isokinetic retraction movements which was accompanied by a change in normal activation patterns in the trapezius muscle activity (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Cools, Witvrouw, Danneels, & Cambier, 2002; Cools, Witvrouw, Declercq, Danneels, & Cambier, 2003; Cools, Witvrouw, Declercq, Vanderstraeten,

& Cambier, 2004). Thus it may be possible to alleviate shoulder pain and dysfunction by properly rehabilitating the musculature surrounding the scapula, to achieve normal scapular motion and to restore proper alignment within the neck and shoulder girdle.

The Scapular Stabilizing System (S3) brace is "a spine and scapula stabilizing brace designed to improve posture, reduce pain, and increase range of motion." The company designed the S3 brace to "trigger the body to correct improper posture by re-educating and re-engineering the musculo-skeletal system surrounding the shoulders and spine" as well as signaling the neuroreceptors in the skin to engage in proper posture. The company also states that the S3 brace "addresses and lends instant relief to fatigue and poor spine alignment associated with unnatural body position at the computer." There have been no published studies yet on this brace although Uhl et al. performed a study on the prototype of the S3 brace that has not yet been published. Fifteen healthy subjects and 15 subjects with scapular dyskinesis were used in this study. The results found that the brace increased posterior tipping by 3 degrees in the first and last 30 degrees of motion, decreased upward rotation in the dominant arm by 4 degrees at 90 degrees of elevation, while increasing upward rotation in the non-dominant arm by 2 degrees in the first and lat 40 deg of elevation. The S3 also decreased internal rotation by 3.5 degrees during the lowering phase of elevation. The authors concluded that the S3 brace affected the scapular kinematics at rest and in the lower ranges of motion and that the increased posterior tipping and decreased internal rotation from wearing the brace may assist the scapular muscles in controlling scapular motion. The S3 brace

appears to be a new way to help correct scapular position and motion to help treat individuals with shoulder pathology.

Statement of Purpose

The purpose of this study was to determine whether or not proper application of the S3 scapular stabilization brace changes the posture of participants with FHRSP. In addition, this study determined whether or not the wearing the S3 scapular stabilization brace has an effect on the EMG activity of patients with FHRSP while performing six scapular stabilization exercises. Comparing the sham group to the treatment group determined whether any changes in EMG seen were due to the corrective straps or if merely wearing a compressive garment produced changes in EMG activity.

Independent Variables

1. Wearing the S3 brace with straps properly applied and tensioned
2. Wearing the S3 brace not using the proper strap set up to correct posture (sham treatment)
3. Not wearing the S3 brace

Dependent Variables

1. Average EMG present in the serratus anterior, upper trapezius, middle trapezius, and lower trapezius during exercises
2. Participants' forward head, rounded shoulder posture

Research Hypothesis

1. It was hypothesized that participants who wore the S3 brace properly applied would have an increase in the average EMG in the serratus anterior, lower trapezius, and middle trapezius as compared to when they were not wearing the brace.

2. It was hypothesized that participants who wore the S3 brace properly applied would have a decrease in average EMG in the upper trapezius as compared to when they were not wearing the brace

3. It was hypothesized that the treatment group would have a significant increase in average EMG in the serratus anterior, lower trapezius, and middle trapezius and a decrease in the average EMG of the upper trapezius when compared to the sham group.

4.   It was hypothesized that the sham group would have no change in average EMG in the serratus anterior, lower trapezius, middle trapezius, and upper trapezius after application of the S3 brace.

5. It was hypothesized that participants who wore the S3 brace properly applied would have a decrease in the forward head and rounded shoulder angles compared to when they were not wearing the brace, which signifies improved posture.

6. It was hypothesized that the treatment group would have a significant change in forward head and rounded shoulder angle compared to the sham group.

7. It was hypothesized that the sham group would have no change in forward head and rounded shoulder angle after application of the brace.

Null Hypothesis

1. Participants who wore the S3 brace properly applied would have no change in the average EMG in the serratus anterior, lower trapezius, and middle trapezius as compared to when they are not wearing the brace.

2. Participants who wore the S3 brace properly applied would have no change in average EMG in the upper trapezius as compared to when they are not wearing the brace

3. The treatment group would have no significant difference in average EMG in the serratus anterior, lower trapezius, middle trapezius, and upper trapezius compared to the sham group.

4. The sham group would have no significant difference in average EMG in the serratus anterior, lower trapezius, middle trapezius, and upper trapezius after application of the brace.

5. Participants who wore the S3 brace properly applied would have a no change in the forward head and rounded shoulder angles compared to when they are not wearing the brace, which signifies no improvement in posture.

6. The treatment group would have a no difference in forward head and rounded shoulder angle compared to the sham group.

7. The sham group would have no difference in forward head and rounded shoulder angle after application of the brace.

Alternate Hypotheses

1. Participants who wore the S3 brace properly applied would have a change in the average EMG in the serratus anterior, lower trapezius, and middle trapezius as compared to when they are not wearing the brace.

2. Participants who wore the S3 brace properly applied would have a change in average EMG in the upper trapezius as compared to when they are not wearing the brace

3. The treatment group would have a significant difference in average EMG in the serratus anterior, lower trapezius, middle trapezius, and upper trapezius compared to the sham group.

4. The sham group would have a significant difference in average EMG in the serratus anterior, lower trapezius, middle trapezius, and upper trapezius after application of the brace.

5. Participants who wore the S3 brace properly applied would have a change in the forward head and rounded shoulder angles compared to when they are not wearing the brace, which signifies no improvement in posture.

6. The treatment group would have a difference in forward head and rounded shoulder angle compared to the sham group.

7. The sham group would have a difference in forward head and rounded shoulder angle after application of the brace.

Operational Definitions

1. Sham treatment- A sham treatment was defined as the patient wearing the S3 scapular stabilization brace without the Velcro straps being properly applied. This gave the feeling that he/she was wearing something that would correct his/her posture without the actual corrective measures being applied. To create this effect a longer Velcro strap was attached to the brace. This longer strap did provide enough tension to make an effective change in the patient's posture.

2. Scapular stabilization exercises- Scapular stabilization exercises included those exercises that strengthen the muscles responsible for maintaining proper positioning of the scapula during shoulder movement. The exercises that have been chosen for this study are scapular punches, forward flexion, shoulder extension, Y's, T's, and W's.

   a. Scapular punches were performed lying supine on a table with the arm in 90° of flexion. The patient then protracted the scapula by raising the fist towards the ceiling.

   b. Y's were described as an arm raise above the head with the upper extremity in line with the lower trapezius muscle fibers in the prone position (Ekstrom, Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a table with arms hanging down in front and palms facing each other. Arms were in the 10 and 2 o'clock position (at about 125°) and thumbs were raised towards the ceiling. Arms were raised until they are parallel to the floor.

c. T's were described as shoulder horizontal extension with external rotation in the prone position (Ekstrom, Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a table with arms hanging down in front. Arms were raised out to the side in horizontal extension until they were parallel to the floor.

d. W's were described as prone external rotation with shoulder abducted to 90° and elbow flexed to 90°. This exercise was performed while lying prone on a table with arms hanging down in front. Arms were raised so that brachium was parallel to the floor with the elbow bent to 90°. The arms were then externally rotated.

e. Forward flexion was performed in the sagittal plane. The exercise began with the arm at 0° of flexion and it was elevated with the forearm in a neutral position (thumb facing ceiling) in the sagittal plane to full shoulder flexion(Myers et al., 2005).

f. Shoulder extension was performed in the sagittal plane. The exercise began with the arm at 90° of flexion with the forearm in a neutral position (thumb facing ceiling) and was moved into full shoulder extension and then back to 90°(Myers et al., 2005).

3. Poor posture was defined as having forward head, rounded shoulder positioning. Reflective markers were placed over the tragus (ear), acromion, and C7 spinous process. Pictures were taken in the sagittal view of each subject and measurements were taken using the pictures. Forward head position was defined as having a forward head angle greater than or equal to

46° relative to the vertical line extending from C7 to the line connecting C7 to the tragus. Rounded shoulder position was described as having a forward head angle of greater than or equal to 46° relative to the vertical line extending from C7 to the line connecting C7 to the acromion (Sawyer, 2006; Thigpen, 2006). Postural alignment criteria were based on a study done by Thigpen in which he screened 310 individuals from the university population. Those with FHA ≥ 46º and FSA ≥ 46º were determined to have the worst posture Sawyer, 2006; Thigpen, 2006).

4. Overhead athlete- An overhead athlete was described as an athlete who competes in a NCAA, club, or recreational overhead sport for at least 3-4 days per week for 1 hour a day or more. Overhead sports were those in which repetitive overhead activity were required including baseball, softball, swimming, volleyball, tennis, water polo, javelin, shot put, and discus.

5. EMG- Electromyography was used to assess muscles activity during the scapular punches, forward flexion, shoulder extension, Y's, T's, and W's. Maximal voluntary isometric contraction (MVIC) readings were taken using EMG to determine what percentage of each patient's MVIC the EMG reads during the exercise. The average value of the EMG was used to normalize MVIC readings.

6. Average EMG- Average smoothed and rectified EMG amplitude during the exercise. This value was normalized to each subject's MVIC.

Assumptions

1. Participants did not know the difference between the S3 brace treatment and sham groups

2. All exercises activated the muscles which they were intended to activate

3. Subjects were able to complete the exercise protocol

4. Individuals gave the same amount of effort whether wearing the S3 brace or not wearing it.

5. EMG was a valid and reliable measuring device and is properly calibrated

6. Researchers could reliably apply the brace.

Delimitations

1. Subjects will be truthful about their history of upper extremity injury

2. Subjects are all overhead athletes

3. Analysis will be performed on the subjects dominant arm for his/ her sport

Limitations

1. Variability of EMG readings between subjects

2. The pressure of the brace may affect EMG readings

3. Exercises were performed in a lab setting with wires attached which may have affected how the patient performed the exercise.

CHAPTER 2

Shoulder injuries account for 8-20% of all athletic injuries. Many of these injuries are classified as overuse (Terry & Chopp, 2000). Research has shown that alterations in scapular motion occur in 68-100% of patients with shoulder injury (Terry & Chopp, 2000; Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). The prevalence of these injuries tends to increase with age as studies have indicated that 21-34% of elderly people are inflicted with shoulder injury, and in about 30% of these cases that injury led to disability (Chakravarty & Webley, 1993; Chard, Hazleman, Hazleman, King, & Reiss, 1991). Athletes involved in overhead sports are at increased risk of developing shoulder injury, but researchers and clinicians believe that many of these injuries (particularly overuse injuries) may be preventable (Lewis, Wright, & Green, 2005; Myers, Laudner, Pasquale, Bradley, & Lephart, 2005; Myers et al., 2005). Nearly 50% of baseball pitchers experience shoulder or elbow pain significant enough to prevent participation at some point in their careers (Myers et al., 2005). Research indicates that shoulder impingement is the most common source of shoulder pain. Lukasiewicz and colleagues found that 16-40% of patients complaining of shoulder pain had signs and symtoms consistent with impingement (Ludewig & Cook, 2000; Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999).

Closely related to incidence of shoulder pain is the incidence of postural abnormalities in the population. Griegel-Morris et. al found that in a convenience

sample of 88 healthy volunteers ages 20-50 66% presented with forward head

posture, 38% presented with thoracic kyphosis, 73% presented with a right rounded

shoulder, and 66% presented with a left rounded shoulder (Griegel-Morris, Larson,

Mueller-Klaus, & Oatis, 1992). This study also investigated the relationship of pain to

postural abnormalities. It was found that the incidence of pain increased in subjects

with more severe postural abnormalities and a significant relationship was found

between forward head and left cervical pain, forward head and headache, forward

head and interscapular pain, left rounded shoulder and interscapular pain and right

rounded shoulder and interscapular pain (Griegel-Morris, Larson, Mueller-Klaus, &

Oatis, 1992). Shoulder pain and postural abnormalities are common and debilitating

problems for the general population and especially for athletes. Improving posture

and decreasing the incidence of shoulder pain may facilitate quicker return to play/

daily activities, as well as decreasing the amount of time lost from sports

participation and/or daily activities.

Anatomy

Sternoclavicular Joint

The sternoclavicular joint is the only true articulation between the upper

extremity and the axial skeleton (Terry & Chopp, 2000). It is a saddle joint formed by

the articulation of the medial end of the clavicle and the upper portion of the sternum.

Stability is provided by the surrounding ligamentous structures (Terry & Chopp,

2000). There are three ligaments that provide stability along with the interarticular

disc. The first ligament is the costoclavicular arise from the superior 1st rib and

connects to the inferior surface of the medial clavicle. Its anterior fibers resist upward

rotation while its downward fibers resist downward rotation (Terry & Chopp, 2000).

The intercalvicular ligament connects the clavicle with the capsular ligament and

upper sternum. This ligament acts as a checkrein against excessive downward

rotation of the clavicle (Terry & Chopp, 2000). Finally, the capsular ligament covers

the anterosuperior and posterior aspects of the sternoclavicular joint. The heavier,

stronger anterior portion is the primary stabilizer against upward displacement which

is caused by a downward force on the distal end of the clavicle. The intra-articular

disc acts as a checkrein against medial displacement of the proximal clavicle (Terry

& Chopp, 2000). While providing stability is essential the SC joint must be

sufficiently mobile to full range of motion in the upper limb. The SC joint allows 45° of

elevation and 10° of depression (Neumann, 2002). When the clavicle is elevated due

to glenohumeral flexion or abduction it rotates around its longitudinal axis

approximately 40-50°. Additionally 15-30 degrees of protraction and retraction are

available at the joint (Neumann, 2002).

Acromioclavicular Joint

The acromioclavicular joint is a diarthroidal joint connecting the lateral border

of the clavicle to the medial border of the acromion. High axial loads are transferred

through this small area and as a result contact stresses are high and may result in

eary failure(Terry & Chopp, 2000). Stability is provided mainly through the static

stabilizers composed of the capsule, intrarticular discs and ligaments (Terry &

Chopp, 2000). The joint capsule is relatively weak, but is strengthened superiorly by

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the fibers of the upper trapezius (Moore, 2006). There are three ligaments which provide stability at the AC joint. The acromioclavicluar ligament connects the distal clavicle to the proximal acromion and strengthens the joint superiorly (Moore, 2006). The coracoacromial ligament connects the coracoid process to the acromion process. This ligament, along with the acromioclavicular ligament provide the primary restraint to posterior translation (Terry & Chopp, 2000). The coracoclavicular ligament is actually composed of a pair of ligaments, the trapezoid and the conoid. These ligaments are the primary restraint to vertical displacement of the clavicle (Terry & Chopp, 2000). While the SC joint permits relative extensive motion of the clavicle, which guides the scapula, the AC joint permits subtle and slight movements of the scapula. These slight movements are physiologically important as they provide the maximum extent of mobility at the scapulothoracic joint (Neumann, 2002). The AC joint allows up to 30 degrees of scapular upward rotation, this motion places a significant stretch on the inferior capsule and coracoclavicular joint. Horizontal and sagittal plane rotational adjustments also occur at the AC joint allowing between 10 and 30° of motion. These adjustments enhance both the quantity and quality of movement at the scapulothoracic joint (Neumann, 2002).

Glenohumeral Joint

The glenohumeral joint is a ball-and-socket joint that provides extreme mobility, but lacks stability. At any given time only 25-30% of the humeral head is in contact with the glenoid fossa (Terry & Chopp, 2000). The stabilizing effect of the articular surfaces and capsulolabral ligamentous complex is magnified by muscle

forces, which produce a concavity-compression effect directed toward the glenoid center(Terry & Chopp, 2000). Biomechanical dysfunction results in a loss of this precise constraint of the center of rotation, more simply stated results in instability (Terry & Chopp, 2000). Instability can occur in anterior, posterior, or inferior directions (or a combination of these) and may range from mild subluxation to dislocation (Terry & Chopp, 2000). The glenoid articular cartilage is thicker at the periphery which creates significant articular surface conformity and resultant stability. This articular conformity provides the foundation for the concavity-compression effect provided by the rotator cuff and surrounding musculature(Terry & Chopp, 2000). The glenoid labrum, a dense fibrous structure located at the glenoid margin, serves to extend the conforming articular surfaces which increases the contact surface area and adds stability. The labrum enhances stability by deepening the concavity of the glenoid socket and also acts as an anchor point for the capsuloligamentous structures.

The glenohumeral joint capsule has a surface area approximately twice that of the humeral head allowing for extensive range of motion. The joint capsule tightens or "winds up" in various extremes of position and the capsuloligamentous structures reciprocally tighten and loosen during rotation of the arm to limit translation (Terry & Chopp, 2000). There are four ligaments that make up the glenohumeral ligament complex, the coracohumeral, the superior glenohumeral, the middle glenohumeral, and the inferior glenohumeral ligaments. The coracohumeral ligament is a thick band of capsular tissue that originates from the base of the lateral coracoid and inserting into the lesser and greater tuberosities. It is taut with the arm

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in adduction and constrains the humeral head on the glenoid (Terry & Chopp, 2000).

The superior glenohumeral ligament extends from the anterosuperior edge of the

glenoid to the top of the lesser tuberosity. It is consider similar in function as the

coracohumeral ligament and together these ligaments stabilize the humeral head

from inferior translation in adduction and from posterior translation in forward flexion,

adduction, and internal rotation (Terry & Chopp, 2000). The middle glenohumeral

ligament is rather variable in its orientation and is absent in 8-30% of patients. Its

function is to limit anterior translation of the humeral head in the lower ranges of

abduction (60-90°) and inferior translation in the adducted position at the side. The

inferior glenohumeral ligament is the thickest and most consistent ligament. It is

often described as having an anterior band, axillary pouch, and posterior band(Terry

& Chopp, 2000). The anterior band is the thickest portion and the primary stabilizer

against anterior translation of the humeral head in abduction and external rotation. In

this position, the complex moves anteriorly and becomes a barrier to anterior

translation. Injury to the inferior glenohumeral ligament through repetitive

microtrauma or single traumatic episode plays an integral role in recurrent stability

(Terry & Chopp, 2000).

Scapulothoracic Joint

Although the scapulothoracic joint is not a true articulation, it represents the

space between the convex surface of the posterior thoracic wall and the concave

surface of the anterior scapula (Terry & Chopp, 2000). This space is occupied by

neurovascular, muscular, and bursal structures that allow a relatively smooth motion

of the scapula on the underlying thorax (Terry & Chopp, 2000). The scapula serves as the bony foundation and the scapulothoracic articulation allows increased shoulder movement beyond the 120 degrees offered solely by the glenohumeral joint (Terry & Chopp, 2000). There are approximately 2 degrees of glenohumeral elevation for every 1 degree of scapulothoracic elevation, although the actual ratio varies for any portion of the arc of motion (Terry & Chopp, 2000). There are seventeen muscles that attach to or originate from the scapula and function to stabilize it and provide motion. Two of the most important are the serratus anterior and the trapezius. The serratus anterior maintains the medial angle against the chest wall, while the trapezius helps rotate and elevate the scapula synchronously with glenohumeral motion (Terry & Chopp, 2000). The motions available at the scapulothoracic joint are elevation/depression, protraction/retraction, and upward/downward rotation. Scapular elevation and depression occurs as a result of composite SC and AC joint rotations. Protraction and retraction occur through a summation of horizontal plane rotations at both the SC and AC joints (Neumann, 2002). Upward rotation occurs as a summation of clavicular elevation at the SC joint and scapular upward rotation at the AC joint. These dual rotations allow a total of 60 degrees of scapular rotation. Downward rotation occurs as the opposite of upward rotation (Neumann, 2002).

Glenohumeral Stabilizers

The rotator cuff muscles are the primary dynamic stabilizers of the glenohumeral joint. The rotator cuff consists of the supraspinatus, infraspinatus,

teres minor, and subscapularis and together they act as a dynamic steering mechanism for the humeral head (Terry & Chopp, 2000). The rotator cuff muscles act as regulators of the dynamic joint stability and controllers of glenohumeral arthrokinematics (Neumann, 2002). Contraction of the rotator cuff muscles results in concavity-compression, and asymmetric contraction acts to cause humeral head rotation during shoulder motion (Terry & Chopp, 2000). The supraspinatus originates from the supraspinatus fossa and inserts on the superior aspect of the greater tuberosity. It stabilizes the glenohumeral join and abducts the arm, along with the deltoid (Terry & Chopp, 2000). The infraspinatus originates from the infraspinatus fossa and inserts on the greater tuberosity as well. The teres minor originates from the mid to upper regions of the axillary border of the scapula and inserts on the greater tuberosity. Together the infraspinatus and teres minor provide the primary external rotation force and stabilize the glenohumeral joint against posterior subluxation. The subscapularis muscle is the only anterior rotator cuff muscle (Terry & Chopp, 2000). Originating the in the subscapularis fossa and inserting on the lesser tuberosity of the humerus, it functions as an internal rotator. Although the long head of the biceps tendon is not a rotator cuff muscle it functions as a humeral head depressor, and may reduce anterior translation and increase torsional rigidity of the joint which resists external rotation (Terry & Chopp, 2000).

Scapular Stabilizers

The trapezius has an extensive origin from the base of the skull to the upper lumbar vertebrae and inserts on the lateral aspect of the clavicle, acromion, and

scapular spine (Terry & Chopp, 2000). The trapezius has three different parts: the

upper trapezius, lower trapezius, and middle trapezius which each provide a slightly

different action. It functions mainly as a scapular retractor and elevator of the lateral

angle of the scapula and is innervated by the spinal accessory nerve (Terry & Chopp,

2000). The serratus anterior originates from the bodies of the first 9 ribs and the

anterolateral aspect of the thorax and inserts in three portions from the superior to

the inferior angle of the scapula (Terry & Chopp, 2000). Activation of the serratus

anterior causes protraction and upward rotation and it is innervated by the long

thoracic nerve. Injuries to the long thoracic nerve often result in a winged scapula

(Terry & Chopp, 2000). Two other important scapular muscles include the rhomboids

and the levator scapulae. The rhomboids include the major, which originates from

the spinous processes of C7-T1, and the minor, which originates on the spinous

processes of T2-T5. They insert on the medial aspect of the scapula and retract and

elevate the scapula. The levator scapulae originate on the transverse processes of

the cervical spine and inserts on the superior angle of the scapula (Terry & Chopp,

2000). This muscle elevates the superior angle resulting in upward and medial

rotation of the scapula. The trapezii muscles and the serratus anterior work

separately and together to create movement and the scapulothoracic articulation.

The upper trapezius along with the levator scapulae and the rhomboids is

responsible for elevation of the clavicle. The lower trapezius along with the lattisimus

dorsi, the pectoralis minor, and the subclavius depress the scapula (Neumann,

2002). The serratus anterior is the prime protractor of the scapula, while the middle

trapezius, rhomboids, and lower trapezius work to protract the scapula. Although

these muscles perform separate and opposite functions alone, the serratus anterior and all parts of the trapezius cooperate to produce upward rotation of the scapula (Neumann, 2002).

Force couples allow muscles that perform different individual motions to act together as a unit to perform a single motion. One such force couple is that of the upper trapezius, lower trapezius, and lower serratus anterior in producing upward rotation (Neumann, 2002). During glenohumeral abduction the upper trapezius upwardly rotates the scapula by its attachment to the clavicle, the serratus anterior is the most effective upward rotator due to its large moment arm, and the lower trapezius has been shown to be particularly active during the later phase of shoulder abduction (Neumann, 2002). The middle trapezius is robbed of its leverage and therefore, does not contribute to the upward rotation torque. It does, however, contribute a needed retraction force on the scapula, which along with the rhomboids helps to balance the protraction effect of the serratus anterior (Neumann, 2002). A force couple is also present between the deltoid and the rotator cuff muscles during glenohumeral abduction. The deltoid rolls the humeral head upward, while the supraspinatus compresses the humeral head into the glenoid fossa. Simultaneously, the subscapularis, infraspinatus, and teres minor exert a downward force on the humeral head to counteract the excessive superior translation (Neumann, 2002). These force couples allow for normal shoulder kinematics, but are disturbed when one muscle becomes overactive while the other muscles become weak and under active.

Kinematics

　　To maintain joint congruency the scapula has a high degree of 3 dimensional mobility that includes its ability to upwardly/downwardly rotate, internally/externally rotate, tip anteriorly/posteriorly, elevate/depress, and protract/retract (Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). It is important for the scapula to have coordinated elevation and upward rotation with the humerus in order to maintain sufficient subacromial space as the humerus is elevated to 90°, thus avoiding impingement of the rotator cuff in this position (Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). Additionally, proper 3D position of the scapula relative to the humerus and trunk is vital for muscle function due to the fact that the scapula acts as the common point of attachment of the rotator cuff and primary humeral movers as well as several scapular stabilizers (Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). The scapula index can be used to define normal resting position of the scapula. The formula used is [(scapular notch to coracoid process/ posterolateral angle of the acromion to thoracic spine) x 100]. A normal scapular index ranges 60.45 to 66.73 (Borstad, 2006). Ludewig and Cook defined normal scapular resting positions as 40° of medial rotation, 11° of upward rotation, and 10° of posterior tipping (Ludewig & Cook, 2000).

　　With shoulder abduction the scapula should go through a specific set of postural changes. Lukasiewicz et. al. found the normal posterior tilt angle at rest to be about 12°, in 90 degrees of abduction it was found to be about 22°, and at maximum abduction it was found to be about 34°. The normal upward rotation angle at rest was approximately 12°, in 90° of abduction it was approximately 28°, and at

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maximum abduction it was approximately 40°. The normal values for internal rotation were found to be approximately 47° at rest, 41° in 90° of abduction, and 39° at maximum abduction. For scapular elevation normal resting position was found to be about 10 centimeters between C7 and the centroid of the scapula at rest, about 8 centimeters between the C7 and the centroid of the scapula in 90° of abduction, and about 7 centimeters between C7 and the centroid of the scapula at maximum abduction. Medial-lateral positioning was the final variable measured. It was defined as the centimeters of horizontal difference between C7 and the centroid of the scapula. At rest the position was 12 centimeters, at 90° of abduction it was about 11 centimeters, and at maximum abduction it was about 10 centimeters (Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999).

Scapular dyskinesis is defined as observable alterations in the position of the scapula and the patterns of scapular motion in relation to the thoracic cage (Kibler & McMullen, 2003). Scapular dyskinesis occurs with a large number of injuries in the shoulder and it often caused by injuries that result in the inhibition or disorganization of activation patterns in the scapular stabilizing muscles. It may be caused by a resting posture of excessive thoracic kyphosis and increased cervical lordosis, commonly referred to as forward head rounded shoulder posture (FHRSP). This condition causes excessive scapular protraction and acromial depression, increasing the potential for impingement (Kibler & McMullen, 2003).

Scapular dyskinesis frequently occurs as a result of alterations in muscle activation or coordination. The motion of the scapula results from patterned muscle activation and passive positioning resulting from trunk and arm acceleration. If the

normal muscular force couples of the scapulohumeral region are disturbed then the scapular kinematics will change as well. Most nonphysiologic motion and thus abnormal mechanics that occur with the scapula can be traced to alterations in function of the muscles that control it (Kibler & McMullen, 2003). Inflexibility or contracture of the muscles and ligaments around the shoulder can also affect the position and motion of the scapula. Tightness in the pectoralis minor or in the short head of the biceps can create an anterior tilt and forward pull on the scapula. Lack of full internal rotation of the glenohumeral joint, caused by tightness in the capsule or musculature, affects the normal motion of the scapulothoracic articulation through a "wind up" effect (Kibler & McMullen, 2003). This "wind up" effect causes the glenoid and scapula to be pulled forward and inferior by the moving rotating arm. This creates an excessive amount of protraction of the scapula as the arm continues into an adducted position. The ellipsoidal shape of the upper portion of the thorax then causes the scapula to move disproportionately anteriorly and inferiorly around the thorax with more scapular protraction (Kibler & McMullen, 2003). Scapular dyskinesis can cause a loss of control over scapular retraction/protraction, which may result in impingement as the scapula rotates downward and forward. It may also cause loss of elevation control, and loss of kinetic chain function (Kibler & McMullen, 2003).

It has been proposed that fatigue of the external rotators may be related to scapular dyskinesis. Impairments in the external rotators have been reported in subjects with shoulder impingement syndrome (Ebaugh, McClure, & Karduna, 2006). Ebaugh et al. investigated this theory and found that healthy subjects who

completed an external rotation fatigue protocol demonstrated less external rotation

of the humerus (Ebaugh, McClure, & Karduna, 2006). More importantly the subjects

had less posterior tilt of the scapula in the beginning phase of arm elevation, and

more scapular upward rotation and clavicular rotation in the mid-ranges of arm

elevation (Ebaugh, McClure, & Karduna, 2006). All of these alterations have been

associated with impingement syndrome. It was concluded from this study that

performing an external rotation fatigue protocol results in altered scapulothoracic

and glenohumeral kinematics (Ebaugh, McClure, & Karduna, 2006).

  Many studies have looked at the relationship between altered scapulothoracic

kinematics and impingement syndrome. Studies have consistently shown that

patients with shoulder impingement syndrome present with decreased posterior

tipping/tilting (sometimes referred to as increased anterior tipping), and increased

medial/ internal rotation (Borstad & Ludewig, 2002; Ebaugh, McClure, & Karduna,

2006; Hebert, Moffet, McFadyen, & Dionne, 2002; Ludewig & Cook, 2000;

Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999). Su et al. studied

swimmers before and after practice and found that before practice scapular

kinematics were the same in healthy subjects and those with impingement. After

practice there were significant decreases in scapular upward rotation in those

subjects with impingement syndrome, while practice resulted in no significant

changes for healthy swimmers (Su, Johnson, Gracely, & Karduna, 2004). The

majority of studies also found decreased upward rotation in subjects with

impingement when compared to healthy subjects; however, Lukasiewicz et al.

presented evidence that no difference exists in upward rotation (Borstad & Ludewig,

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2002; Hebert, Moffet, McFadyen, & Dionne, 2002; Ludewig & Cook, 2000; Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999). It has been suggested that a decrease in the amount of scapular posterior tilt may reduce the size of the subacromial space which subjects the rotator cuff tendons to greater compressive forces (Lukasiewicz, McClure, Michener, Pratt, & Sennett, 1999). Karduna et al studied the effects of scapular orientation on contact forces in the subacromial space using cadavers. It was found that posterior tilt and external rotation did not affect subacromial space, but upward rotation did (Karduna, Kerner, & Lazarus, 2005). An increase in scapular upward rotation was found to decrease subacromial clearance. Endo et al. found through radiographic assessment, that in patients with impingement syndrome, upward rotation was impaired at the painful arc angle of abduction. This resulted is reduced available subacromial clearance as the shoulder was abducted (Endo, Ikata, Katoh, & Takeda, 2001). In conclusion, results in the research disagree as to whether upward rotation contributes to impingement syndrome; however, more recent research has found that there are differences in upward rotation between healthy shoulders and those with shoulder impingement syndrome.

Altered scapulothoracic function is often a result of muscular imbalance and may contribute to shoulder instability and impingement. Warner et al used Moire topographic analysis to determine static and dynamic differences in scapulothoracic function, the authors specifically studied scapulothoracic asymmetry which is indicative of scapulothoracic dysfunction. Moire topography uses an optical effect produced when a subject is positioned behind a grid of horizontal lines illuminated by

a point light source. The line shadows cast by the grid conform to the surface topography of the subject. Fringe patterns are formed that appear as contour lines o the subject and as long as the subject is kept parallel to the apparatus the lines will accurately reflect asymmetry of the scapulothoracic area (Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). This study found that when performing a dynamic movement 64% of patients with anterior shoulder instability and 100% of patients with shoulder impingement syndrome demonstrated either asymmetry, increased topography, or frank scapular winging during shoulder flexion whereas only 18% of the control group demonstrated asymmetry or increased topography (Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). The static Moire test demonstrated 57% of patients with impingement syndrome had asymmetry with the affected side being higher than the unaffected side. Thirty-two percent of the patients in the instability group demonstrated asymmetry with the affected side being lower than the unaffected side (Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1992). The findings of this study reiterate that there is a relationship between abnormal scapulothoracic motion, and glenohumeral instability and impingement syndrome. It remains undetermined whether or abnormal scapulothoracic motion causes glenohumeral instability and impingement syndrome or whether it is a result of these disorders.

Posture

Ideal posture maintains the structural integrity and optimum alignment of each component of the kinetic chain. This promotes optimum length-tension relationships,

force couple relationships, and joint kinematics (Clark, 2006). Ideal posture is frequently measured using a plumb line to determine the alignment of specific points on the body to one another. The points of reference used to measure ideal posture include the lobe of the ear, the seventh cervical vertebrae, the acromion process, the greater trochanter, just anterior to the midline of the knee, and slightly anterior to the lateral malleolus. These points form a theoretical line (and should all be aligned along the plumb line) around which the body is balanced in perfect skeletal alignment, yielding equal weight distribution and maximum joint stability (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992). Forward head posture is defined as the tragus (ear) being in front of the plumb line while the rest of the body remains in alignment. The exact angle can be calculated by taking a lateral-medial picture of the subject and measuring the angle made between the vertical plane and the line starting at C7 and running through the tragus of the ear (Figure 1) (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005). Rounded/ forward shoulder posture is described as the acromion of the shoulder being located in front of the plumb line while the rest of the body remains in alignment. The exact angle can be calculated by taking a lateral-medial picture of the subject and measuring the angle made between the vertical plane and the line starting at C7 and running through the midpoint of the shoulder (Figure 1) (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005). These two postural abnormalities often occur in conjunction with one another and are thought to be related to many overuse injuries in the shoulder.

While researchers suggest that FHRSP is related to changes in scapular kinematics, there is no clear relationship in the literature. Finley et al. studied range

of motion in 16 healthy patients with full pain-free range of motion and no history of

shoulder pathology. When compared to an upright posture, adopting a slouched

position significantly increased scapular anterior tip and upward rotation in the

neutral position (Finley & Lee, 2003). Although the stated changes in scapular

movement were small the study clearly showed that a slouched posture with

increased thoracic kyphosis would lead to a decreased posterior tip and decreased

lateral rotation of the scapula. The author hypothesized that more pronounced

alterations in scapular motion would be present with greater humeral elevation

(Finley & Lee, 2003) especially given the previously stated research on dynamic

scapular kinematics. However, Lewis et al found that there is no distinct pattern of

postural deviation when comparing asymptomatic subjects without impingement

syndrome to symptomatic subjects with impingement syndrome (Lewis, Green, &

Wright, 2005). It was found that forward head posture (FHP) was not related to

forward shoulder posture (FSP), thoracic kyphosis, protraction, GH flexion, or GH

abduction. It was also found that thoracic kyphosis was not related to protraction,

GH flexion, or GH abduction (Lewis, Green, & Wright, 2005). From these findings

the authors concluded that static posture in asymptomatic subjects and subjects with

shoulder impingement syndrome does not follow a set pattern. The authors state

that posture may appear to be faulty, yet the individual may be flexible and capable

of large ranges of movement (Lewis, Green, & Wright, 2005). Greenfield et al. found

that protraction, retraction, midthoracic curvature, and scapular symmetry were not

significantly different between healthy subjects and those with overuse injuries. The

authors did find that scapula protraction and rotation were significantly different from

one another. Based on several confounding variables that may have affected the

outcome, the authors deduced that their findings regarding the influence of posture

to shoulder injury were inconclusive (Greenfield et al., 1995).

It has been found that FHRSP may have some effect on shoulder overuse

injuries, although this relationship is still unclear. It has been found that a decrease

in posterior tipping and lateral rotation of the scapula has been associated with

glenohumeral impingement and instability. It may also be argued that repetitive

humeral elevation in a slouched posture may increase the likelihood of

encroachment of the supraspinatus tendon and the development of shoulder

pathology (Finley & Lee, 2003). Furthermore, although Griegel-Morris et al. did not

find a relationship between the severity of postural deviations and the severity and

frequency of pain in the thoraco-cervial-shoulder region they found that the

incidence of pain increased in subjects with more severe postural abnormalities

including kyphosis and interscapular pain, FHP and right cervical pain, FHP and left

cervical pain, FHP and headache, FHP and interscapular pain, LRSP and

interscapular pain and RRSP and interscapular pain (Griegel-Morris, Larson,

Mueller-Klaus, & Oatis, 1992). These postural abnormalities are seemingly related to

pain in the thoraco-cervical-shoulder region, but no clear relationship has been

determined.

Muscular balance

Muscular balance plays a significant role in proper posture and normal

scapular kinematics. Having muscular balance means that anterior and posterior,

and medial and lateral muscles are equal in strength and move in an appropriate sequence with one another. The National Academy of Sports Medicine (NASM) divides muscles into two groups: the movement system that encompasses those muscles that are prime movers, and the stabilization system whose primary job is to stabilize other parts of the body (Clark, 2006). The movement system is characterized as being prone to develop tightness, readily activated during most functional movements, and overactive in fatigue situations or during new movement patterns. The stabilization group is characterized as being prone to weakness and inhibition, less activated in most functional movement patterns, and fatigues easily during dynamic activities (Clark, 2006). The upper extremity movement group consists of the pectoralis major and minor, latissimus dorsi, teres major, upper trapezius, levator scapulae, sternocleidomastoid, and scalenes. The upper extremity stabilization group includes the serratus anterior, middle and lower trapezii, rhomboids, teres minor, infraspinatus, posterior deltoid, longus coli/capitus, and deep cervical stabilizers (Clark, 2006).

Common muscular imbalances include tight anterior shoulder musculature and weak scapular stabilizer musculature, including an overactive upper trapezius and an under active middle trapezius and serratus anterior. It is common that inhibition and/ or weakness of the scapular stabilizers is caused by a direct-blow trauma; microtrauma-induced strain in the muscles; fatigue from repetitive tensile forces; or inhibition by painful conditions around the shoulder (Kibler & McMullen, 2003). Anyone of these situations can cause discord in the normal force couple.

Weakness of the middle trapezius or serratus anterior disrupts the resting position of the scapula (Neumann, 2002).

As previously stated, the upper trapezius often becomes overactive while the serratus anterior becomes under active. This can lead to a shoulder-shrugging motion with upward rotation of the scapula, which causes excess superior translation of the scapula with less efficient upward rotation and reduced posterior tipping (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Clinical consequences of these alterations may include subacromial impingement, associated subacromial bursitis, and rotator cuff or biceps tendonitis (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Upper-extremity distortion pattern is described by the NASM and is characterized by rounded shoulders and a forward head position. This pattern is common in individuals who sit a lot or who develop pattern overload from uni-dimensional training products (Clark, 2006). Common short muscles of interest include the pectoralis minor, pectoralis major, and the upper trapezius. Common lengthened muscles of interest include the lower trapezius, serratus anterior, and the rhomboids (Clark, 2006). This positioning results in protraction of the scapula, and narrowing of the subacromial space which may lead to shoulder impingement syndrome.

It has been suggested in the literature and is commonly used in clinical practice that exercise may be helpful in correcting poor shoulder posture. Wang et al. investigated this theory in twenty asymptomatic patients with forward shoulder posture. The patients performed 5 exercises with therabands (scapular retraction, shoulder shrugging, shoulder abduction, and shoulder external rotation) as well as

one stretch (corner pec stretching) (Wang, McClure, Pratt, & Nobilini, 1999). The subjects were called once a week to encourage compliance and a log was given to them to record how often they did the exercises, however it was not stated how often the subjects completed the exercises. The authors found that there were significant gains in isometric force for both external and internal rotation as well as horizontal abduction (Wang, McClure, Pratt, & Nobilini, 1999). They also found that resting scapular posture did not change and that the scapula showed less superior translation after the exercise program.

Ludewig et al. compared the activation of the upper trapezius and serratus anterior when healthy subjects and those with mild shoulder dysfunction performed a standard push up plus compared to modified versions on the knees, elbows, and against a wall (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). The hypothesis that the standard push up plus would maximally activate the serratus anterior for both groups was correct. The standard push up with a plus also had a low upper trapezius/ serratus anterior ratio, signifying that the serratus anterior was highly activated proportionally to the upper trapezius being minimally activated (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). It was found that selective activation of the serratus anterior with minimal activation of the upper trapezius may improve the relative strength of the serratus anterior and improve the balance of these two muscles in patients with shoulder dysfunction (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Overall, subjects with shoulder dysfunction responded similarly to healthy subjects across all exercise conditions. In clinical cases of shoulder impingement or scapular winging where maximum activation of

the serratus anterior with minimal activation of the upper trapezius is desired the standard push up plus is an optimal exercise. Those patients who are not ready to begin the standard push up plus may benefit from a progression beginning with the wall push up plus, to the elbow push up plus, to the knee push up plus (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). The push up plus is a very beneficial exercise in strengthening the serratus anterior, which is crucial to restoring normal movement patterns and decreasing rounded shoulder posture. Decreasing rounded shoulder posture will help to restore the scapula to a normal resting position.

EMG Analysis

Electromyography (EMG) is commonly used to analyze muscle activation levels and patterns during exercise. The most common muscles analyzed in regards to scapular stabilization are the upper trapezius, lower trapezius, middle trapezius, and serratus anterior (Decker, Hintermeister, Faber, & Hawkins, 1999; Ekstrom, Donatelli, & Soderberg, 2003; Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004; Moseley, Jobe, Pink, Perry, & Tibone, 1992; Moynes, Perry, Antonelli, & Jobe, 1986; Townsend, Jobe, Pink, & Perry, 1991). EMG has been used to analyze several rehabilitation exercises that are intended to improve scapular function and stabilization (Decker, Hintermeister, Faber, & Hawkins, 1999; Ekstrom, Donatelli, & Soderberg, 2003; Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004; Moseley, Jobe, Pink, Perry, & Tibone, 1992; Moynes, Perry, Antonelli, & Jobe, 1986; Townsend, Jobe, Pink, & Perry, 1991). EMG data is most commonly reported as a percentage of a maximal voluntary contraction of the muscle, and most studies on

the scapular stabilizers report the mean and/or peak values during a movement.

(Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Decker, Hintermeister, Faber, & Hawkins, 1999; Ekstrom, Donatelli, & Soderberg, 2003; Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004; Moseley, Jobe, Pink, Perry, & Tibone, 1992; Myers et al., 2005; Townsend, Jobe, Pink, & Perry, 1991). Many articles also studied a ratio of the MVIC of the upper trapezius compared to the lower trapezius, middle trapezius, and serratus anterior (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004).

The exercises that produced the most muscle activity in the serratus anterior included the scapular punches, push up with a plus, and the dynamic hug, shoulder flexion, and shoulder abduction with the best exercise being the flexion and abduction (Ekstrom, Donatelli, & Soderberg, 2003; Moseley, Jobe, Pink, Perry, & Tibone, 1992). However, when looking at literature that focused primarily on serratus anterior exercises it was found that dynamic hugs, push-ups with a plus, and serratus anterior punches were the best exercises (Decker, Hintermeister, Faber, & Hawkins, 1999; Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Exercises that produced the most activity in the upper trapezius were the shoulder shrug, rowing, and abduction in the plane of the scapula above 120 deg (Ekstrom, Donatelli, & Soderberg, 2003; Moseley, Jobe, Pink, Perry, & Tibone, 1992). Exercises that produced the most activity in the middle trapezius were horizontal abduction, prone arm raise overhead, and abduction in the plane of the scapula (Ekstrom, Donatelli, & Soderberg, 2003), (Decker, Hintermeister, Faber, & Hawkins, 1999; Moseley, Jobe, Pink, Perry, & Tibone, 1992). Exercises that produced the most activity in the lower

trapezius were prone arm raise overhead in line with the plane of the scapula, shoulder external rotation at 90 deg of abduction, and abduction (Ekstrom, Donatelli, & Soderberg, 2003; Moseley, Jobe, Pink, Perry, & Tibone, 1992; Myers et al., 2005).

Cools et al studied the balance of the trapezius muscles in overhead athletes with impingement syndrome compared to those without impingement syndrome. It was found that participants with impingement syndrome showed significantly higher EMG activity in the upper trapezius of their injured side compared to the dominant side of the control group (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007). It was also found that within each group a significant increase in EMG activity on the injured side of the patient group was found (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007). There were no interaction effects for middle trapezius muscle activity. In regards to lower trapezius muscle activity, there were significant group effects, but no significant interaction effects. Regardless of the side, there was decreased muscle activity in the lower trapezius in the patient group compared to the control group (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007). This study supports the idea that in patients with impingement syndrome the upper trapezius is over active while the lower trapezius is under active which may cause excess superior translation of the scapula with less efficient upward rotation and reduced posterior tipping (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004).

S3 scapular stabilization brace

The bracing company AlignMed has come out with a new brace designed to correct posture and scapular positioning similar to the theory behind scapular taping.

The Scapular Stabilizing System (S3) brace is "a spine and scapula stabilizing brace designed to improve posture, reduce pain, and increase range of motion." The company designed the S3 brace to "trigger the body to correct improper posture by re-educating and re-engineering the musculo-skeletal system surrounding the shoulders and spine" as well as signaling the neuroreceptors in the skin to engage in proper posture. The company also states that the S3 brace "addresses and lends instant relief to fatigue and poor spine alignment associated with unnatural body position at the computer." There have been no published studies yet on this brace although Uhl et al. performed a study on the prototype of the S3 brace that has not yet been published. The abstract from this study states that the objective was to evaluate the S3 brace on scapular kinematics at rest and during active arm elevation. Fifteen healthy subjects and 15 subjects with scapular dyskinesis were used in this study. The results found that the brace increased posterior tipping by 3 degrees in the first and last 30 degrees of motion, decreased upward rotation in the dominant arm by 4 degrees at 90 degrees of elevation, while increasing upward rotation in the non-dominant arm by 2 degrees in the first and lat 40 deg of elevation. The S3 also decreased internal rotation by 3.5 degrees during the lowering phase of elevation. The authors concluded that the S3 brace affected the scapular kinematics at rest and in the lower ranges of motion and that the increased posterior tipping and decreased internal rotation from wearing the brace may assist the scapular muscles in controlling scapular motion.

Forward head rounded shoulder posture causes excessive scapular protraction and acromial depression increasing the potential for impingement and

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other chronic shoulder injuries. If the S3 brace decreases the shoulder angle this may improve scapular motion by restoring normal posterior tipping, upward rotation, and medial rotation. If the scapula is returned to optimal positioning while wearing the S3 brace then the scapular stabilizers may be more effectively strengthened while performing strengthening exercises. Theoretically, due to improved scapular positioning the lower trapezius, middle trapezius, and serratus anterior activity will increase and upper trapezius activity will decrease. Improved scapular positioning caused by wearing the S3 brace may improve muscular activation of the scapular stabilizers. As a result the scapular stabilizers may be more effectively strengthened while performing strengthening exercises. In conclusion, improving posture will help to decrease the incidence of shoulder pain as well as decreasing the amount of time lost from sports participation and/ or daily activities. This will improve the playing time for overhead athletes as well as the quality of their performance.

CHAPTER 3

Subjects

Males and females between the ages of 18-25 were recruited from the student population at the University of North Carolina at Chapel Hill. Forty subjects were recruited through mass e-mails sent to the student population, through flyers placed around campus, and through exercise and sports science classes. An a priori power analysis was performed on all study variables using previously published data (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Lewis, Wright, & Green, 2005). A sample size of 20 subjects per group was needed in order to achieve a power of 0.80.

Subjects were included if they currently participated in a NCAA, club, or recreational overhead sport 3-4 days a week for at least 1 hour or more. An overhead sport was defined as baseball, softball, swimming, volleyball, tennis, water polo, javelin, shot put, or discus. Subjects displayed forward head rounded shoulder posture. Forward head posture was defined as having a forward head angle ≥ 46º. Rounded shoulder posture was defined as having a forward shoulder angle ≥ 46º. Postural alignment criteria were based on a study done by Thigpen in which he screened 310 individuals from the university population. Those with FHA ≥46° and FSA ≥46° were determined to have the worst posture (Thigpen, 2006). Subjects

were excluded if they had had a shoulder or back injury in the last 6 months,

previous history of shoulder or back surgery, are currently performing formal

shoulder rehabilitation, had any congenital postural abnormalities, a forward head or

rounded shoulder posture less than the specified criteria, and had any prior

experience with the S3 brace. The dominant arm (arm they would throw a ball with)

was tested for each subject. Subjects were randomly assigned to either the

treatment groups or sham group by trained research assistants to allow the principal

investigator to remain blinded to group assignment and treatment condition.

Study Design

This was a single blind randomized-control study. Each subject was blind to

group assignment and brace condition. Subjects were randomly assigned to groups,

and measurements were taken both with the brace applied and without for control

purposes.

Instruments

Posture

Postural screening was performed to ensure that each subject met the criteria

for FHRSP. The principal investigator evaluated posture for each subject by taking a

digital photo of the subject in a sagittal view and using Adobe Photoshop® to

evaluate the head and shoulder angle. Markers were placed on the subject's right

tragus (ear), right acromion, and C7(Griegel-Morris, Larson, Mueller-Klaus, & Oatis,

1992; Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; Sawyer, 2006; Thigpen, 2006) (see Figure 1).

EMG

Surface electromyographic analysis was used to measure muscle activity of the serratus anterior, upper trapezius, lower trapezius, and middle trapezius. The Delsys Bagnoli-8 hard-wired EMG system (Boston, MA) was used, with differential amplification, CMRR >80 dB input input impedance >1015//0.2ohm//pF, SNR > 40dB using an 8 channel amplifier. The EMG signal was amplified by a factor of 1000, over a bandwidth of 0.01 to 2000 Hz passed via an A/D converter (National Instruments, Austin, Texas) sampling at 1000 Hz and corrected for DC bias. Raw EMG data was collected using Motion Monitor® (Innovative Sports Training Inc. Chicago, IL) software.

The skin was prepared prior to EMG placement by cleaning the area with alcohol to ensure good electrode contact and transmission. A bar Ag/AgCl single differential surface electrode (Delsys Inc., Boston, MA) was fixed onto the mid-point of each muscle belly so that the bars lay perpendicular to the muscle fibers. The electrodes were attached using surgical tape and adhesive stickers. Proper electrode placement was determined for each muscle according to the direction of the muscle fibers. Electrode placements were as follows for each muscle:

Upper trapezius- One half the distance from the mastoid process to the root of the spine of the scapula, approximately at the angle of the neck and shoulder (Thigpen, 2006) (See Figure 11).

Middle trapezius- Midway along a horizontal line between the root of the spine of the scapula and the third thoracic spinous process (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Cools, Witvrouw, Declercq, Danneels, & Cambier, 2003) (See Figure 11).

Lower trapezius- Two finger widths medial to the inferior angle of the scapula on a 45° angle towards T10 (Thigpen, 2006) (See Figure 11).

Serratus anterior- Below the axilla, anterior to the latissimus dorsi, placed over 4th through 6th ribs angled at 30° above the nipple line (Thigpen, 2006) (See Figure 11).

Common reference electrode- A common reference electrode was placed over the opposite acromion (Thigpen, 2006) (See Figure 11).

Motion Analysis

The Motion Star electromagnetic motion analysis system (Ascension Technologies, Burlington, VT) was used to determine the start and end of each repetition during each of the exercises for each muscle. This was also used to ensure that the same motion was performed during each exercise under each brace condition. A receiver was placed on the posterior brachium distal humerus (See Figure 11). Positional data was collected with The Motion Monitor® (Innovative Sports Training Inc. Chicago, IL) and sampled at 50 Hz.

S3 Brace

The S3 brace was fitted and applied by two trained research assistants according to manufacturer specifications using a two strap method. The research

assistants fit all subjects for the correct size. If a subject was in between sizes then he or she tried on both sizes and the research assistants determined which size had the best fit. Neither the treatment group nor the sham group was educated on the reasons for wearing the S3 brace. Men were shirtless and women wore a sports bra. After putting on and zipping up the S3 brace; both groups tightened the Velcro pads on the waist band so that they were snug, but not uncomfortable. Both groups were instructed to retract and depress the shoulder blades in preparation for strap placement. The treatment group had a small (C) strap applied from the posterior, superior Velcro pad (over the upper trapezius muscle) to the contralateral waist band. This method was repeated for the opposite side. Next, the medium (B) strap was attached from the lateral, superior Velcro pad (over the pectoralis major muscle) to the contralateral waistband Velcro pad inferior to the (C) strap. This method was repeated for the opposite side (Figure 3). The sham group used the same method of applying the brace, but the medium (B) straps were used in place of the short (C) straps and the long (A) straps were used in place of the medium (B) straps. There was a 5 ½ to 6 inch difference between the B and C straps and a 6 inch difference between the A and B straps. Due to this difference in length the straps did not cause retraction, but maintained the look of the brace.

Procedures

Screening

Subjects were brought into the Sports Medicine Research Laboratory (SMRL) for a 10 minute screening session prior to the beginning of testing. Those subjects

that fit the criteria for FHRSP were brought back to the SMRL for one fitting session

and one testing session. All subjects read and signed a consent form to participate

in the study.

Counterbalancing

Counterbalancing was used to determine whether subject performs exercises

with or without brace first. Counterbalancing was also used to determine in what

order each subject performed the exercises and what order the MVIC's were

performed.

Posture

During postural alignment assessment subject's stood 40cm in front of a grid

screen with reflective markers placed on the subject's right tragus (ear), right

acromion, and 7th cervical vertebrae spinous process (see Figure 2).   High

resolution digital pictures were then taken in a sagittal plane to determine the plumb

line through the C7 spinous process. The primary investigator stood 3m from the

grid and the camera was positioned on a tripod. The photos were then uploaded

onto a personal computer for postural analysis using Adobe® Photoshop. The

photos were then used to calculate the shoulder and head angle of each subject to

determine whether or not they were included in the study. Forward head position

was defined as having a forward head angle greater than or equal to 46° relative to

the vertical line extending from C7 to the line connecting C7 to the tragus. Rounded

shoulder position was described as having a forward shoulder angle of greater than

or equal to 46° relative to the vertical line extending from C7 to the line connecting

C7 to the acromion (Sawyer, 2006; Thigpen, 2006). Postural alignment criteria were

based on a study done by Thigpen in which he screened 310 individuals from the

university population.

MVIC

A maximal voluntary isometric contraction (MVIC) assessment was performed

against manual resistance. Each subject performed one sub-maximal contraction to

familiarize themselves with the manual muscle testing position. Subjects performed

3 MVIC's for each muscle (lasting 5 seconds each) with 1 minute rest between each

muscle and 30 seconds between each trial. The average EMG amplitude for all of

the trials was recorded. The order of the muscles tested was randomized. MVIC's

were tested as follows:

Upper trapezius- The subject was seated with arms at his/her sides. The tester

stood behind the subject and gave the subject instructions to "shrug the shoulder"

which was being tested and "rotate the head in the opposite direction." The tester

applied a stabilizing force to the back of the head and a downward force to the

acromion for 5 seconds. The subject was then instructed to "relax" (Kendall, 1993).

Middle trapezius- The subject laid in the prone position with the shoulder abducted

to 90° and externally rotated. The tester stood at the subject's side and gave the

subject instructions to "raise the arm towards the ceiling" while the tester applied a

downward force to the proximal end of the brachium for 5 seconds. The subject was

then instructed to "relax" (Kendall, 1993).

Lower trapezius- The subject laid in the prone position with the arm raised overhead

in line with the lower trapezius muscle fibers. The tester stood at the subject's side

and gave the subject instructions to "raise the arm towards the ceiling" while the

tester applied a downward force to the proximal end of the brachium for 5 seconds.

The subject was then instructed to "relax" (Kendall, 1993).

Serratus anterior- The subject was seated with the arm shoulder flexed between

120° and 130°, with the arm internally rotated. The tester stood beside the subject

and gave the subject instructions to "raise the arm towards the ceiling," while the

tester applied a downward force to the proximal end of the brachium for 5 seconds.

The subject was then instructed to "relax" (Kendall, 1993).

Exercises

The exercises performed were scapular punches, Y's, T's, W's forward flexion,

and shoulder extension. The exercises were performed as follows:

1. Scapular punches were performed lying supine on a table with the arm in 90°

    of flexion. The patient then protracted the scapula by raising the fist towards

    the ceiling (see Figure 7).

2. Y's were described as an arm raise above the head with the upper extremity

    in line with the lower trapezius muscle fibers in the prone position (Ekstrom,

    Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a

    table with arms hanging down in front and palms facing each other. Arms

    were in the 10 and 2 o'clock position (at about 125°) and thumbs were raised

towards the ceiling. Arms were raised until they were parallel to the floor (see Figure 4).

3. T's were described as shoulder horizontal extension with external rotation in the prone position (Ekstrom, Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a table with arms hanging down in front. Arms were raised out to the side in horizontal extension until they were parallel to the floor (see Figure 5).

4. W's were described as prone external rotation with shoulder abducted to 90° and elbow flexed to 90°. This exercise was performed while lying prone on a table with arms hanging down in front. Arms were raised so that brachium is parallel to the floor with the elbow bent to 90°. The arms were then externally rotated (see Figure 6).

5. Forward flexion was performed in the sagittal plane. The exercise began with the arm at 0° of flexion and it was elevated with the forearm in a neutral position (thumb facing ceiling) in the sagittal plane to full shoulder flexion(Myers et al., 2005) (see Figure 8).

6. Shoulder extension was performed in the sagittal plane. The exercise began with the arm at 90° of flexion with the forearm in a neutral position (thumb facing ceiling) and was moved into full shoulder extension and then back to 90°(Myers et al., 2005) (see Figure 9).

Prior to data collection the proper amount of weight for each exercises was determined. The amount of weight used for each exercise was 1% of the subject's body weight for Y's, T's, W's, forward flexion, and shoulder extension. The amount

of weight used for scapular punches was 5% of the subject's body weight. Subjects were allowed to perform no more than 5 repetitions of each exercise as practice. During testing the subjects performed 10 repetitions of each exercise. A 1 minute rest period was allowed between each exercise. A metronome set at 60 beats per minute was used to control the movement velocity of each exercise.

Data Processing and Reduction

All data were exported into a custom MatLab program (Mathworks, Natick, MA). EMG data were rectified, bandpass filtered from 10-350Hz and smoothed via root mean square with a time constant of 15 ms. EMG was normalized to the mean EMG amplitude obtained during the middle seconds of 3 MVIC trials. Mean normalized EMG amplitude was calculated across the entire movement (from the onset of movement to the end of that repetition). Onset of movement and end of the repetition was visually identified using the positional data from the electromagnetic motion analysis system. The EMG amplitudes were averaged across all 10 trials for data analysis. Posture measurement and EMG values were imported into SPSS version 14.0 for analysis.

Statistical Analyses

Twelve separate mixed-model ANOVA's were used to analyze EMG activity between the sham group and the treatment group, as well as comparing within subjects when they were wearing the brace and when they were not wearing the brace. Two separate 2x2 mixed model ANOVA were used to analyze posture

between groups and within groups regarding the brace condition. SPSS statistical

software (version 14.0, SPSS Inc, Chicago, IL) was used to analyze all data. For

statistical analyses an a priori level of 0.05 was set as the level of significance.

CHAPTER 4

Descriptive Statistics

A total of 38 participants were tested for this study. Nineteen subjects were in the sham group and 19 subjects were in the treatment group. Nine males and 29 females were tested. The participant's average age was 19.5 years and average weight was 165.9 lbs. Thirty-six participants were right hand dominant and 2 participants were left hand dominant. One baseball player, 6 softball players, 13 swimmers, 9 volleyball players, and 9 track throwers were tested in this study. Twenty-three varsity athletes, 11 club athletes, and 4 recreational athletes participated in this study. Descriptive statistics are presented in table 1.

EMG activity was excluded for a few subjects in specific muscles and exercises due to the fact that they were outliers and would skew the data if left in during statistical analysis. For braced forward flexion for the upper trapezius one subject was eliminated. For braced forward flexion for the middle trapezius three subjects were removed. For braced forward flexion for the lower trapezius one subject was removed. For braced forward flexion for the serratus anterior four subjects were removed. For braced shoulder extension for the upper trapezius one subject was removed. For braced shoulder extension for the middle trapezius one subject was removed. For braced shoulder extension for the serratus anterior four

subjects were removed. For braced scapular punches for the serratus anterior three subjects were removed. For non braced forward flexion for the upper trapezius one subject was removed. For non braced forward flexion for the middle trapezius three subjects were removed. For non braced forward flexion for the lower trapezius three subjects were removed. For non braced forward flexion for the serratus anterior five subjects were removed. For non braced shoulder extension for the upper trapezius one subject was removed. For non braced shoulder extension for the middle trapezius, three subjects were removed. For non brace shoulder extension for the lower trapezius three subjects were removed. For non braced shoulder extension for the serratus anterior three subjects were removed. For non braced T's for the middle trapezius two subjects were removed. For non braced scapular punches for the serratus anterior one subject was removed.

Posture

The average change in forward head posture for the sham group was 0.79 ± 1.87 degrees. The average change in forward shoulder posture for the sham group was 1.63 ± 6.55 degrees. The average change in forward head posture for the treatment group was 2.00 ± 2.03 degrees. The average change in forward shoulder posture for the treatment group was 8.00 ± 7.78 degrees. Means and standard deviations are listed in table 2. Power and effect size are listed in table 6. A significant main effect was found for forward shoulder posture for the brace vs. no brace condition ($F_{1,38}$= 5.106, p=0.030)There was an average decrease of 3.19° from the braced condition to the no brace condition. There were no significant

differences for forward head or forward shoulder posture for group. There were no significant differences for forward head posture for brace condition. There were no interaction effects found for forward head or forward shoulder posture. (See figures 20 and 21 for graphs.) The results tell us that there was no improvement in forward head angle when comparing brace to no brace or when comparing treatment group to sham group. The results also show that there was a decrease in forward shoulder angle when comparing the brace condition to the non-braced condition; however there was no difference in comparing sham group to treatment group.

EMG

Means and standard deviations for normalized EMG are listed in tables 3, 4 & 5. Power and effect size are listed in table 6. A significant main effect was found for normalized EMG shoulder extension for the upper trapezius for brace vs. no brace condition ($F_{1,34}=12.837$, p=0.001). There was an average decrease of 2.97% in normalized upper trapezius EMG from the no brace condition compared to the brace condition (see figure 15). There were no main group effects or interaction effects for this exercise and muscle. A significant interaction effect was found for normalized EMG W's for the upper trapezius ($F_{1,36}=4.710$, p=0.037). This means that upper trapezius activity in the treatment group decreased from the non braced condition to the braced condition, while upper trapezius activity in the sham group increased from the non braced condition to the braced condition (see figure 18). There were no main group effects or main condition effects for this exercise and muscle. There

were no main or interaction effects for the upper trapezius in forward flexion (See figure 14).

A significant main effect was found for normalized EMG shoulder extension for the middle trapezius for braced vs. no brace condition ($F_{1,33}$=7.282, p=0.011). There was an average decrease of .95% in the normalized middle trapezius EMG from the no brace condition compared to the brace condition. There were no significant main or interaction effects for forward flexion or T's for middle trapezius (see figures 14 and 17, respectively)

A significant main effect was found for normalized EMG forward flexion for the lower trapezius for brace vs. no brace condition ($F_{1,33}$=12.563, p=0.001). There was an average increase of 3.55% in normalized lower trapezius EMG from the no brace condition compared to the brace condition (see figure 14). There were no main group effects or interaction effects for this exercise and muscle. A significant main effect was found for normalized EMG Y's for the lower trapezius for braced vs. no brace ($F_{1,36}$=6.685, p=0.041). There was an average increase of 6.5% in the normalized lower trapezius EMG from the no brace condition to the brace condition (see figure 16). There were no main group effects or interaction effects for this exercise and muscle. There were no main or interaction effects for the lower trapezius when looking and shoulder extension (see figure 15).

There were no main or interaction effects for the serratus anterior for any exercise (see figure 19). This includes forward flexion, shoulder extension, and scapular punches. These results tell us that the wearing the brace increased lower trapezius activity when performing forward flexion and Y's. The results also tell us

that wearing the brace decreased lower trapezius activity when performing shoulder extension and W's. Wearing the brace also decreased middle trapezius activity during shoulder extension. The results show that the muscle activity of the serratus anterior was not significantly affected by wearing the brace. Muscle activity was not significantly affected by wearing the sham strap application of the brace compared to the treatment strap application.

CHAPTER 5

The purpose of this study was to determine whether or not the S3 scapular stabilizing brace corrects the posture of participants with FHRSP. In addition, this study determined whether or not wearing the S3 scapular stabilizing brace has an effect on the muscle activity of participants with FHRSP while performing six scapular stabilization exercises. Our results indicate that wearing the brace compared to not wearing the brace had an effect on both posture and EMG; however there was no significant difference between then sham group and the treatment group.

Posture

It was found that forward head posture was not improved with sham or treatment application of the brace. Although it was hypothesized that the brace would decrease forward head posture this did not occur. Since the S3 brace did not apply any direct force to the head or the cervical spine then it is not surprising that there was no change in FHP. Lewis et al. however, found that scapular taping did improve FHP compared to a placebo tape job when Leukotape was applied from the center of the spine of the scapula to the spinous process of T12 in a diagonal fashion (Lewis, Wright, & Green, 2005). The subjects were asked to retract and depress their scapulas as were our subjects during application of the S3 brace. This

difference in these findings cannot be fully explained, but it is possible that the direct application of the Leukotape to the skin may have allowed for a greater change in forward head posture compared to the brace where the attachment of the Velcro pads to a strap that goes over the acromion inside the brace is what retracts the shoulders.

Although FHP was not changed, FSP was significantly decreased when subjects were wearing the brace compared to when they were not wearing the brace. However, there was not significant difference in the sham group compared to the treatment groups, in both groups FSA was decreased when wearing the brace compared to not wearing the brace. This suggests that it may not be the straps that cause the decrease in shoulder angle, but it may be the proprioceptive effects of the brace. Lewis et al. also found that scapular taping in the manner described previously caused a decrease in FSA (Lewis, Wright, & Green, 2005). Again, the tape was applied directly to the skin and this may be more effective than applying the straps to the brace. It is also possible that although the straps used in the sham treatment were 51/2 to 6 inches longer than the treatment straps they may not have been long enough to completely prevent shoulder retraction. Further studies should be done to investigate different brace applications and how they affect FHP and FSP. While the change in FSP may seem small this may be enough to make a difference clinically. Since this wearing the brace one time had positive effects, it is possible that with regular use of the S3 brace this difference would increase and have more of an effect overtime.

EMG

There were no group effects found for EMG meaning that there were no significant differences between the sham group and the treatment group. Condition effects were found for certain muscles during certain exercises, which generally demonstrated that bracing, regardless of group, changed EMG activity. When evaluating EMG in relation to shoulder pathology it has been found that the upper trapezius is overactive while the middle trapezius, lower trapezius, and the serratus anterior are under active. This causes a disruption in the force couple which leads to changes in scapular kinematics. Ultimately these changes in the force couples and in scapular kinematics may lead to chronic shoulder pathologies such as subacromial impingement, associated subacromial bursitis, and rotator cuff or biceps tendonitis (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Cools et al studied the balance of the trapezius muscles in overhead athletes with impingement syndrome compared to those without impingement syndrome and it was found that patients with impingement syndrome showed significantly higher EMG activity in the upper trapezius of their injured side compared to the dominant side of the control group (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007). It was hypothesized that wearing the S3 brace while performing shoulder exercises would decrease the muscle activity of the upper trapezius and increase the muscle activity of the middle trapezius, lower trapezius, and serratus anterior thereby creating a more normal force couple for these muscles.

Upper Trapezius

This study found the most changes with upper trapezius activity. With shoulder extension the EMG activity of the upper trapezius was decreased when wearing the brace compared to not wearing the brace, which is desirable to restore a normal force couple. However there was no difference between the sham group and the treatment group. An interaction effect was observed for the upper trapezius when performing W's in which the EMG activity of the upper trapezius was decreased. The changes in EMG activity of the upper trapezius during W's and shoulder extension support the hypothesis that EMG activity will be decreased when wearing the brace compared to not wearing the brace. Given these findings it is possible that wearing the brace may help to inhibit the upper trapezius during rehab and daily activity. This may decrease the incidence of chronic shoulder injury by restoring a more normal force couple to the shoulder which will thereby change the scapular kinematics and decrease shoulder shrugging which leads to a closing off of the subacromial space. The fact that upper trapezius activity did not change when comparing the sham group to the treatment does no support out hypothesis that the treatment group will show a decrease in activity while the sham group shows no change. This suggests that it is not the particular strap placement that caused the change in EMG since using much looser straps also caused a change. This could mean that there are proprioceptive changes caused by wearing a compression shirt that effect EMG activity or it could mean that there was not enough of a difference in the tension of the straps in the sham group compared to the tension of the straps in the treatment group to cause significant changes.

Lower Trapezius

An increase in lower trapezius activity was found when comparing braced to non braced condition for forward flexion and Y's. Again this is what was hypothesized and could have a positive effect in changing scapular kinematics. However, as with the upper trapezius no group effect was found for the lower trapezius meaning that there was no difference between the sham group and the treatment group. Given these findings, wearing the brace during exercises that target the lower trapezius could help to activate the muscle thereby more effectively strengthening it. As previously stated, strengthening the lower trapezius is desirable to restore a more normal force couple and prevent narrowing of the subacromial space. The fact that there were no significant changes between the sham and treatment group suggests again that either EMG changes were due to proprioceptive reactions or that this strap placement was not the most effective.

Middle Trapezius

The middle trapezius was found to have a very slight decrease in EMG activity when comparing the braced to the non brace conditions during shoulder extension. This decrease is not readily explained by the literature, but it is possible that since the middle trapezius would have been most active during the end range of extension the brace may have limited this range of motion thereby decreasing the overall EMG activity. No change was shown in the middle trapezius comparing the braced condition to the non braced condition when performing T's. Although the middle trapezius does not have an effect on the force couple created at the scapula

by the other muscles discussed and therefore may not change with functional motions, it seems logical that for horizontal abduction some change would occur, but this did not happen. Moseley et al found that horizontal abduction with external rotation (T's) was on of the best exercises to produce activity in the middle trapezius (Moseley, Jobe, Pink, Perry, & Tibone, 1992). It is possible that since the brace should cause some scapular retraction the middle trapezius did not have to work as hard to move the scapula. However, further research is necessary to determine why these changes occurred.

Serratus Anterior

There were no significant changes found for serratus anterior EMG during forward flexion, shoulder, extension, or scapular punches. While it was expected that serratus anterior activity would significantly increase during scapular punches it is possible that the muscles was not loaded enough to should significant changes. While scapular punches have been shown to be effective in activating the serratus anterior and the subjects used 5% of their body weight for the punches, push up with a plus has been shown to be the most effective exercise (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). This exercise was not chosen for this particular study due to the fact that perfoming a push up with a plus is somewhat challenging and takes time to learn how to perform it properly as well as the fact that it may have fatigued some subjects and prevent them from completing all of the exercises.

Although the changes seen in EMG for the UT and LT were not great they may be enough to show a significant clinical effect. The changes in EMG may

become more significant overtime if the brace is regularly paired with rehabilitation exercises. As is true with all strengthening exercises, results are not seen after one session, but will show overtime. The same is true of rehabilitation exercises and it is possible that greater EMG changes would be seen when comparing baseline EMG with no brace to EMG with the brace after several weeks of a rehabilitation program.

Many studies have looked at the effects that a compressive brace, such as a neoprene sleeve have on proprioception of the joint around which it is worn. Studies in both the knee and shoulder have determined that wearing a neoprene or other compressive sleeve do help to improve joint repositioning sense. Most of these studies found that improvements were significant or greater for those who had what was classified as "poor proprioception" to begin. However when using a fatigue protocol and comparing knee sleeve to no knee sleeve conditions Van Tiggelen et al. found that pre-fatigue the knee sleeve only improved active joint position sense in those with poor proprioception and not good proprioception. After the fatigue protocol however, the researchers found that proprioception was improved in both the good and poor proprioception groups when wearing the knee sleeve compared to not wearing the knee sleeve (Tiggelen, Coorevits, & Witvrouw, 2008).   Perlau et al. found that wearing an elastic bandage around the knee helped to improve passive joint reposition sense for the knee in uninjured patients (Perlau, Frank, & Fick, 1995). It was also determined in this study that the effects of the elastic bandage were maintained after 60-90 minutes of light activity while still wearing the elastic bandage. The improvement in passive joint reposition sense was maintained after the elastic bandage was removed and there was no significant difference in

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that measure compared to the pre-application measure (Perlau, Frank, & Fick, 1995).

On the other hand, Beynnon et al found that in an ACL deficient population that

neither wearing a functional knee brace or a neoprene sleeve improved passive joint

reposition sense when compared to the other knee significantly although changes

were noted. The threshold to detection of passive knee motion was significantly

worse for the ACL deficient knee than for the uninjured knee in this study (Beynnon

et al., 1999). Although most studies investigating the effects of a neoprene sleeve

on joint reposition sense have looked at the knee or sometimes ankle there have

been a few done on the shoulder joint. Ulkar et al. studied the effect of positioning

and bracing on passive joint position sense in the shoulder. This study looked at

patients with healthy shoulders and tested the subjects at different start positions

with and without a neoprene sleeve. This study found that there was a significant

difference in joint repositioning sense when wearing the neoprene sleeve compared

to not wearing it (Ulkar, Kunduracioglu, Cetin, & Guner, 2004). Therefore the

neoprene sleeve may improve proprioception by interfering with cutaneous

mechanoreceptors. In relation to this study it means that the compressive aspects of

the brace could have some effect of the improved posture. The company states that

proprioceptive padding helps to improve scapular kinematics along with the Velcro

strapping system. Given the effects of the neoprene sleeve studies it could be

possible that the padding cues mechanoreceptors to keep the scapulas down and

back. However, much more research needs to be done to prove that this occurs.

The S3 Brace

The S3 brace has been designed to improve posture and reduce pain in patients suffering from poor posture and shoulder injuries. It has been found in previous unpublished studies that the S3 brace improves scapular kinematics and rest and in the lower ranges of motion. The designers of the brace state that through a "Velcro strapping system coupled with proprioceptive padding" the brace attempts to restore normal shoulder kinematics. Previous studies have found that exercise may improve scapular kinematics although it is unclear whether scapular positioning is improved. Wang et al found that when patients performed an exercises regimen that included 5 shoulder exercises resting scapular posture did not change and that the scapula showed less superior translation after the exercise program(Wang, McClure, Pratt, & Nobilini, 1999). Ludewig et al found that selective activation of the serratus anterior with minimal activation of the upper trapezius may improve the relative strength of the serratus anterior and improve the balance of these two muscles in patients with shoulder dysfunction (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). It is believed that strengthening the lower trapezius, middle trapezius, and serratus anterior muscles with the scapula in the proper position and a more normal force couple restored would overtime help to restore the force couple in the long run during rehabilitation exercises, sport activity, and everyday movements. Given the findings of this study it can be stated that wearing the brace does cause positive changes in forward shoulder posture and EMG activity of the upper and lower trapezii, however it has not been determined that these changes are a direct result of the strap placement suggested by the AlignMed company. This study does not disprove the claims that the AlignMed company has made in regards

to the effectiveness of the brace, but further studies must be done to determine whether the changes seen are a result of corrective straps or merely the result of the proprioception caused by wearing a compressive shirt.

Limitations

Limitations include the fact that the brace was fitted and applied by the two research assistants who were trained by a bracing representative rather than the bracing representative herself. The initial study design called for the braces to be fit by the bracing representative however this was not possible during the actual study. This may have negatively affected the study since a trained professional was not fitting the braces and the straps for the sham group could have been fit too tightly while the straps for the treatment groups could have been fitted too loosely. A second limitation is that in meeting with the trained bracing company representative for brace fitting training she stated that she sometimes uses the corresponding straps for the brace one size up if a patient has a long torso. There is about a two-inch difference between sizes for corresponding straps. If this method is effective then the effectiveness of the sham treatment for those with longer torsos may have been decreased if the straps of the brace size that they were fitted for were used. What this means is that some people in the sham group could have inadvertently received the actual treatment because there would be more tension at the straps than for someone with a shorter torso. Also addressing correct fit of the brace, it was found throughout the study that the brace fit males better than females. It was found the brace was often too wide in the shoulders for females which moved the

placement of the internal strap over the acromion rather than between the acromion and the neck. This could decrease the effectiveness of the brace in females since it is not fitting as it was designed. A third limitation was that during exercises the brace tended to gather in the back between the placement of the C straps. This affects the pull of the straps on the shoulders and may change the effectiveness of the brace. It is likely that, since the straps were not adjusted after the initial application, the straps lost their tension and prevented significant findings. It is suggested that the brace be adjusted between exercises to ensure proper alignment of the straps. A fourth limitation is that we used only one type of brace application. This was the application recommended by representatives from the AlignMed company and is most commonly used clinically by them. There are also several other brace applications that could be used. Different brace applications may affect posture and EMG differently and using a different method may be more beneficial.

A fifth limitation is that the straps could have restricted motion or caused a mechanical restraint prevent a normal movement pattern. Guide poles were used to determine the end of motion and therefore the movement pattern should have been relatively the same for the brace and non-brace condition; however if the brace provided a mechanical restraint then the muscle may have to work harder during the end range of motion to reach the guide pole. If the muscle worked harder then t is possible that EMG would have been increased and therefore given a false positive that EMG activity had increased due to better position of the scapula. Restricted motion could be a possible cause of the decrease seen in the middle trapezius during shoulder extension as was previously discussed. A sixth limitation is that as

with all studies involving EMG there is variability and due to this variability outliers can exist. In this study several values had to be removed for specific exercises and muscles because they were outliers and would have skewed the data. Finally, a possible limitation was found in the measurement technique used to determine FHRSP. It has already been established that technique of taking a profile picture and measuring posture using Adobe Photoshop® has a 4-5 ° error rate (Thigpen, 2006). It is possible that shrugging the shoulders may cause an increase change in the FSA.

Future Research

Future research should investigate different the brace applications described by the bracing company and how they affect FHRSP and EMG activity. Future research should compare different strap applications to just wearing the compression shirt portion of the brace without the straps applied. This was not done in this study in an effort to blind the primary researcher to the group that the subject was in. Future research should also evaluate different exercises which may better engage the specified muscles such as the push up plus for the serratus anterior.

Future research should investigate the cumulative effects of wearing the brace while performing exercises to determine whether or not changes continue to occur. This could be done through an intervention program lasting several weeks in which the subjects wear the brace while performing various daily or weekly rehab exercises. Not only would this better help to determine the long-term effects of the brace, but it would further help to determine clinical significance since this is the manner in which the brace would be used clinically rather than wearing it just once

and expecting large changes. It would also be useful to include a survey in future research to determine whether the patient feels that the brace is improving posture, the comfort level of the brace, whether the brace felt different after exercises compared to before. This would be especially useful in studies comparing a treatment group to a sham group as this one did to determine if patients feel they are receiving a treatment and how that affects results. Further investigation should be done to determine whether or not it is the strap application or the proprioceptive effects of the brace that caused changes in the FSA and muscle activity for the upper, middle, and lower trapezii.

Conclusion

In conclusion, this study found that there were significant changes in FSA and upper, middle, and lower trapezii EMG activity caused when wearing the S3 brace compared to not wearing it. However, this study did not find significant differences in the treatment group compared to the sham group for FHRSP or EMG activity in any muscles. This indicates that the specific strap application may not be the cause (or at least not the sole cause) of the changes in posture and EMG activity. This is not to say that use of the brace is ineffective or unwarranted, but future studies should be performed to further determine the effectiveness of the brace in improving posture and EMG activity.

APPENDIX A: TABLES

Table 1: Means and numbers for subject characteristics

Males		9
Females		29
Average Age in yrs		19.5 ± 1.2
Average Weight in pounds		165.9 ± 34.0
Right hand dom.		36
Left hand dom.		2
Sport	Baseball	1
	Softball	6
	Swimming	13
	Volleyball	9
	track throws	9
Level	Varsity	23
	Club	11
	Recreational	4

Table 2: Means and standard deviations for posture measurements in degrees

Measurement	Condition	Sham	Sham SD	95% CI	Treatment	Treatment SD	95% CI
Forward Head Angle	Brace	47.89	2.865	(46.30, 50.59)	46.58	4.273	(44.13, 48.64)
	No Brace	48.58	2.168	(43.96, 49.27)	47.32	4.773	(46.75, 50.36)
Forward Shoulder Angle*	Brace	58.63	9.962	(51.52, 68.26)	57.21	7.315	(51.78, 60.68)
	No Brace	61	8.212	(53.75, 67.36)	61.21	12.309	(52.38, 68.38)

*Significant main effect for brace ($F_{1,38}$= 5.106, p=0.030)

Table 3: Means and standard deviations for forward flexion normalized EMG in percentages

Muscle	Condition	Sham	Sham SD	95% CI	Treatment	Treatment SD	95% CI
UT	Brace	50.42%	32.90%	(17.59%, 89.90%)	47.48%	16.02%	(35.81%, 56.68%)
	No Brace	50.97%	42.06%	(9.73%, 104.6%)	52.57%	17.62%	(38.42%, 60.90%)
MT	Brace	23.77%	11.75%	(14.19%, 34.71%)	26.83%	10.55%	(19.01%, 31.32%)
	No Brace	24.94%	11.62%	(13.59%, 34.51%)	26.10%	10.96%	(20.31%, 30.27%)
LT*	Brace	25.41%	6.96%	(21.73%, 31.24%)	28.15%	11.65%	(17.65%, 31.24%)
	No Brace	23.22%	9.05%	(16.25%, 29.01%)	23.46%	11.65%	(14.64%, 26.48%)
SA	Brace	37.41%	11.84%	(29.80%, 48.60%)	43.47%	16.51%	(33.76%, 55.86%)
	No Brace	39.61%	11.88%	(33.12%, 50.00%)	43.71%	10.74%	(36.43%, 51.03%)

*Significant main effect for brace ($F_{1,33}$=12.563, p=0.001)

Table 4: Means and standard deviations for shoulder extension normalized EMG in percentages

Muscle	Condition	Sham	Sham SD	95% CI	Treatment	Treatment SD	95% CI
UT**	Brace	17.79%	7.44%	(12.12%, 24.08%)	18.46%	6.56%	(14.52%, 21.64%)
	No Brace	20.95%	10.07%	(12.63%, 30.48%)	21.03%	7.82%	(16.26%, 24.32%)
MT***	Brace	12.90%	4.73%	(8.37%, 14.50%)	12.58%	4.33%	(9.98%, 15.17%)
	No Brace	14.31%	4.40%	(9.56%, 16.20%)	13.02%	4.33%	(10.91%, 15.88%)
LT	Brace	25.08%	10.55%	(15.00%, 34.12%)	19.09%	11.58%	(11.86%, 27.87%)
	No Brace	24.21%	8.09%	(11.75%, 21.32%)	16.89%	7.27%	(15.33%, 27.36%)
SA	Brace	12.47%	5.91%	(9.10%, 19.31%)	15.14%	6.32%	(11.73%, 18.12%)
	No Brace	12.78%	6.69%	(9.02%, 19.72%)	15.01%	7.11%	(10.54%, 18.18%)

**Significant main effect for brace ($F_{1,34}=12.837$, p=0.001)
***Significant main effect for brace ($F_{1,33}=7.282$, p=0.011)

Table 5: Means and standard deviations for normalized EMG in percentages
†

Muscle	Condition	Sham	Sham SD	95% CI	Treatment	Treatment SD	95% CI
Y's- LT†	Brace	70.61%	30.37%	(42.77%, 69.83%)	67.88%	25.12%	(50.65%, 77.41%)
	No Brace	65.97%	29.72%	(39.66%, 67.84%)	59.51%	19.74%	(44.10%, 70.90%)
T's- MT	Brace	67.24%	19.50%	(56.95%, 84.10%)	62.10%	19.27%	(51.61%, 72.69%)
	No Brace	67.70%	18.62%	(59.79%, 88.85%)	62.99%	20.76%	(52.02%, 76.46%)
W's- T††	Brace	45.06%	23.60%	(22.42%, 59.89%)	38.96%	23.39%	(24.04%, 51.31%)
	No Brace	40.93%	22.48%	(16.57%, 59.34%)	45.76%	22.89%	(29.12%, 58.70%)
Scapular punch- SA	Brace	23.98%	10.25%	(13.85%, 28.49%)	27.28%	11.43%	(20.00%, 34.75%)
	No Brace	25.89%	9.08%	(18.65%, 28.16%)	24.21%	0.85%	(19.40%, 67.84%)

† Significant main effect for brace ($F_{1,36}=6.685$, p=0.014)
†† Significant interaction effect ($F_{1,36}=4.710$, p=0.037)

Table 6: Effect Size and Power

Activity	Muscle	Comparison	Effect size	Power
Forward flexion	UT	within-subjects	0.450	0.241
		interaction	0.030	0.173
		between subjects	0.000	0.051
	MT	within-subjects	0.001	0.053
		interaction	0.015	0.104
		between subjects	0.001	0.088
	LT	within-subjects	0.276	0.931
		interaction	0.048	0.241
		between subjects	0.222	0.074
	SA	within-subjects	0.034	0.173
		interaction	0.022	0.128
		between subjects	0.042	0.204
Shoulder extension	UT	within-subjects	0.274	0.936
		interaction	0.004	0.065
		between subjects	0.001	0.052
	MT	within-subjects	0.181	0.745
		interaction	0.056	0.274
		between subjects	0.009	0.084
	LT	within-subjects	0.042	0.215
		interaction	0.008	0.080
		between subjects	0.133	0.587
	SA	within-subjects	0.001	0.053
		interaction	0.007	0.074
		between subjects	0.038	0.193
Y	LT	within-subjects	0.157	0.711
		interaction	0.015	0.112
		between subjects	0.009	0.084
T	MT	within-subjects	0.003	0.060
		interaction	0.000	0.057
		between subjects	0.019	0.122
W	UT	within-subjects	0.008	0.081
		interaction	0.116	0.561
		between subjects	0.008	0.051
Scapular Punch	SA	within-subjects	0.005	0.067
		interaction	0.078	0.369
		between subjects	0.002	0.058
Forward head angle		within-subjects	0.085	0.430
		interaction	0.000	0.051
		between subjects	0.035	0.200
Forward shoulder angle		within-subjects	0.124	0.595
		interaction	0.009	0.087
		between subjects	0.001	0.005

APPENDIX B: FIGURES

Figure 1: Head and Shoulder Angle Measures
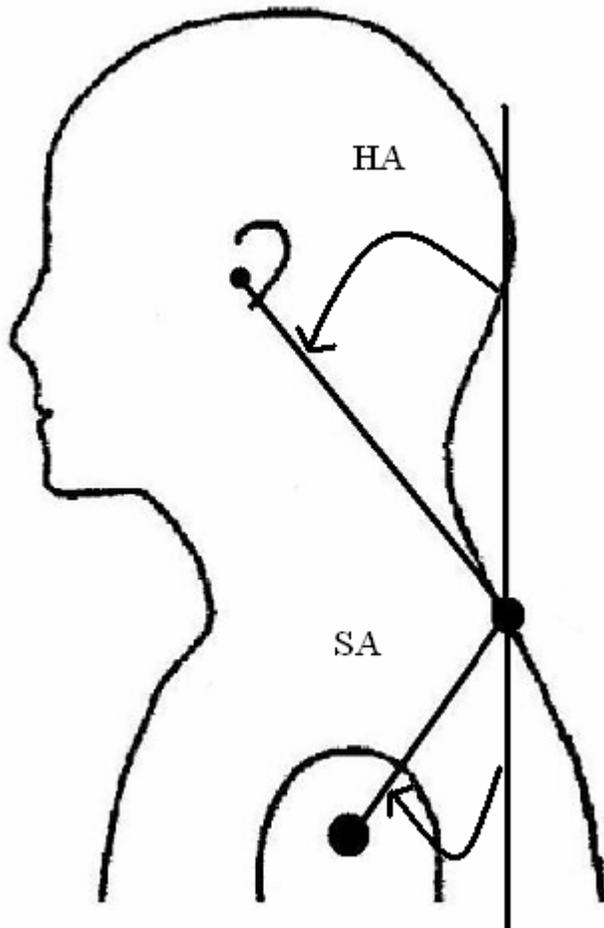
Head angle: The angle made between the vertical line extending superiorly

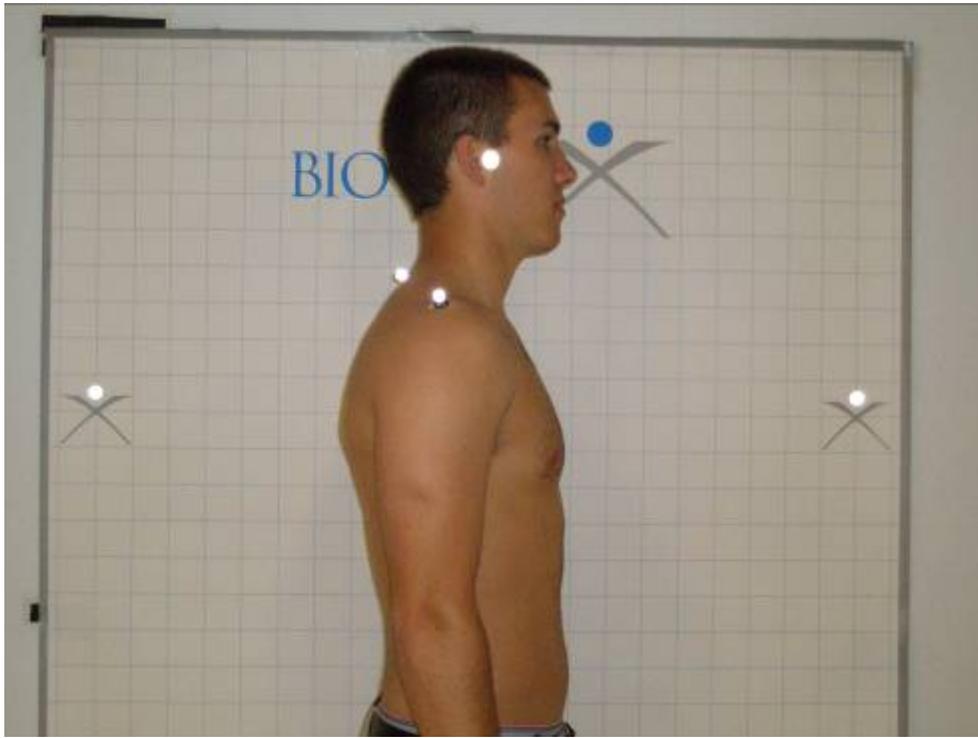from C7 and the line connecting C7 to the tragus

Forward Head angle: ≥ 46°

Shoulder angle: The angle made between the vertical line extending inferiorly

from C7 and the line connecting C7 to the acromion

Forward Shoulder angle: ≥ 46°
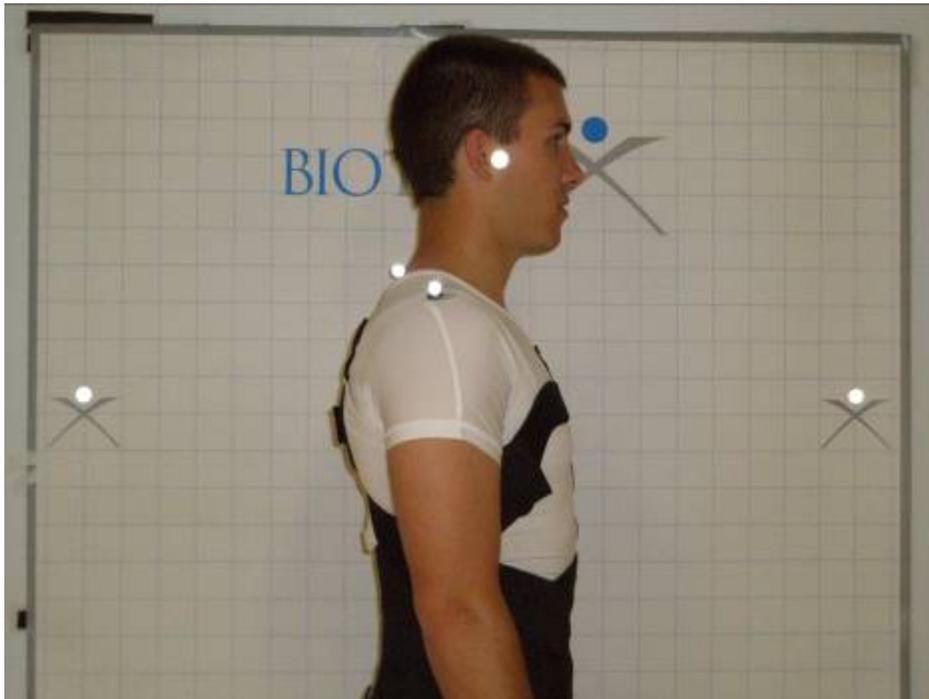
Figure 2: Postural Screening
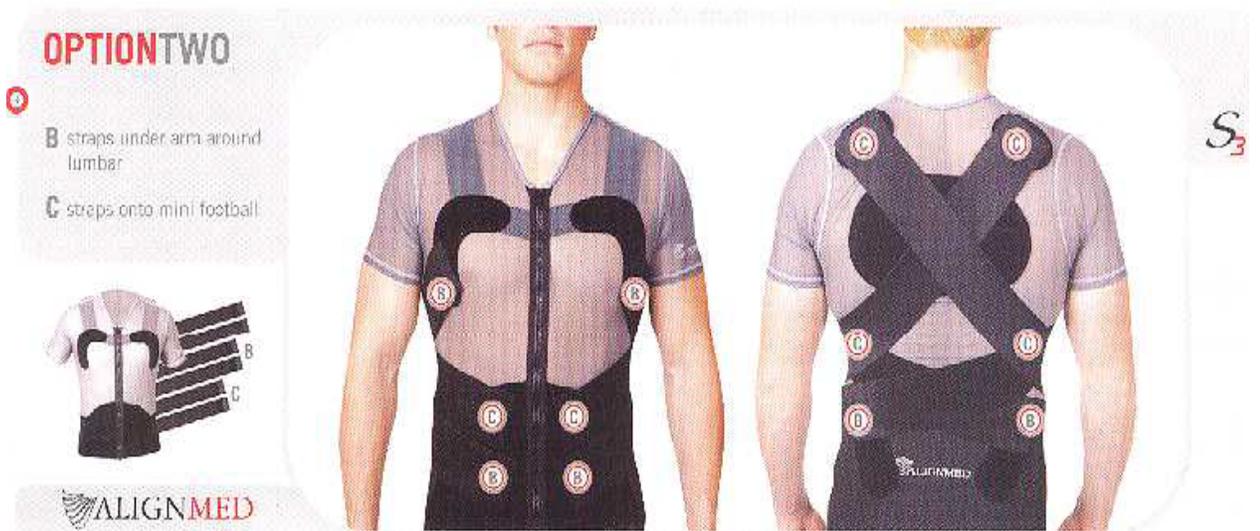
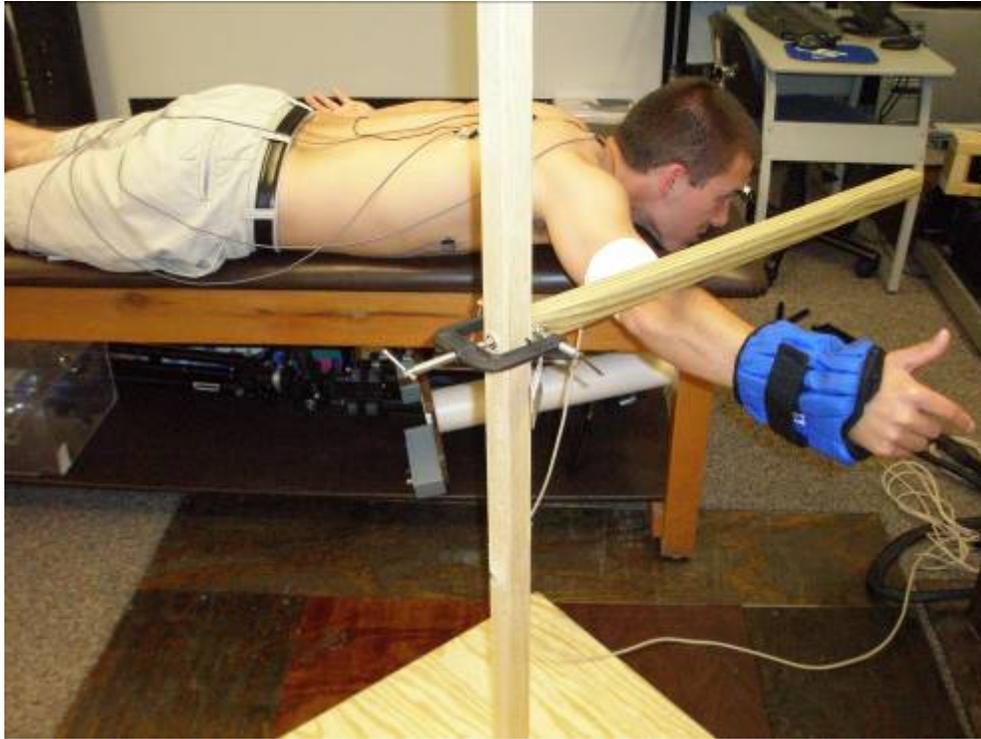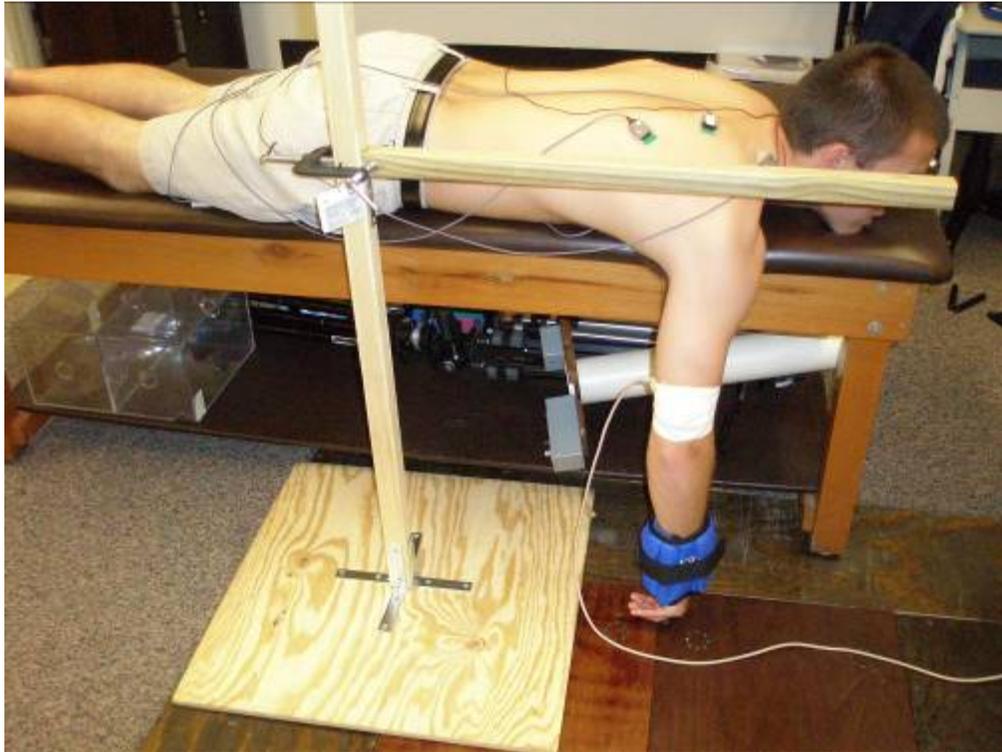No Brace

Brace

Figure 3: Brace Application

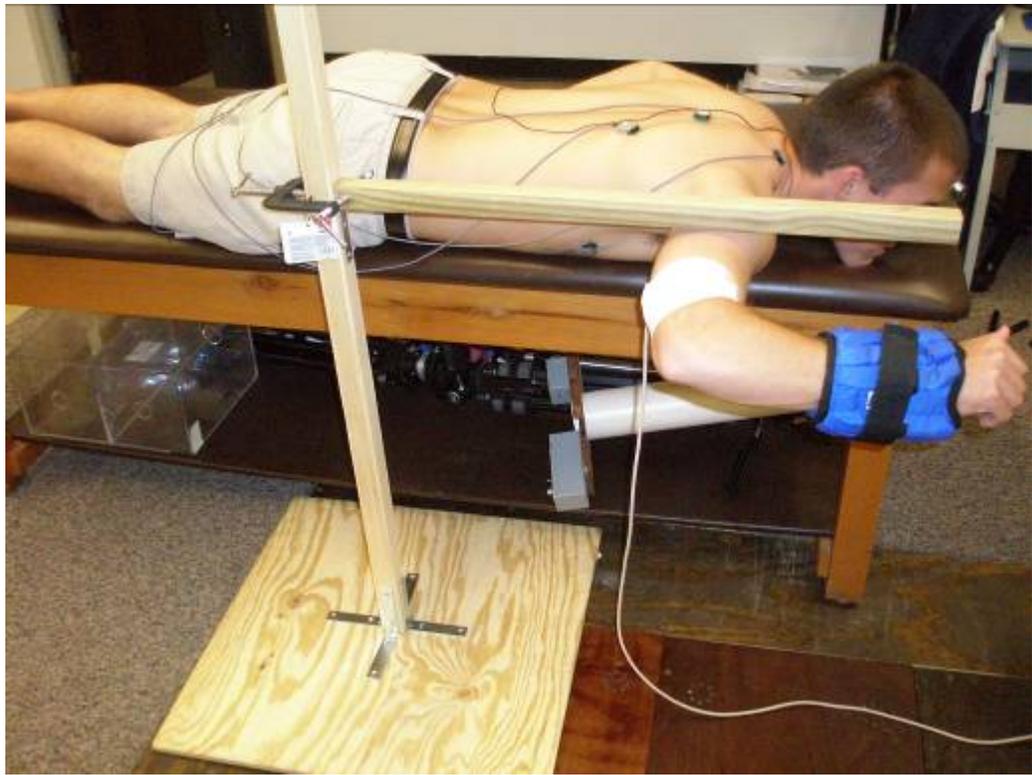Figure 4: Y

Figure 5: T

Figure 6: W
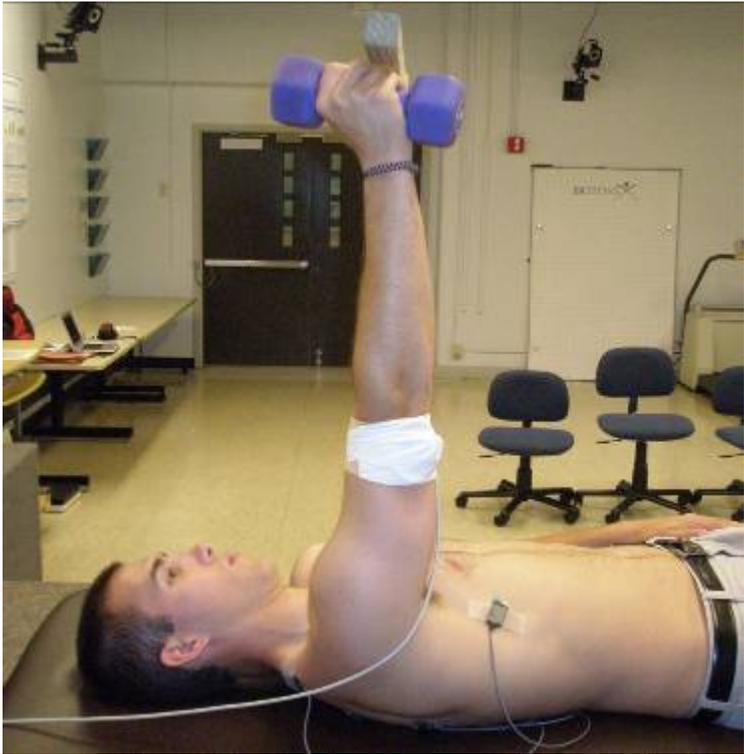
Figure 7: Scapular Punch

Figure 8: Forward Flexion

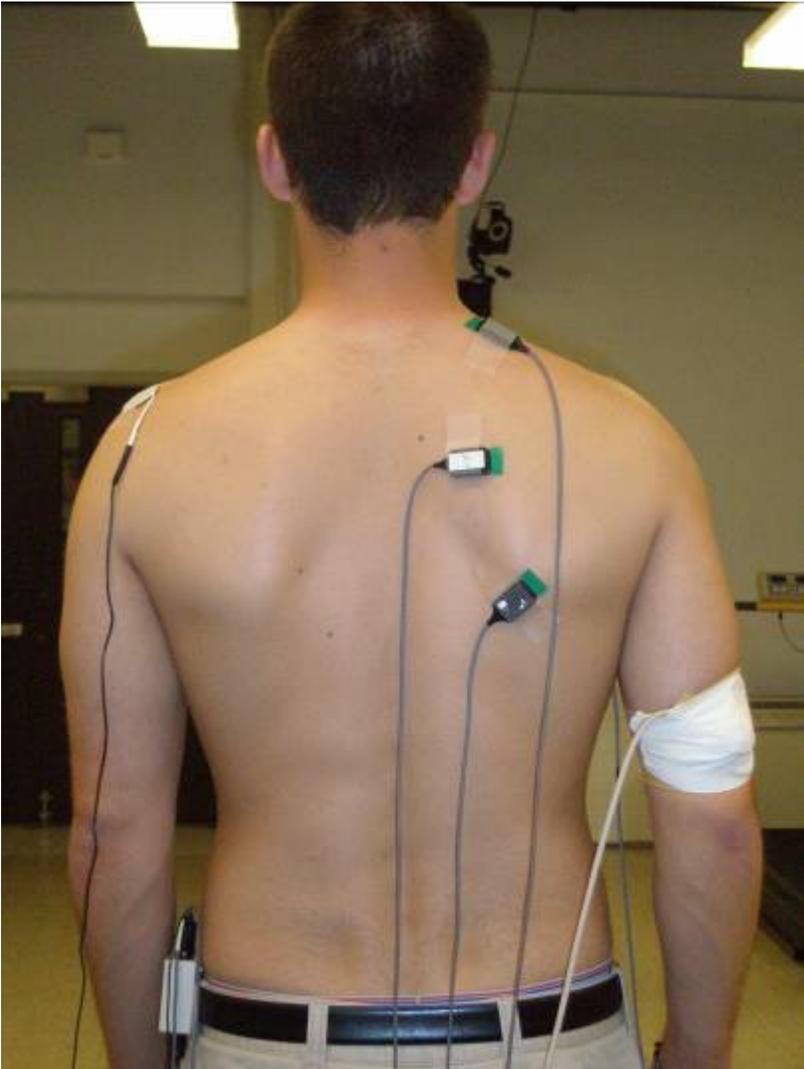Figure 9: Shoulder Extension

Figure 11: EMG electrode placement
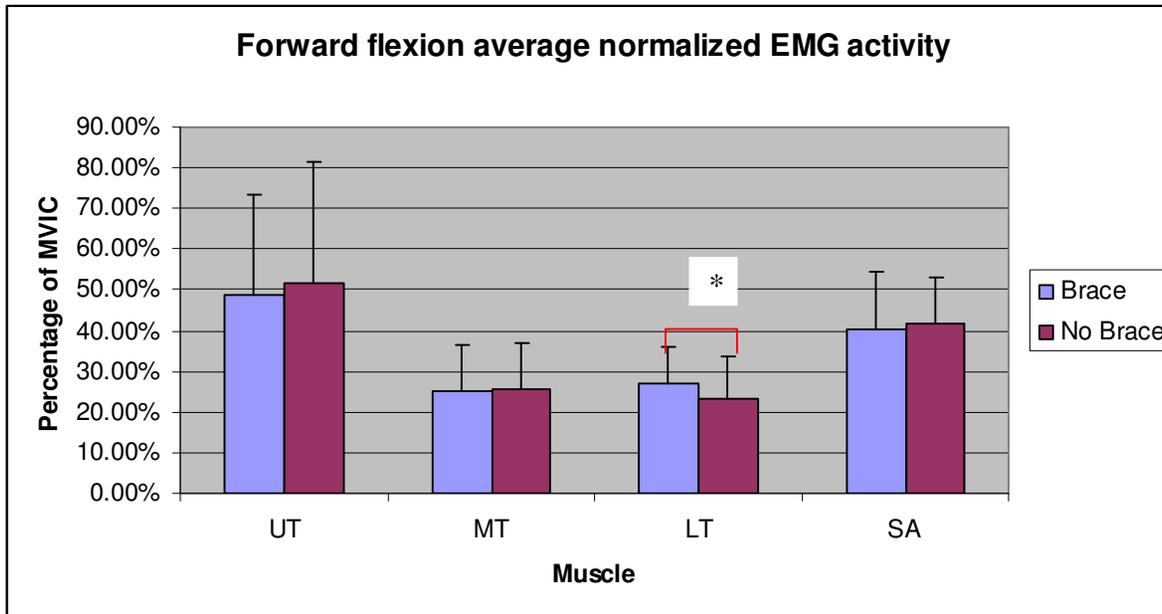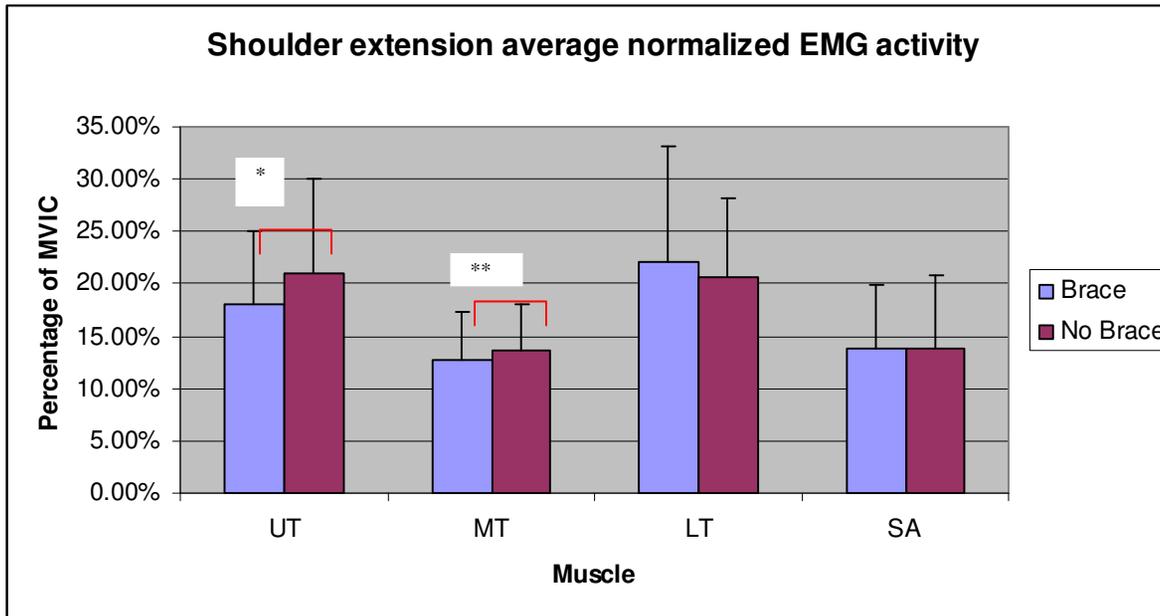
Figure 14:Forward flexion average normalized EMG activity

Forward flexion average normalized EMG activity

*Significant main effect for brace ($F_{1,33}$=12.563, p=0.001)

Figure 15: Shoulder extension average normalized EMG activity

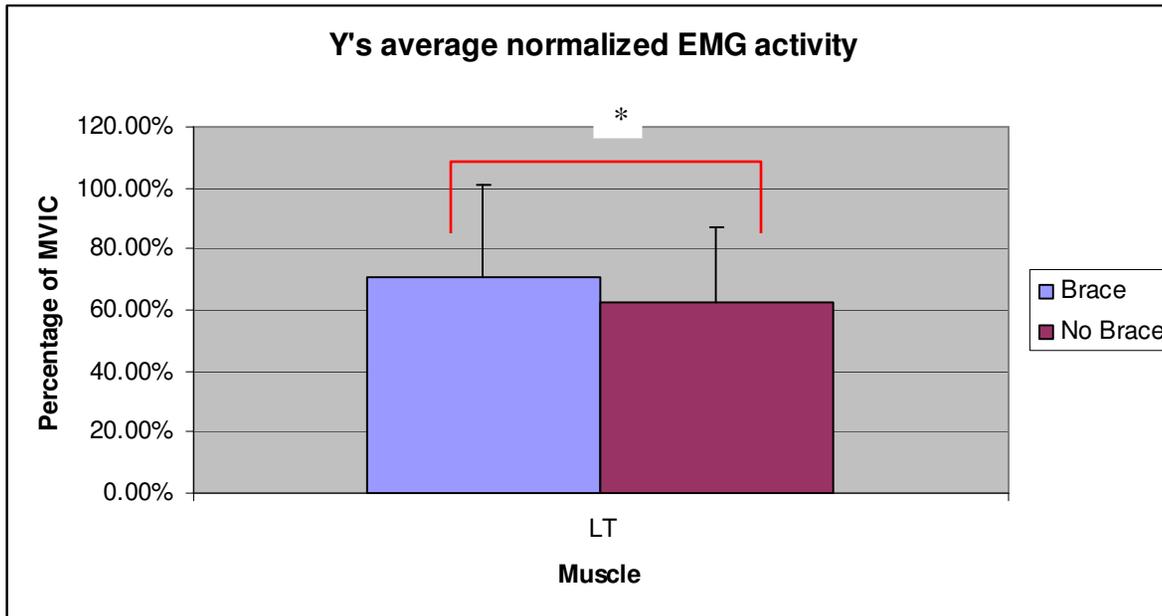**Shoulder extension average normalized EMG activity**

*Significant main effect for brace ($F_{1,34}=12.837$, p=0.001)
**Significant main effect for brace ($F_{1,33}=7.282$, p=0.011)

Figure 16: Y's average normalized EMG activity

Y's average normalized EMG activity

* Significant main effect for brace ($F_{1,36}=6.685$, p=0.014)

Figure 17: T's average normalized EMG activity

ıre 18: W's average normalized EMG activity

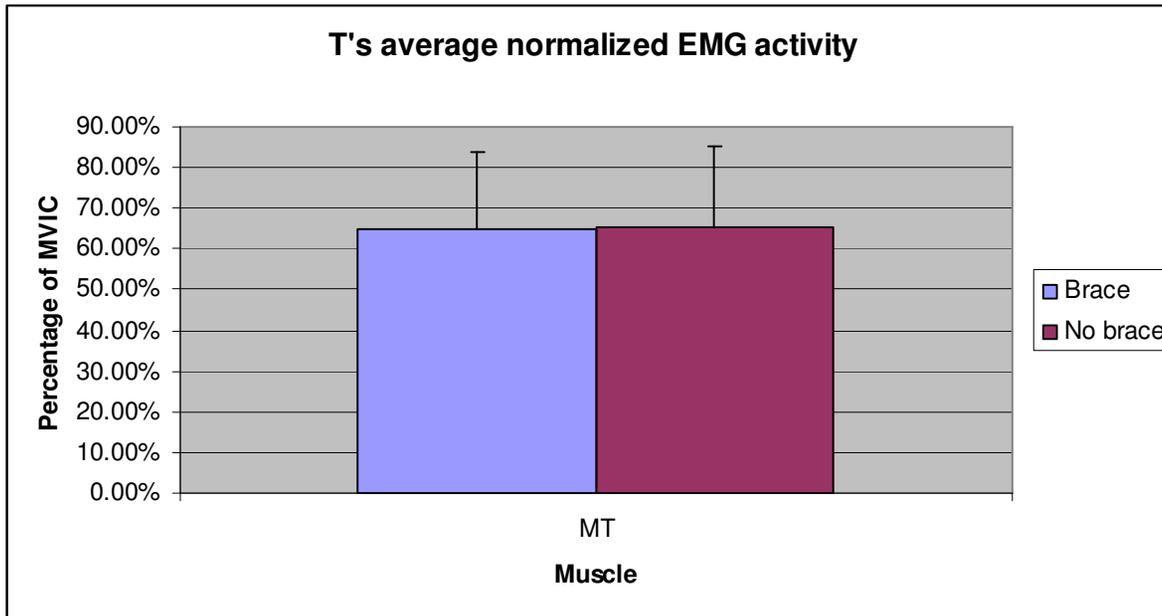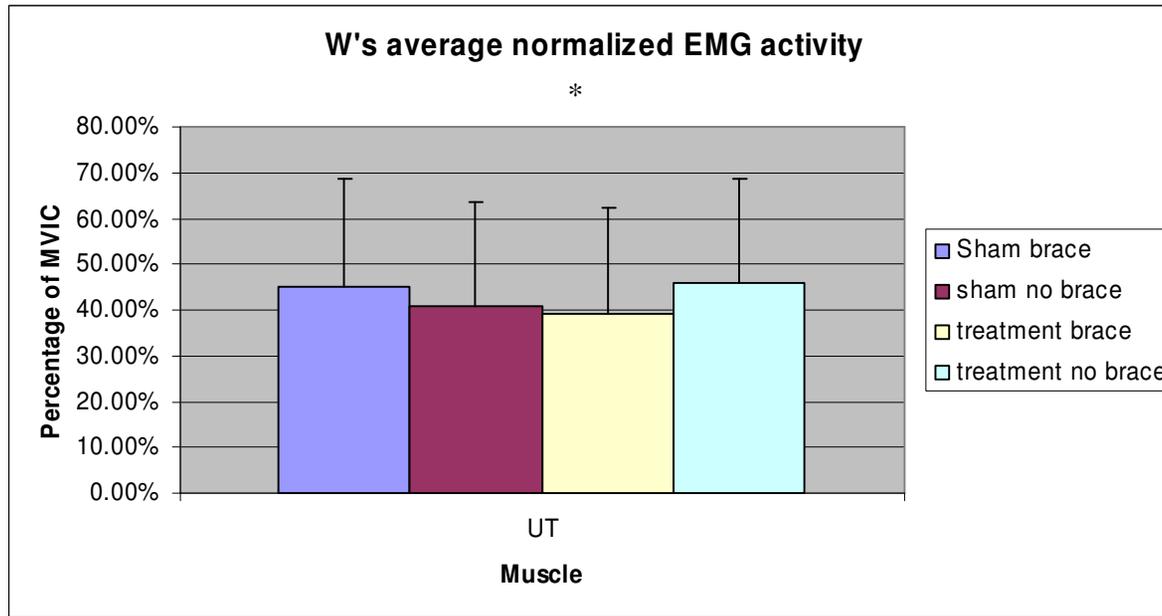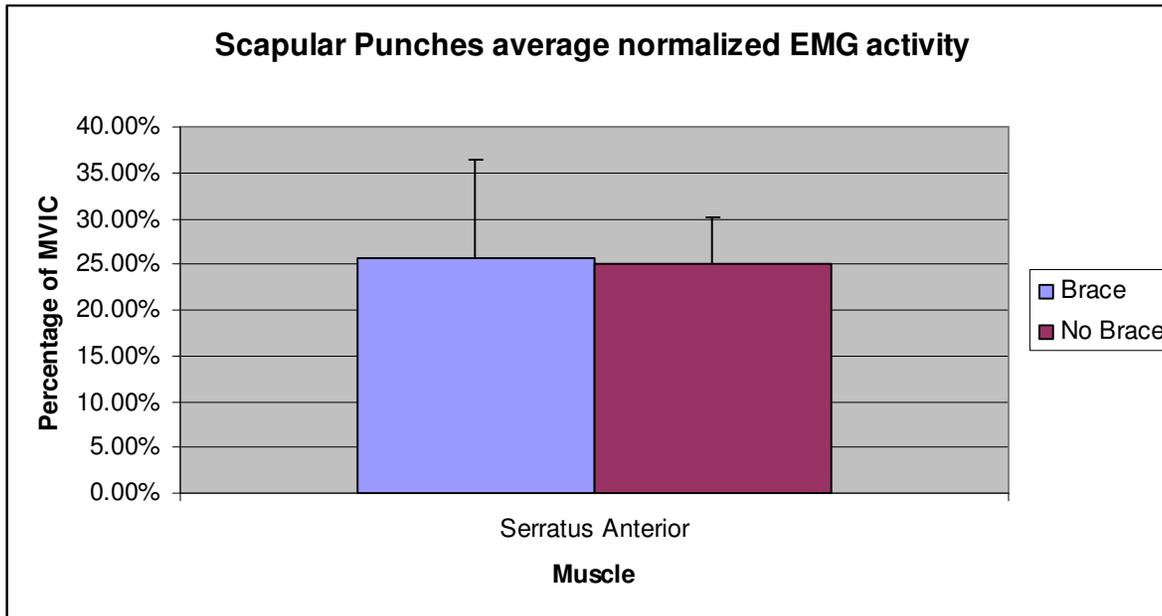W's average normalized EMG activity

*Significant interaction effect ($F_{1,36}$=4.710, p=0.037)

Figure 19: Scapular punches average normalized EMG activity

Scapular Punches average normalized EMG activity

Average Postural Measurments

Figure 21: Average postural measurement

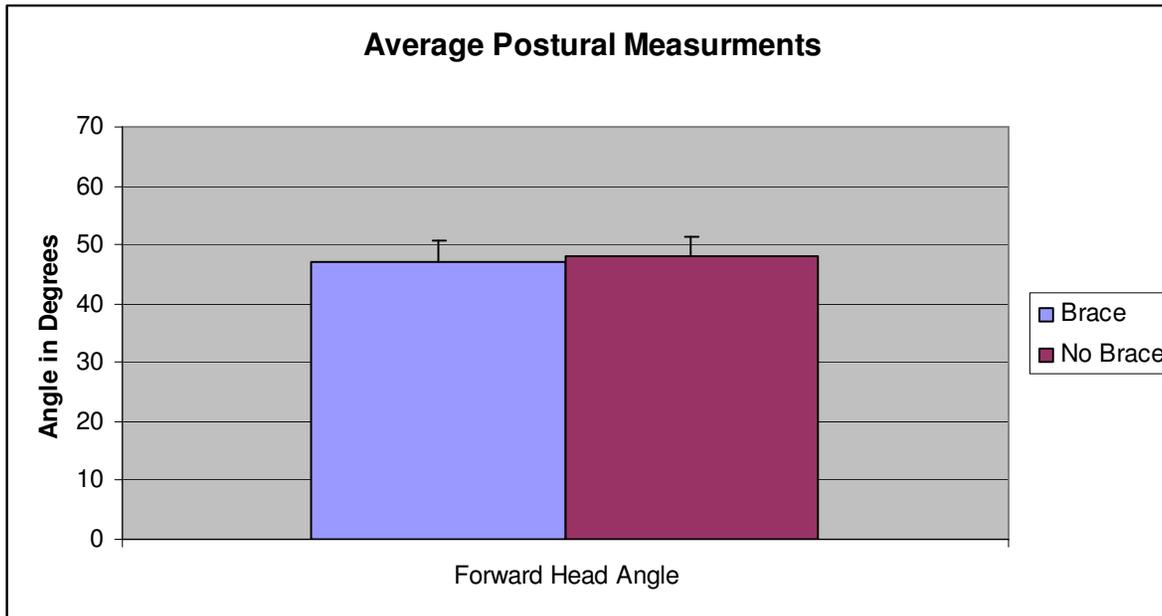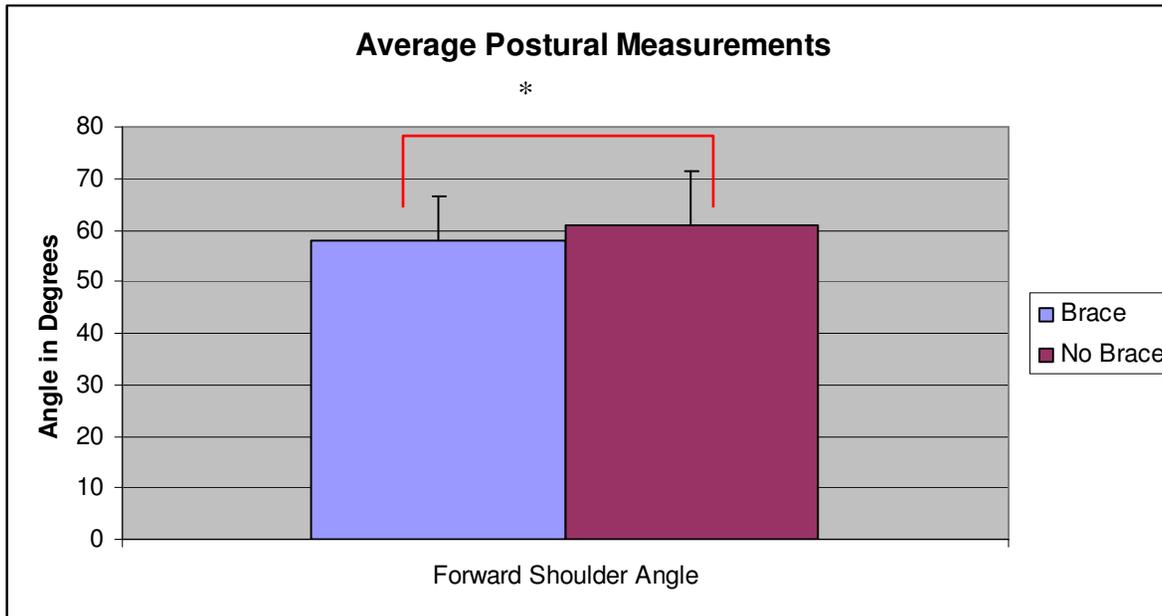**Average Postural Measurements**
*

* Significant main effect for brace ($F_{1,38}= 5.106$, p=0.030)

APPENDIX C: MANUSCRIPT

Introduction

Shoulder injuries are a common and disabling condition among many athletes, particularly overhead athletes. Recent NCAA injury surveillance system research has shown that shoulder injuries account for 39.4% of all injuries in baseball. Similar studies were done for softball and women's volleyball with shoulder injuries accounting for 15.8% and 21.7% overall (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007; Dick et al., 2007; Marshall, Hamstra-Wright, Dick, Grove, & Agel, 2007). Thus finding ways to treat and prevent shoulder injuries is critical to the sports medicine profession. A specific postural anomaly, forward head rounded shoulder posture, may play a role in the development of shoulder pain. Forward head posture is defined as the tragus (ear) being in front of the plumb line while the rest of the body remains in alignment (Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005). Rounded/ forward shoulder posture is described as the acromion of the shoulder being located in front of the plumb line while the rest of the body remains in alignment (Lewis, Wright, & Green, 2005). These two postural abnormalities often occur in conjunction with one another and are thought to be related to many overuse injuries in the shoulder. One study found that when healthy patients adopted a slouched position this significantly increased scapular anterior tilt and upward rotation in neutral position, when compared to the neutral position with the upright posture (Finley & Lee, 2003). These specific scapular alterations are believed to be related to the development of shoulder pathology(Finley & Lee, 2003; Lewis, Wright, & Green, 2005).

Muscular balance plays a significant role in proper posture and normal scapular kinematics. Common muscular imbalances include tight anterior shoulder musculature and weak scapular stabilizer musculature, including an overactive upper trapezius and an under active middle trapezius and serratus anterior. It is common that inhibition and/ or weakness of the scapular stabilizers is caused by a direct-blow trauma; microtrauma-induced strain in the muscles; fatigue from repetitive tensile forces; or inhibition by painful conditions around the shoulder (Kibler & McMullen, 2003). Anyone of these situations can cause discord in the normal force couple. Weakness of the middle trapezius or serratus anterior disrupts the resting position of the scapula (Neumann, 2002). As previously stated, the upper trapezius often becomes overactive while the serratus anterior becomes under active. This can lead to a shoulder-shrugging motion with upward rotation of the scapula, which causes excess superior translation of the scapula with less efficient upward rotation and reduced posterior tipping (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Clinical consequences of these alterations may include subacromial impingement, associated subacromial bursitis, and rotator cuff or biceps tendonitis (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Upper-extremity distortion pattern is described by the NASM and is characterized by rounded shoulders and a forward head position. This pattern is common in individuals who sit a lot or who develop pattern overload from uni-dimensional training products (Clark, 2006). One way to correct scapular positioning and FHRSP is to correct muscular imbalances surrounding the shoulder complex. Weakness of the scapulothoracic muscles has been shown to potentially lead to abnormal positioning of the scapula,

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disturbances in scapulothoracic rhythm, and generalized shoulder dysfunction (Voight & Thomson, 2000).

The Scapular Stabilizing System (S3) brace is designed "to improve posture, reduce pain, and increase range of motion by re-educating and re-engineering the musculo-skeletal system surrounding the shoulders and spine." Uhl et al. performed an unpublished study on the prototype of the S3 brace. Fifteen healthy subjects and 15 subjects with scapular dyskinesis were used in this study. The results found that the brace increased posterior tipping, decreased upward rotation in the dominant arm and non-dominant arm, and decreased internal rotation during the lowering phase of elevation. The authors concluded that the S3 brace affected the scapular kinematics at rest and in the lower ranges of motion and may assist the scapular muscles in controlling scapular motion. The S3 brace appears to be a new way to help correct scapular position and motion to help treat individuals with shoulder pathology. However, no published studies have demonstrated how the S3 brace affects upper extremity posture or muscle activity, particularly in athletes who demonstrate poor posture.

Past studies have investigated the suggestion that scapular taping may be a way to help correct scapular positioning along with active exercise. Cools et al. hypothesized that with tape the upper trapezius activity would decrease and the lower trapezius would increase and that taping would change the overall recruitment pattern of all scapular rotators including the serratus anterior and middle trapezius. The results showed that there were no significant changes in EMG activity in the scapular muscles based on the application of tape (Cools, Witvrouw, Danneels, &

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Cambier, 2002). Lewis et al. researched the effect that changing posture by instructing the patient and with the help of scapular taping had on shoulder range of motion. The authors found that the placebo taping group did not did not produce a significant change in the static position of the scapula, or on the range of pain free flexion and abduction in the plane of the scapula (Lewis, Wright, & Green, 2005). In the postural correction taping group, on the other hand, the taping technique did a have a significant effect on FHP angle, FSP angle, thoracic kyphosis angle, amount of lateral linear displacement of the scapula, and elevation and sagittal plane position of the acromion (Lewis, Wright, & Green, 2005).

The purpose of this study is to determine whether or not the S3 scapular stabilization brace corrects the posture of patients with forward head, rounded shoulder posture. In addition, this study will determine whether or not wearing the S3 scapular stabilization brace has an effect on the muscle activity of patients with poor posture while performing six strengthening exercises.

Methods

Subjects

Forty subjects, males (n= 9) and females (n=29) between the ages of 18-25 were recruited from the student population at the University of North Carolina at Chapel Hill (age= 19.5 years weight in pounds 165.9). Thirty-six participants were right hand dominant and 2 participants were left hand dominant. One baseball player, 6 softball players, 13 swimmers, 9 volleyball players, and 9 track throwers were tested in this study. Twenty-three varsity athletes, 11 club athletes, and 4 recreational athletes participated in this study. Descriptive statistics are presented in table 1. An a priori power calculation using data from prior studies revealed that 40 subjects (20

subjects per group) would be required for a power of 0.80. (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Lewis, Wright, & Green, 2005).

Subjects were recruited through mass e-mails sent to the student population, through flyers placed around campus, through exercise and sports science classes, and through intercollegiate and club sporting groups. Subjects were included if they currently participated in a NCAA, club, or recreational overhead sport 3-4 days a week for at least 1 hour or more. An overhead sport was defined as baseball, softball, swimming, volleyball, or tennis. Subjects were also required to have forward head rounded shoulder posture, defined as having a forward head angle ≥ 46º and a forward shoulder angle ≥ 46º. Postural alignment criteria were based on a study done by Thigpen in which he screened 310 individuals from a university population. Those with FHA ≥46° and FSA ≥46° were determined to have the worst posture(Thigpen, 2006). Subjects were excluded if they had had a shoulder or back injury in the last 6 months, previous history of shoulder or back surgery, are currently performing formal shoulder rehabilitation, had any congenital postural abnormalities, a forward head or rounded shoulder posture less than the specified criteria, and had any prior experience with the S3 brace. The dominant arm (arm they would throw a ball with) was tested for each subject.

Equipment and Materials

Posture

Postural screening was performed to ensure that each subject met the criteria for FHRSP. The principal investigator evaluated posture for each subject by taking a digital photo of the subject in a sagittal view and using Adobe Photoshop® to

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evaluate the head and shoulder angle. Markers were placed on the subject's right tragus (ear), right acromion, and C7(Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992; Lewis, Green, & Wright, 2005; Lewis, Wright, & Green, 2005; Sawyer, 2006; Thigpen, 2006).

EMG

Electromyography analyses were used to measure muscle activity of the serratus anterior, upper trapezius, lower trapezius, and middle trapezius. The Delsys Bagnoli-8 hard-wired EMG system (Boston, MA) was used, with differential amplification, CMRR >80 dB input input impedance >1015//0.2ohm//pF, SNR > 40dB using an 8 channel amplifier. The EMG signal was amplified by a factor of 1000, over a bandwidth of 0.01 to 2000 Hz passed via an A/D converter (National Instruments, Austin, Texas) sampling at 1000 Hz and corrected for DC bias. Raw EMG data was collected using Motion Monitor® (Innovative Sports Training Inc. Chicago, IL) software.

The skin was prepared prior to EMG placement by cleaning the area with alcohol to ensure good electrode contact and transmission. A bar Ag/AgCl single differential surface electrode (Delsys Inc., Boston, MA) was fixed onto the mid-point of each muscle belly so that the bars lay perpendicular to the muscle fibers. The electrodes were attached using surgical tape and adhesive stickers. Proper electrode placement was determined for each muscle according to the direction of the muscle fibers. Electrode placements were as follows for each muscle:

Upper trapezius- One half the distance from the mastoid process to the root of the spine of the scapula, approximately at the angle of the neck and shoulder (Thigpen, 2006).

Middle trapezius- Midway along a horizontal line between the root of the spine of the scapula and the third thoracic spinous process (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007; Cools, Witvrouw, Declercq, Danneels, & Cambier, 2003).

Lower trapezius- Two finger widths medial to the inferior angle of the scapula on a 45° angle towards T10 (Thigpen, 2006).

Serratus anterior- Below the axilla, anterior to the latissimus dorsi, placed over 4th through 6th ribs angled at 30° above the nipple line (Thigpen, 2006).

Common reference electrode- A common reference electrode was placed over the opposite acromion (Thigpen, 2006).

Motion Analysis

The Motion Star electromagnetic motion analysis system (Ascension Technologies, Burlington, VT) was used to determine the onset of each repetition during each of the exercises for each muscle. This was also used to ensure that the same motion was performed during each exercise under each brace condition. A receiver was placed on the posterior brachium distal humerus. Positional data was collected with The Motion Monitor® (Innovative Sports Training Inc. Chicago, IL) and sampled at 50 Hz.

S3 Brace

The S3 brace was fitted and applied by two secondary researchers according to manufacturer specifications using a two strap method. The secondary researchers fit all subjects for the correct size. If a subject was in between sizes then he or she

tried on both sizes and the secondary researchers determined which size had the best fit. Neither the treatment group nor the sham group was educated on the reasons for wearing the S3 brace. Men were shirtless and women wore a sports bra. After putting on and zipping up the S3 brace; both groups tightened the Velcro pads on the waist band so that they were snug, but not uncomfortable. Both groups were instructed to retract and depress the shoulder blades in preparation for strap placement. The treatment group had a small (C) strap applied from the posterior, superior Velcro pad (over the upper trapezius muscle) to the contralateral waist band. This method was repeated for the opposite side. Next, the medium (B) strap was attached from the lateral, superior Velcro pad (over the pectoralis major muscle) to the contralateral waistband Velcro pad inferior to the (C) strap. This method was repeated for the opposite side. The sham group used the same method of applying the brace, but the medium (B) straps were used in place of the short (C) straps and the long (A) straps were used in place of the medium (B) straps. There was a 5 ½ to 6 inch difference between the B and C straps and a 6 inch difference between the A and B straps. Due to this difference in length the straps did not cause retraction, but maintained the look of the brace.

Testing Procedures

Screening

Subjects were brought into the Sports Medicine Research Laboratory (SMRL) for a 10 minute screening session prior to the beginning of testing. Those subjects that fit the criteria for FHRSP were brought back to the SMRL for one fitting session and one testing session. All subjects read and signed a consent form to participate in the study.

Counterbalancing

Counterbalancing was used to determine whether subject performs exercises with or without brace first. Counterbalancing was also used to determine in what order each subject performed the exercises and what order the MVIC's were performed.

Posture

During postural alignment assessment subject's stood 40cm in front of a grid screen with reflective markers placed on the subject's right tragus (ear), chin, labella (between eyes), right acromion, and 7th cervical vertebrae spinous process. High resolution digital pictures were then taken in a sagittal plane to determine the plumb line through the C7 spinous process. The primary investigator stood 3m from the grid and the camera was positioned on a tripod. The photos were then uploaded onto a personal computer for postural analysis using Adobe® Photoshop. The photos were then used to calculate the shoulder and head angle of each subject to determine whether or not they were included in the study. Forward head position was defined as having a forward head angle greater than or equal to 46° relative to the vertical line extending from C7 to the line connecting C7 to the tragus. Rounded shoulder position was described as having a forward shoulder angle of greater than or equal to 46° relative to the vertical line extending from C7 to the line connecting C7 to the acromion (Sawyer, 2006; Thigpen, 2006). Postural alignment criteria were based on a study done by Thigpen in which he screened 310 individuals from the university population. Those with FHA ≥46° and FSA ≥46° were determined to have the worst posture (Sawyer, 2006; Thigpen, 2006).

MVIC

A maximal voluntary isometric contraction (MVIC) assessment was performed as the subject performed a maximal voluntary isometric contraction against manual resistance. Each subject performed one sub-maximal contraction to familiarize themselves with the manual muscle testing position. Subjects performed 3 MVIC's for each muscle (lasting 5 seconds each) with 1 minute rest between each muscle and 30 seconds between each trial. The average amplitude for all of the trials was recorded. The order of the muscles tested was randomized. MVIC's were tested as follows:

Upper trapezius- The subject was seated with arms at his/her sides. The tester stood behind the subject and gave the subject instructions to "shrug the shoulder" which was being tested and "rotate the head in the opposite direction." The tester applied a stabilizing force to the back of the head and a downward force to the acromion for 5 seconds. The subject was then instructed to "relax" (Kendall, 1993).

Middle trapezius- The subject laid in the prone position with the shoulder abducted to 90° and externally rotated. The tester stood at the subject's side and gave the subject instructions to "raise the arm towards the ceiling" while the tester applied a downward force to the proximal end of the brachium for 5 seconds. The subject was then instructed to "relax" (Kendall, 1993).

Lower trapezius- The subject laid in the prone position with the arm raised overhead in line with the lower trapezius muscle fibers. The tester stood at the subject's side and gave the subject instructions to "raise the arm towards the ceiling" while the tester applied a downward force to the proximal end of the brachium for 5 seconds. The subject was then instructed to "relax" (Kendall, 1993).

Serratus anterior- The subject was seated with the arm shoulder flexed between 120° and 130°, with the arm internally rotated. The tester stood beside the subject and gave the subject instructions to "raise the arm towards the ceiling," while the tester applied a downward force to the proximal end of the brachium for 5 seconds. The subject was then instructed to "relax" (Kendall, 1993).

Exercises

Prior to EMG testing of muscle activity a proper amount of weight for each exercise was determined. The amount of weight used for each exercise was 1% of the subject's body weight for Y's, T's, W's, forward flexion, and shoulder extension. The amount of weight used for scapular punches was 5% of the subject's body weight. Subjects were allowed to perform no more than 5 repetitions of each exercise as practice. During the actual trial each subject performed 10 repetitions of each exercise. A 1 minute rest period was allowed between each exercise. A metronome set at 60 beats per minute was used to time each exercise.

The exercises performed were scapular punches, Y's, T's, W's forward flexion, and shoulder extension. The exercises were performed as follows:

Scapular punches were performed lying supine on a table with the arm in 90° of flexion. The patient then protracted the scapula by raising the fist towards the ceiling.

Y's were described as an arm raise above the head with the upper extremity in line with the lower trapezius muscle fibers in the prone position (Ekstrom, Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a table with arms hanging down in front and palms facing each other. Arms were in the 10 and 2

o'clock position (at about 125°) and thumbs were raised towards the ceiling. Arms were raised until they were parallel to the floor.

T's were described as shoulder horizontal extension with external rotation in the prone position (Ekstrom, Donatelli, & Soderberg, 2003). This exercise was performed lying prone on a table with arms hanging down in front. Arms were raised out to the side in horizontal extension until they were parallel to the floor.

W's were described as prone external rotation with shoulder abducted to 90° and elbow flexed to 90°. This exercise was performed while lying prone on a table with arms hanging down in front. Arms were raised so that brachium is parallel to the floor with the elbow bent to 90°. The arms were then externally rotated.

Forward flexion was performed in the sagittal plane. The exercise began with the arm at 0° of flexion and it was elevated with the forearm in a neutral position (thumb facing ceiling) in the sagittal plane to full shoulder flexion(Myers et al., 2005).

Shoulder extension was performed in the sagittal plane. The exercise began with the arm at 90° of flexion with the forearm in a neutral position (thumb facing ceiling) and was moved into full shoulder extension and then back to 90°(Myers et al., 2005).

Data Collection and Processing

All data was exported into a custom MatLab program (Mathworks, Natick, MA). EMG was rectified, bandpass filtered from 10-350Hz and smoothed via root mean square with a time constant of 15 ms. EMG was normalized to the mean EMG amplitude obtained during the middle 1 second of 3 MVIC trials. Mean normalized EMG amplitude was calculated across the entire movement (from the onset of movement to the end of that repetition). Onset of movement and end of the repetition was visually identified using the positional data from the electromagnetic

motion analysis system. The EMG amplitudes were averaged across all 10 trials for data analysis. Posture measurement and EMG values were imported into SPSS version 14.0 for analysis.

Statistical Analyses

Twelve separate mixed-model ANOVA's were used to analyze EMG activity, between the sham group and the treatment group, as well as comparing within subjects when they were wearing the brace and when they were not wearing the brace. Two separate 2x2 mixed model ANOVAs were used to analyze posture between groups and within groups regarding the brace condition. SPSS statistical software (version 13.0, SPSS Inc, Chicago, IL) was used to analyze all data. For statistical analyses an a priori level of 0.05 was set as the level of significance.

Results

Posture

The average change in forward head posture for the sham group was 0.79 ± 1.87 degrees. The average change in forward shoulder posture for the sham group was 1.63 ± 6.55 degrees. The average change in forward head posture for the treatment group was 2.00 ± 2.03 degrees. The average change in forward shoulder posture for the treatment group was 8.00 ± 7.78 degrees. Means and standard deviations are listed in table 2. Power and effect size are listed in table 6. A significant main effect was found for forward shoulder posture for the brace vs. no brace condition ($F_{1,38}$= 5.106, p=0.030)There was an average decrease of 3.19° from the braced condition to the no brace condition. There were no significant differences for forward head or forward shoulder posture for group. There were no significant differences for forward head posture for brace condition. There were no

interaction effects found for forward head or forward shoulder posture. (See figures

20 and 21 for graphs.) The results tell us that there was no improvement in forward

head angle when comparing brace to no brace or when comparing treatment group

to sham group. The results also show that there was a decrease in forward shoulder

angle when comparing the brace condition to the non-braced condition; however

there was no difference in comparing sham group to treatment group.

EMG

Means and standard deviations for normalized EMG are listed in tables 3, 4 &

5. Power and effect size are listed in table 6. A significant main effect was found for

normalized EMG shoulder extension for the upper trapezius for brace vs. no brace

condition ($F_{1,34}=12.837$, $p=0.001$). There was an average decrease of 2.97% in

normalized upper trapezius EMG from the no brace condition compared to the brace

condition (see figure 15). There were no main group effects or interaction effects for

this exercise and muscle. A significant interaction effect was found for normalized

EMG W's for the upper trapezius ($F_{1,36}=4.710$, $p=0.037$). This means that upper

trapezius activity in the treatment group decreased from the non braced condition to

the braced condition, while upper trapezius activity in the sham group increased

from the non braced condition to the braced condition (see figure 18). There were no

main group effects or main condition effects for this exercise and muscle. There

were no main or interaction effects for the upper trapezius in forward flexion (See

figure 14).

A significant main effect was found for normalized EMG shoulder extension

for the middle trapezius for braced vs. no brace condition ($F_{1,33}=7.282$, $p=0.011$).

There was an average decrease of .95% in the normalized middle trapezius EMG

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from the no brace condition compared to the brace condition. There were no significant main or interaction effects for forward flexion or T's for middle trapezius (see figures 14 and 17, respectively)

A significant main effect was found for normalized EMG forward flexion for the lower trapezius for brace vs. no brace condition ($F_{1,33}$=12.563, p=0.001). There was an average increase of 3.55% in normalized lower trapezius EMG from the no brace condition compared to the brace condition (see figure 14). There were no main group effects or interaction effects for this exercise and muscle. A significant main effect was found for normalized EMG Y's for the lower trapezius for braced vs. no brace ($F_{1,36}$=6.685, p=0.041). There was an average increase of 6.5% in the normalized lower trapezius EMG from the no brace condition to the brace condition (see figure 16). There were no main group effects or interaction effects for this exercise and muscle. There were no main or interaction effects for the lower trapezius when looking and shoulder extension (see figure 15).

There were no main or interaction effects for the serratus anterior for any exercise (see figure 19). This includes forward flexion, shoulder extension, and scapular punches. These results tell us that the wearing the brace increased lower trapezius activity when performing forward flexion and Y's. The results also tell us that wearing the brace decreased lower trapezius activity when performing shoulder extension and W's. Wearing the brace also decreased middle trapezius activity during shoulder extension. The results show that the muscle activity of the serratus anterior was not significantly affected by wearing the brace. Muscle activity was not

significantly affected by wearing the sham strap application of the brace compared to the treatment strap application.

Discussion

Posture

It was found that forward head posture was not improved with sham or treatment application of the brace. Although it was hypothesized that the brace would decrease forward head posture this did not occur. Since the S3 brace did not apply any direct force to the head or the cervical spine then it is not surprising that there was no change in FHP. Lewis et al. however, found that scapular taping did improve FHP compared to a placebo tape job when Leukotape was applied from the center of the spine of the scapula to the spinous process of T12 in a diagonal fashion (Lewis, Wright, & Green, 2005). The subjects were asked to retract and depress their scapulas as were our subjects during application of the S3 brace. This difference in these findings cannot be fully explained, but it is possible that the direct application of the Leukotape to the skin may have allowed for a greater change in forward head posture compared to the brace where the attachment of the Velcro pads to a strap that goes over the acromion inside the brace is what retracts the shoulders.

Although FHP was not changed, FSP was significantly decreased when subjects were wearing the brace compared to when they were not wearing the brace. However, there was not significant difference in the sham group compared to the treatment groups, in both groups FSA was decreased when wearing the brace compared to not wearing the brace. This suggests that it may not be the straps that cause the decrease in shoulder angle, but it may be the proprioceptive effects of the

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brace. Lewis et al. also found that scapular taping in the manner described previously caused a decrease in FSA (Lewis, Wright, & Green, 2005). Again, the tape was applied directly to the skin and this may be more effective than applying the straps to the brace. It is also possible that although the straps used in the sham treatment were 51/2 to 6 inches longer than the treatment straps they may not have been long enough to completely prevent shoulder retraction. Further studies should be done to investigate different brace applications and how they affect FHP and FSP. While the change in FSP may seem small this may be enough to make a difference clinically. Since this wearing the brace one time had positive effects, it is possible that with regular use of the S3 brace this difference would increase and have more of an effect overtime.

EMG

There were no group effects found for EMG meaning that there were no significant differences between the sham group and the treatment group. Condition effects were found for certain muscles during certain exercises, which generally demonstrated that bracing, regardless of group, changed EMG activity. When evaluating EMG in relation to shoulder pathology it has been found that the upper trapezius is overactive while the middle trapezius, lower trapezius, and the serratus anterior are under active. This causes a disruption in the force couple which leads to changes in scapular kinematics. Ultimately these changes in the force couples and in scapular kinematics may lead to chronic shoulder pathologies such as subacromial impingement, associated subacromial bursitis, and rotator cuff or biceps tendonitis (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). Cools et al studied the balance of the trapezius muscles in overhead athletes with impingement

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syndrome compared to those without impingement syndrome and it was found that patients with impingement syndrome showed significantly higher EMG activity in the upper trapezius of their injured side compared to the dominant side of the control group (Cools, Declercq, Cambier, Mahieu, & Witvrouw, 2007). It was hypothesized that wearing the S3 brace while performing shoulder exercises would decrease the muscle activity of the upper trapezius and increase the muscle activity of the middle trapezius, lower trapezius, and serratus anterior thereby creating a more normal force couple for these muscles.

Upper Trapezius

This study found the most changes with upper trapezius activity. With shoulder extension the EMG activity of the upper trapezius was decreased when wearing the brace compared to not wearing the brace, which is desirable to restore a normal force couple. However there was no difference between the sham group and the treatment group. An interaction effect was observed for the upper trapezius when performing W's in which the EMG activity of the upper trapezius was decreased. The changes in EMG activity of the upper trapezius during W's and shoulder extension support the hypothesis that EMG activity will be decreased when wearing the brace compared to not wearing the brace. Given these findings it is possible that wearing the brace may help to inhibit the upper trapezius during rehab and daily activity. This may decrease the incidence of chronic shoulder injury by restoring a more normal force couple to the shoulder which will thereby change the scapular kinematics and decrease shoulder shrugging which leads to a closing off of the subacromial space. The fact that upper trapezius activity did not change when comparing the sham group to the treatment does no support out hypothesis that the

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treatment group will show a decrease in activity while the sham group shows no change. This suggests that it is not the particular strap placement that caused the change in EMG since using much looser straps also caused a change. This could mean that there are proprioceptive changes caused by wearing a compression shirt that effect EMG activity or it could mean that there was not enough of a difference in the tension of the straps in the sham group compared to the tension of the straps in the treatment group to cause significant changes.

Lower Trapezius
    An increase in lower trapezius activity was found when comparing braced to non braced condition for forward flexion and Y's. Again this is what was hypothesized and could have a positive effect in changing scapular kinematics. However, as with the upper trapezius no group effect was found for the lower trapezius meaning that there was no difference between the sham group and the treatment group. Given these findings, wearing the brace during exercises that target the lower trapezius could help to activate the muscle thereby more effectively strengthening it. As previously stated, strengthening the lower trapezius is desirable to restore a more normal force couple and prevent narrowing of the subacromial space. The fact that there were no significant changes between the sham and treatment group suggests again that either EMG changes were due to proprioceptive reactions or that this strap placement was not the most effective.

Middle Trapezius
    The middle trapezius was found to have a very slight decrease in EMG activity when comparing the braced to the non brace conditions during shoulder extension. This decrease is not readily explained by the literature, but it is possible

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that since the middle trapezius would have been most active during the end range of extension the brace may have limited this range of motion thereby decreasing the overall EMG activity. No change was shown in the middle trapezius comparing the braced condition to the non braced condition when performing T's. Although the middle trapezius does not have an effect on the force couple created at the scapula by the other muscles discussed and therefore may not change with functional motions, it seems logical that for horizontal abduction some change would occur, but this did not happen. Moseley et al found that horizontal abduction with external rotation (T's) was on of the best exercises to produce activity in the middle trapezius (Moseley, Jobe, Pink, Perry, & Tibone, 1992). It is possible that since the brace should cause some scapular retraction the middle trapezius did not have to work as hard to move the scapula. However, further research is necessary to determine why these changes occurred.

Serratus Anterior
          There were no significant changes found for serratus anterior EMG during forward flexion, shoulder, extension, or scapular punches. While it was expected that serratus anterior activity would significantly increase during scapular punches it is possible that the muscles was not loaded enough to should significant changes. While scapular punches have been shown to be effective in activating the serratus anterior and the subjects used 5% of their body weight for the punches, push up with a plus has been shown to be the most effective exercise (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). This exercise was not chosen for this particular study due to the fact that perfoming a push up with a plus is somewhat challenging and

takes time to learn how to perform it properly as well as the fact that it may have

fatigued some subjects and prevent them from completing all of the exercises.

Although the changes seen in EMG for the UT and LT were not great they

may be enough to show a significant clinical effect. The changes in EMG may

become more significant overtime if the brace is regularly paired with rehabilitation

exercises. As is true with all strengthening exercises, results are not seen after one

session, but will show overtime. The same is true of rehabilitation exercises and it is

possible that greater EMG changes would be seen when comparing baseline EMG

with no brace to EMG with the brace after several weeks of a rehabilitation program.

Many studies have looked at the effects that a compressive brace, such as a

neoprene sleeve have on proprioception of the joint around which it is worn. Studies

in both the knee and shoulder have determined that wearing a neoprene or other

compressive sleeve do help to improve joint repositioning sense. Most of these

studies found that improvements were significant or greater for those who had what

was classified as "poor proprioception" to begin. However when using a fatigue

protocol and comparing knee sleeve to no knee sleeve conditions Van Tiggelen et al.

found that pre-fatigue the knee sleeve only improved active joint position sense in

those with poor proprioception and not good proprioception. After the fatigue

protocol however, the researchers found that proprioception was improved in both

the good and poor proprioception groups when wearing the knee sleeve compared

to not wearing the knee sleeve (Tiggelen, Coorevits, & Witvrouw, 2008).   Perlau et

al. found that wearing an elastic bandage around the knee helped to improve

passive joint reposition sense for the knee in uninjured patients (Perlau, Frank, &

Fick, 1995). It was also determined in this study that the effects of the elastic

bandage were maintained after 60-90 minutes of light activity while still wearing the

elastic bandage. The improvement in passive joint reposition sense was maintained

after the elastic bandage was removed and there was no significant difference in

that measure compared to the pre-application measure (Perlau, Frank, & Fick, 1995).

On the other hand, Beynnon et al found that in an ACL deficient population that

neither wearing a functional knee brace or a neoprene sleeve improved passive joint

reposition sense when compared to the other knee significantly although changes

were noted. The threshold to detection of passive knee motion was significantly

worse for the ACL deficient knee than for the uninjured knee in this study (Beynnon

et al., 1999). Although most studies investigating the effects of a neoprene sleeve

on joint reposition sense have looked at the knee or sometimes ankle there have

been a few done on the shoulder joint. Ulkar et al. studied the effect of positioning

and bracing on passive joint position sense in the shoulder. This study looked at

patients with healthy shoulders and tested the subjects at different start positions

with and without a neoprene sleeve. This study found that there was a significant

difference in joint repositioning sense when wearing the neoprene sleeve compared

to not wearing it (Ulkar, Kunduracioglu, Cetin, & Guner, 2004). Therefore the

neoprene sleeve may improve proprioception by interfering with cutaneous

mechanoreceptors. In relation to this study it means that the compressive aspects of

the brace could have some effect of the improved posture. The company states that

proprioceptive padding helps to improve scapular kinematics along with the Velcro

strapping system. Given the effects of the neoprene sleeve studies it could be

possible that the padding cues mechanoreceptors to keep the scapulas down and back. However much more research needs to be done to prove that this occurs.

The S3 Brace

The S3 brace has been designed to improve posture and reduce pain in patients suffering from poor posture and shoulder injuries. It has been found in previous unpublished studies that the S3 brace improves scapular kinematics and rest and in the lower ranges of motion. The designers of the brace state that through a "Velcro strapping system coupled with proprioceptive padding" the brace attempts to restore normal shoulder kinematics. Previous studies have found that exercise may improve scapular kinematics although it is unclear whether scapular positioning is improved. Wang et al found that when patients performed an exercises regimen that included 5 shoulder exercises resting scapular posture did not change and that the scapula showed less superior translation after the exercise program(Wang, McClure, Pratt, & Nobilini, 1999). Ludewig et al found that selective activation of the serratus anterior with minimal activation of the upper trapezius may improve the relative strength of the serratus anterior and improve the balance of these two muscles in patients with shoulder dysfunction (Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). It is believed that strengthening the lower trapezius, middle trapezius, and serratus anterior muscles with the scapula in the proper position and a more normal force couple restored would overtime help to restore the force couple in the long run during rehabilitation exercises, sport activity, and everyday movements. Given the findings of this study it can be stated that wearing the brace does cause positive changes in forward shoulder posture and EMG activity of the upper and lower trapezii, however it has not been determined that these changes

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are a direct result of the strap placement suggested by the AlignMed company. This study does not disprove the claims that the AlignMed company has made in regards to the effectiveness of the brace, but further studies must be done to determine whether the changes seen are a result of corrective straps or merely the result of the proprioception caused by wearing a compressive shirt.

Limitations

Limitations include the fact that the brace was fitted and applied by the two research assistants who were trained by a bracing representative rather than the bracing representative herself. The initial study design called for the braces to be fit by the bracing representative however this was not possible during the actual study. This may have negatively affected the study since a trained professional was not fitting the braces and the straps for the sham group could have been fit too tightly while the straps for the treatment groups could have been fitted too loosely. A second limitation is that in meeting with the trained bracing company representative for brace fitting training she stated that she sometimes uses the corresponding straps for the brace one size up if a patient has a long torso. There is about a two-inch difference between sizes for corresponding straps. If this method is effective then the effectiveness of the sham treatment for those with longer torsos may have been decreased if the straps of the brace size that they were fitted for were used. What this means is that some people in the sham group could have inadvertently received the actual treatment because there would be more tension at the straps than for someone with a shorter torso. Also addressing correct fit of the brace, it was found throughout the study that the brace fit males better than females. It was found the brace was often too wide in the shoulders for females which moved the

placement of the internal strap over the acromion rather than between the acromion and the neck. This could decrease the effectiveness of the brace in females since it is not fitting as it was designed. A third limitation was that during exercises the brace tended to gather in the back between the placement of the C straps. This affects the pull of the straps on the shoulders and may change the effectiveness of the brace. It is likely that, since the straps were not adjusted after the initial application, the straps lost their tension and prevented significant findings. It is suggested that the brace be adjusted between exercises to ensure proper alignment of the straps. A fourth limitation is that we used only one type of brace application. This was the application recommended by representatives from the AlignMed company and is most commonly used clinically by them. There are also several other brace applications that could be used. Different brace applications may affect posture and EMG differently and using a different method may be more beneficial.

A fifth limitation is that the straps could have restricted motion or caused a mechanical restraint prevent a normal movement pattern. Guide poles were used to determine the end of motion and therefore the movement pattern should have been relatively the same for the brace and non-brace condition; however if the brace provided a mechanical restraint then the muscle may have to work harder during the end range of motion to reach the guide pole. If the muscle worked harder then t is possible that EMG would have been increased and therefore given a false positive that EMG activity had increased due to better position of the scapula. Restricted motion could be a possible cause of the decrease seen in the middle trapezius during shoulder extension as was previously discussed. A sixth limitation is that as

with all studies involving EMG there is variability and due to this variability outliers can exist. In this study several values had to be removed for specific exercises and muscles because they were outliers and would have skewed the data. Finally, a possible limitation was found in the measurement technique used to determine FHRSP. It has already been established that technique of taking a profile picture and measuring posture using Adobe Photoshop® has a 4-5 ° error rate (Thigpen, 2006). It is possible that shrugging the shoulders may cause an increase change in the FSA.

Future Research

Future research should investigate different the brace applications described by the bracing company and how they affect FHRSP and EMG activity. Future research should compare different strap applications to just wearing the compression shirt portion of the brace without the straps applied. This was not done in this study in an effort to blind the primary researcher to the group that the subject was in. Future research should also evaluate different exercises which may better engage the specified muscles such as the push up plus for the serratus anterior.

Future research should investigate the cumulative effects of wearing the brace while performing exercises to determine whether or not changes continue to occur. This could be done through an intervention program lasting several weeks in which the subjects wear the brace while performing various daily or weekly rehab exercises. Not only would this better help to determine the long-term effects of the brace, but it would further help to determine clinical significance since this is the manner in which the brace would be used clinically rather than wearing it just once and expecting large changes. It would also be useful to include a survey in future research to determine whether the patient feels that the brace is improving posture,

the comfort level of the brace, whether the brace felt different after exercises compared to before. This would be especially useful in studies comparing a treatment group to a sham group as this one did to determine if patients feel they are receiving a treatment and how that affects results. Further investigation should be done to determine whether or not it is the strap application or the proprioceptive effects of the brace that caused changes in the FSA and muscle activity for the upper, middle, and lower trapezii.

Conclusion

In conclusion, this study found that there were significant changes in FSA and upper, middle, and lower trapezii EMG activity caused when wearing the S3 brace compared to not wearing it. However, this study did not find significant differences in the treatment group compared to the sham group for FHRSP or EMG activity in any muscles. This indicates that the specific strap application may not be the cause (or at least not the sole cause) of the changes in posture and EMG activity. This is not to say that use of the brace is ineffective or unwarranted, but future studies should be performed to further determine the effectiveness of the brace in improving posture and EMG activity.

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