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The Effect of McConnell Shoulder Taping on Shoulder Muscle EMG and Shoulder Torque Productions in Subjects With Anterior Shoulder Instability

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THE EFFECT OF McCONNELL SHOULDER TAPING ON SHOULDER MUSCLE EMG AND SHOULDER TORQUE PRODUCTIONS IN SUBJECTS WITH ANTERIOR SHOULDER INSTABILITY

By

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ABSTRACT

Introduction: Anterior shoulder instability (ASI), a common clinical problem, causes significant functional impairments. Despite little evidence to support its use, rehabilitation directed at the unstable glenohumeral joint often includes McConnell shoulder taping. This taping technique consists of a base layer of tape followed by application of a rigid strapping tape (corrective) to restrain excessive translation of the humeral head. The aims of this study were to determine the effects of McConnell shoulder taping on EMG amplitude of ten shoulder muscles and on shoulder joint peak torque between three conditions: no tape and base tape alone; no tape and McConnell tape (base plus corrective) and between base tape alone and McConnell tape during isokinetic scaption and external rotation at two abduction positions in subjects with ASI.

Methods: Eleven subjects with ASI completed concentric isokinetic testing in three functional exercise movement patterns while wearing a combination of fine wire and surface electrodes. Peak EMG amplitude for three phases of each movement pattern and peak isokinetic shoulder joint torque were evaluated. The absolute values of the change scores between the three tape conditions were analyzed using t tests ($p<.0166$).

Results: Changes in EMG activity between each of the taping conditions increased in some subjects and decreased in others. On the whole, significant differences in EMG amplitude occurred after application of full McConnell taping

as well as after application of base tape alone for the rotator cuff and deltoid muscles in all three movement patterns. The remaining six muscles demonstrated significant changes in EMG amplitude over selective arcs of motion in some movement patterns, although findings were less consistent. No significant differences in shoulder joint peak torque for any of the taping conditions arose.

Discussion: McConnell taping effects a change in EMG activity for most shoulder muscles but not on peak torque in subjects with ASI. Similarly, the base tape alone can also cause a change in EMG activity. This suggests a possible sensory effect from tape on the skin.

Conclusion: This study supports the use of McConnell shoulder taping as a means for influencing neuromuscular activity during a shoulder rehabilitation program for persons with ASI.

CHAPTER I

INTRODUCTION

Background of the problem:

The glenohumeral joint (GHJ) of the shoulder serves as a critical articulation for functional upper extremity movement. Its ball and socket joint design affords a tremendous range of motion (ROM) in multiple anatomic planes, however the GHJ frequently becomes unstable. This is largely due to the shoulder joint socket (glenoid) being too shallow to fully contain the ball (humeral head) (Curl & Warren, 1996). Therefore, the shoulder joint relies heavily on the local soft tissues for stability and restriction of excessive motion.

Static stability is afforded by the joint capsule, glenohumeral ligaments and labrum, a rim of fibrocartilage that encircles and deepens the socket (Curl & Warren, 1996). Dynamic stability is provided primarily by the four rotator cuff muscles: supraspinatus, infraspinatus, teres minor and subscapularis, whose combined action line draws the humeral head directly into the glenoid, centering the humeral head thus limiting excessive motion (Lippitt, Vanderhooft, Harris et al., 1993). Adding to glenohumeral joint control the deltoids, latissimus dorsi, pectoralis major, biceps brachii and serratus anterior provide secondary dynamic stability. Numerous cadaveric laboratory experiments demonstrate a decrease in movement of the humeral head when tension is applied to the rotator cuff (Blasier, Guldberg, & Rothman, 1992; Lippitt et al., 1993), biceps (Itoi, Newman, Kuechle, Morrey, & An, 1994; Pagnani, Deng, Warren, Torzilli, & O'Brien, 1996) and the deltoids (Kido, Itoi, Lee, Neale, & An, 2003).

Deficiency in any part of the stabilizing system (static, dynamic or both) can allow excessive translatory movement of the humeral head on the glenoid, termed subluxation (Dodson & Cordasco, 2008). Repeated subluxation results in clinical shoulder instability. Matsen (1991) defines instability as a clinical condition in which unwanted translation of the humeral head on the glenoid compromises the comfort and function of the shoulder While abnormal motion of the humeral head in any direction can cause instability, the most common type of shoulder instability occurs in the anterior (forward) direction (Dodson & Cordasco, 2008).

The clinical manifestation of anterior shoulder instability (ASI) includes a patient complaint that the shoulder is slipping out of place, most notably when the arm is placed in full abduction (sideways elevation) and external (outward) rotation (Dodson & Cordasco, 2008). As this is the position of the arm during throwing (coined the 90/90 position), ASI often precludes an athlete from participating in their sport. Studies using electromyographic analysis (EMG), which records the electrical activity in contracting muscles (DeLuca, 2002), demonstrate abnormal muscle activity in subjects who have ASI during throwing (Glousman et al., 1988; Kim, Ha, Kim, & Kim, 2001; McMahon, Jobe, Pink, Brault, & Perry, 1996). In a study of 26 subjects with ASI, 59% of subjects reported a marked decrease in the ability to perform in sports as well as other symptoms of impaired strength, decreased ROM and pain induced by activity (Tsai, 1991). Functional limitations resulting from ASI are seen not only in sport, but also during more routine activities of daily living (ADL) such as pulling a shirt over one's head.

Rehabilitation of patients with anterior shoulder instability, therefore, focuses on strategies to improve function by strengthening the dynamic stabilizers (Jobe, Moynes, & Brewster, 1987; Jaggi & Lambert, 2010). Strengthening an unstable joint without causing symptoms of subluxation can be challenging. One method to restrain excessive humeral head motion during strengthening exercises is shoulder taping. Jenny McConnell, an Australian physical therapist, first introduced her taping technique in 1986 to treat patella (knee cap) instability (McConnell, 1986) and later expanded her technique to remedy the unstable shoulder joint (McConnell & McIntosh, 2009). McConnell taping uses two layers of tape; a base tape layer to protect the skin (Coverall ®) followed by a rigid corrective tape (Leukotape ®) used to realign the joint. With patella taping, McConnell proposes that pulling the patella more medially (inwards) helps restore normal joint alignment that facilitates activation of the vastus medialis oblique (VMO), the primary medial muscular stabilizer (McConnell, 1986). Alterations to VMO electromyographic activity after McConnell patella taping in subjects with patellofemoral pain (PFP) occurred in numerous investigations. One author reports increased EMG magnitude (relative activity) after application of patella tape (Christou, 2004), another reported a decrease in EMG magnitude (Ng & Cheng, 2002) and a third found both increases and decreases in EMG magnitude (Cowan, Hodges, Crossley, & Bennell, 2006). It appears from these studies that patient response to McConnell taping varies on an individual basis.

Additionally, Christou (2004) found an increase in EMG magnitude of the VMO after application of a placebo tape. Placebo taping, wherein tape is applied to the skin with no joint correction made, is often employed in experimental taping studies as a control. The increased EMG activity in subjects during placebo taping in Christou's study may point to a possible sensory effect of tape on muscle activity. MacGregor and colleagues (2005) tested this concept that tape may partially exert its effect due to stimulation of the sensory neurons in the skin. They found that a stretch applied to the skin with tape, without correction of patella position, increased VMO activity by as much as 9% (Macgregor, Gerlach, Mellor, & Hodges, 2005).

While EMG activity provides useful information regarding the magnitude and timing of muscle activity, it cannot provide information about a muscle's force producing capability (Soderberg & Knutson, 2000). One method to measure force output is through isokinetic testing wherein a mechanical dynamometer records torque (force about a joint's axis of rotation) (Soderberg & Knutson, 2000). Several authors reported increased knee extension peak torque after patella taping during isokinetic knee extension (Conway, Malone, & Conway, 1992; Handfield & Kramer, 2000; Werner, Knutsson, & Eriksson, 1993), however another author found no change (Christou, 2004). This discrepancy points out the limited evidence present in the current literature for the use of McConnell taping at the knee. Despite a multitude of investigations of the effect of McConnell taping on the EMG activity and force production of the knee joint, there are to date no similar investigations involving the shoulder. The effect of tape on shoulder muscle EMG activity and force output is needed to substantiate the efficacy for the use of tape during physical therapy treatment protocols for anterior shoulder instability.

Hence, the objectives for this study were two fold. The primary objective of this study was to document the effect of McConnell shoulder taping on the EMG magnitude of ten shoulder muscles and on shoulder joint peak torque in subjects with ASI during three isokinetic movement patterns: scaption (elevation in the scapular plane), external rotation at 45° of shoulder abduction (ER 45°) and external rotation at 90° of abduction (ER 90°).

As the literature points to a possible sensory effect of placing tape on the skin, the secondary objective of this study was to document the effect of the base tape alone on EMG and torque during the identical testing protocol. Accordingly, we tested three research hypotheses:

Research Hypotheses

H1 : There will be a change in the EMG magnitude of the shoulder muscles and in shoulder joint peak torque after the application of McConnell tape when compared to no tape during isokinetic:

$H1_a$ Scaption

$H1_b$ External Rotation at 45 degrees of Abduction (ER 45°)

$H1_c$ External Rotation at 90 degrees of Abduction (ER 90°)

H2 : There will be a change in the EMG magnitude of the shoulder muscles and in shoulder joint peak torque after the application of base tape alone when compared to no tape during isokinetic:

$H2_a$ Scaption

$H2_b$ External Rotation at 45 degrees of Abduction (ER 45°)

$H2_c$ External Rotation at 90 degrees of Abduction (ER 90°)

H3 : There will be a change in EMG amplitude of the shoulder muscles and in shoulder joint peak torque after the application of McConnell tape when compared to base tape alone during isokinetic:

$H3_a$ Scaption

$H3_b$ External Rotation at 45 degrees of Abduction (ER 45°)

$H3_c$ External Rotation at 90 degrees of Abduction (ER 90°)

As the literature is inconclusive as to the direction of change in EMG activity, a two tailed hypothesis was employed.

CHAPTER II

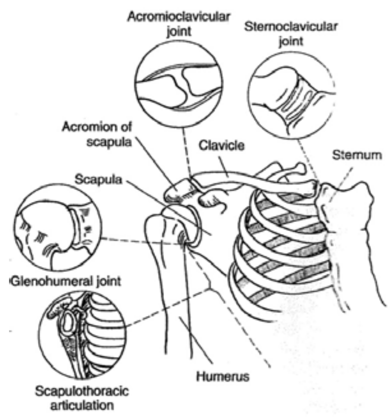
REVIEW OF LITERATURE

This study was designed to investigate the effect of McConnell shoulder taping and McConnell base layer taping on the electromyographic activity of the shoulder muscles and on shoulder joint torque production. The review of literature is divided into four sections: Anatomy and biomechanics, etiology of ASI, EMG comparison of the normal and unstable shoulder and review of the current taping literature.

Anatomy and Biomechanics

The scapula, clavicle, humerus and sternum form four joints provide the bony framework for the shoulder complex (Figure 1).

Figure 1: Bony Anatomy of the Shoulder Complex



(Nordin & Frankel, 2001)

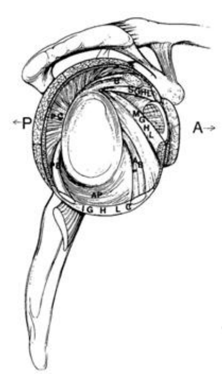
The first joint of the shoulder complex is the sternoclavicular joint formed from the articulation between the sternum and the medial end of the clavicle. The articulation between the acromion process of the scapula and the lateral end of the clavicle form the acromioclavicular (AC) joint. The motions available at these two joints involve elevation, depression, protraction, retraction, upward and downward rotation. Motion at these two joints must occur for the shoulder joint to move through it's full range of motion (Soderberg, 1997).

Another important link in the shoulder complex is the scapula's articulation with the rib cage, which forms the scapulothoracic joint. The primary motions of the scapula on the thorax consist of upward and downward rotation, as well as protraction and retraction. Most important to overhead movement is the upward scapular rotation that occurs during shoulder elevation (Soderberg & Knutson, 2000).

Lastly is the glenohumeral joint (GHJ) formed by the ball and socket articulation of the head of the humerus with the glenoid cavity of the scapula. The triplanar motions available at the shoulder joint include flexion and extension (sagittal plane), abduction and adduction (frontal plane) and internal and external rotation (transverse plane) (Soderberg & Knutson, 2000). A unique shoulder motion is scaption, occurring when the humerus is positioned 30° anterior to the frontal plane. Functionally, the large motions at the GHJ allow the arm and hand to be well positioned for many of our daily and recreational activities. The ability to move the shoulder through a large ROM in the various planes is conducive to joint mobility however sacrifices joint stability. The diminished stability is largely due to the surface area of the humeral head being approximately three to four times the size of that of the glenoid (Soderberg, 1997). For this reason, the shoulder joint relies heavily on the local soft tissue restraints for its stability.

Static restraints to shoulder motion include the joint capsule, the three glenohumeral ligaments: superior, middle and inferior, as well as the glenohumeral labrum. The shoulder joint capsule is large, loose and redundant, further contributing to the large ROM in all three planes (Soderberg, 1997). In contrast, the three glenohumeral ligaments seen as discrete thickenings of the joint capsule serve as the primary restraints to excessive anterior translation of the humeral head on the glenoid (O'Brien, Schwartz, Warren, & Torzilli, 1995). The labrum, a fibrous rim of cartilage encircling the glenoid, functions to deepen the glenoid and serves as an attachment site for the glenohumeral ligaments (O'Brien et al., 1990). Together these soft tissue structures limit anterior humeral head translation but require the surrounding musculature to aid in stability.

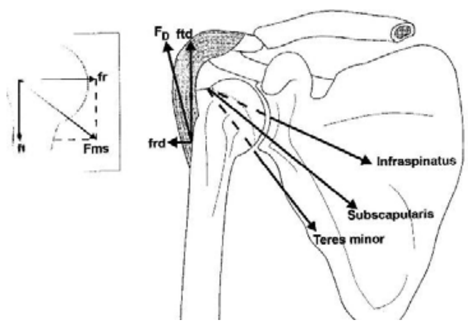
Figure 2: Ligaments of the Shoulder Complex



(O'Brien et al., 1990)

The primary muscular stabilizers of the glenohumeral joint include the four rotator cuff muscles (supraspinatus, infraspinatus, subscapularis and teres minor), the deltoids and the long head of the biceps brachii (LHB) (Lippitt & Matsen, 1993; Soderberg, 1997). Because the rotator cuff muscles are oriented perpendicular to the glenoid, their contraction compresses the humeral head directly into the glenoid fossa (Lippitt et al., 1993). This concavity compression is a crucial stabilizing mechanism preventing the excessive anterior translation that causes ASI.

Figure 3: Concavity Compression



(Soderberg, 1997)

While contraction of the rotator cuff provides the primary dynamic stabilization at the shoulder joint, pectoralis major and latissimus dorsi muscles offer important secondary stabilization. Additionally, the serratus anterior muscle plays an important role in shoulder stability causing upward rotation of the scapula that allows the glenoid fossa to maintain contact with the humeral head throughout the ROM (Soderberg, 1997).

The role of the rotator cuff, deltoids and biceps muscles in limiting anterior humeral head translation is well documented through biomechanical laboratory studies using the cadaver model. During these studies, selective cutting of the glenohumeral ligaments and/or labrum is performed in order to simulate an unstable shoulder. The resulting humeral head translation after ligament cutting and the effect of simulated muscle contractions along their anatomic line of action are then measured.

In one of the earlier studies, Cain et al (1987) examined the effect of simulated rotator cuff forces on the strain in the inferior glenohumeral ligament (IGHL) during shoulder external rotation. These authors found that simulated contraction of all 4 rotator cuff muscles caused a significant decrease in strain in the IGHL during external rotation at lower loads, but only the infraspinatus/teres minor component was significant at higher loads (Cain, Mutschler, Fu, & Lee, 1987). This finding elucidates the importance of the teres minor and infraspinatus in restraining humeral head motion during the high velocities and subsequent loads requisite to overhead sports.

Blasier et al (1992) using a similar cadaveric model, quantified the contributions to shoulder stability made by the four rotator cuff muscles. They measured the force required to produce an anterior shoulder subluxation while applying tension to the individual rotator cuff tendons. These authors found that more force was required to sublux the joint when tension was applied to any of the four rotator cuff tendons (Blasier et al., 1992). The results of these studies are supported by the works of other authors (Lippitt et al., 1993; Itoi et al., 1994; Wuelker, Schmotzer, Thren, & Korell, 1994). Similar biomechanical studies demonstrate that contraction of the long head of the biceps (Rodosky, Harner, &

Fu, 1994; Itoi et al., 1994; Pagnani et al., 1996), and deltoids (Kido et al., 2003) decrease excessive anterior humeral head translation as well. In summary, these biomechanical studies elucidate the critical stabilizing role of the shoulder joint musculature in helping to restrain excessive anterior motion of the humeral head.

Etiology of ASI

Traumatic ASI

Traumatic dislocation is the most common cause of shoulder instability (Dodson & Cordasco, 2008). The typical mechanism of injury for a traumatic dislocation occurs following a fall onto an outstretched arm with the shoulder abducted and externally rotated (Dodson & Cordasco, 2008). Dislocation causes tearing of the glenohumeral ligaments and the joint capsule, disrupting the integrity of the joint. Thus, after the primary dislocation, reoccurrence rates can be between 55% and 90%, with a higher incidence in the younger population (Henry & Genung, 1982; Hovelius, 1999).

These high reoccurrence rates are largely due to shoulder dislocation causing disruption of the glenohumeral ligaments, joint capsule and labrum. Detachment of the anterior inferior glenoid labrum, called a Bankart tear, occurs in 87%-100% of patients after traumatic dislocation (Baker, Uribe, & Whitman, 1990; Norlin, 1993; Owens et al., 2010). Using a cadaver model, Lippitt (1993) found that resection of the glenoid labrum reduced resistance to anterior humeral head translation by 20%. Because of the damage to the soft tissue stabilizers during dislocation, ASI is the most common complication following traumatic dislocation. Robinson followed 252 patients after traumatic dislocation (aged 15-35) and determined that 55.7% of subjects developed ASI during the first two years, with the incidence increasing to 66.8% by the 5th year (Robinson, Howes, Murdoch, Will, & Graham, 2006).

Atraumatic ASI:

A second form of ASI occurs in athletes who participate in demanding overhead sports such as baseball, swimming, volleyball and tennis. During these sports, the shoulder undergoes repetitive and excessive amounts of external rotation at high movement velocities. This repetitive tensile loading of the anterior structures during external rotation and abduction is thought to cause a gradual, excessive stretching of the anterior joint capsule and ligaments over time (Jobe & Pink, 1993), which creates ASI.

Electromyography of the Shoulder Muscles

Alteration in the normal functioning of the shoulder muscles is documented in subjects with ASI. Glousman et al (1988) in one of the earliest studies compared the EMG activity of subjects with ASI to normal subjects during throwing. These authors found a significant increase in supraspinatus activity during the late cocking phase of the throw when the shoulder was positioned in maximal abduction and external rotation. They speculate that increased supraspinatus activity aids in stabilizing the shoulder when in its vulnerable apprehension position. In contrast to increased supraspinatus activity, the same authors found a significant decrease in serratus anterior EMG activity during the late cocking phase of the throw. The serratus anterior upwardly rotates the scapula during shoulder elevation allowing congruency between the ball and socket. Diminished serratus anterior activity then may have an adverse effect on joint stability.

In a similar study design, McMahon (1996) compared the EMG activity of the rotator cuff and scapular muscles between subjects with ASI and subjects with healthy shoulders during abduction, scaption and forward flexion movements. In both abduction and scaption the supraspinatus demonstrated significantly less EMG activity from 30 to 60 degrees in subjects with ASI. Similar to Glousman's (1988) study, McMahon (1996) found that during all three motions, shoulders with ASI demonstrated significantly less EMG activity in the serratus anterior.

Kim and colleagues (2001) investigated the EMG activity of the biceps muscle in the vulnerable abduction and external rotation position in subjects with traumatic ASI compared to their unaffected side. These authors reported that the EMG activity of the biceps muscle was significantly greater in the unstable shoulder than the opposite shoulder. They concluded that the increase in biceps activity may be compensatory serving to increase joint stability.

More recently, Jaggi and colleagues (2012) in a qualitative study, sought to identify abnormal activation patterns of the pectoralis major (sternal head), anterior deltoid, latissimus dorsi and infraspinatus muscles in subjects with anterior shoulder instability during motions of the shoulder. The authors compared the temporal EMG pattern of the four muscles and compared them to the expected normal patterns of activity established by previous researchers. The pectoralis major and latissimus dorsi were found to be inappropriately active 60% and 81% of the time respectively and the deltoid 22% of the time. This study, however, was based on retrospective EMG data and unfortunately the specific movement in which the muscles were acting inappropriately were not identified.

The aforementioned studies identify altered EMG activity in the major stabilizing muscles of the glenohumeral complex in subjects with anterior shoulder instability. Altered muscle activity in the stabilizing muscles may affect their ability to restrain humeral head motion, further contributing to the continued functional losses in these subjects. Rehabilitation of subjects with ASI must then be focused on strategies to enhance the neuromuscular control of the stabilizing muscles. It is suggested that joint taping has a positive influence on muscular activity. Jenny McConnell, an Australian physical therapist, first introduced her taping technique in 1986 to treat patella (knee cap) instability (McConnell, 1986) and later expanded her technique to remedy the unstable shoulder joint (McConnell & McIntosh, 2009). McConnell taping uses two layers of tape; a base tape layer to protect the skin (Coverall ®) followed by a rigid corrective tape

(Leukotape ®) used to realign the joint. A review of the pertinent taping literature follows.

McConnell Taping

Patella taping:

Several investigations document the effect of patella taping on the EMG magnitude of the VMO and on isokinetic force production after patella taping. Ng and Cheng (2002) examined the effects of patellar taping on the EMG activity ratio of the VMO to the vastus lateralis (VL). Fifteen subjects with patellofemoral pain (PFP) performed a single leg squat with and without tape. The authors reported a significant decrease in the EMG ratio of the VMO to the VL after taping. They attribute the relative decrease in VMO activity to a decreased need for the VMO to pull the patella medially.

Christou (2004) investigated the influence of patellar taping on isokinetic force production and on the EMG activity of the VMO and VL in females with and without PFP. Subjects performed maximal isokinetic leg presses under three conditions: no tape (control), no glide (placebo tape) and medial and lateral taping (experimental). The authors found that medial and lateral taping were both associated with increased VMO activity whereas VL activity did not differ between groups. Peak leg press force did not differ between conditions or between groups.

Cowan and Hodges (2006) investigated the effect of patellar taping on the EMG amplitude of the vasti muscles during a stair stepping task in subjects with and without PFP. The authors reported that some subjects showed increased EMG and some showed decreased EMG after taping. Herrington (2005) examined the effect of patellar taping on isokinetic peak torque of the quadriceps in 14 females with PFPS finding that patellar taping significantly increased quadriceps peak torque during isokinetic knee extension. Herrington suggested that repositioning the patella with tape may alter the leverage of the patella, maximizing the mechanical advantage of the quadriceps (Herrington, Malloy, & Richards, 2005). In summary, the use of McConnell tape in subjects actively contracting the quadriceps during various functional lower extremity activities influences EMG activity of the VMO and VL. However, the patella taping literature does not offer a clear consensus regarding the direction of change in VMO activity or the effect of taping on isokinetic torque production.

Glenohumeral taping

The literature surrounding McConnell shoulder taping deals primarily with its effect on glenohumeral joint ROM and was all performed by McConnell herself. In the first of her three papers, glenohumeral passive range of motion (PROM) in asymptomatic tennis players was measured pre and post both placebo taping (tape applied without tension) and McConnell taping. Both conditions were compared to a no tape condition that served as a control.

McConnell tape resulted in a significant increase in passive external and internal rotation when compared to both the control and placebo conditions (McConnell & McIntosh, 2009). The author speculates that the increased ROM is desirable as it may optimize the shoulder obtaining a more normal axis of rotation. A limitation to this study is that it was performed on nonsymptomatic subjects, thus extrapolating the results to unstable subjects is not possible. McConnell did, however, follow up with an investigation examining the effect of McConnell taping on shoulder joint ROM and on ball velocity in both uninjured and previously injured athletes during a seated throw. The authors reported that both shoulder internal and external rotation ROM decreased in the previously injured group after McConnell taping, but increased in the group of subjects who had never been injured (McConnell, Donnelly, Hamner, Dunne, & Besier, 2011). Maximum abduction ROM and the ball velocity were not affected in either group (McConnell et al., 2011). The author speculates that a decrease in the maximum external rotation limits the excessive joint ROM thought to be harmful to the shoulder during over head sports. McConnell (2012) also measured the dynamic ROM during the seated throw in this same group, published under separate cover. She reported that McConnell shoulder taping decreased the dynamic range (AROM) of the previously injured athlete so that it was nearer the dynamic range found in the group of uninjured athletes. As with their finding of decreased PROM in this group, McConnell (2012) speculates that the decrease in the dynamic ROM might also provide protection for the injured athlete's shoulder during overhead sports.

Placebo taping

To evaluate the possibility of a stimulation of cutaneous afferents contributing to the effectiveness of taping, many studies employ a placebo taping condition. Reflex coupling between individual mechanoreceptors in the skin and voluntary muscle contractions is well described in the literature. Aniss (1992) found that stimulation of cutaneous afferents in the skin of the hand caused both excitatory and inhibitory EMG responses in the muscles of the ankle. Similar results were reported in a later investigation by Fallon, Bent, McNulty, & Macefield (2005). Additionally, McNulty and group (1999) reported that stimulation of cutaneous afferents in the skin of the hand caused both excitatory and inhibitory EMG responses in the muscles acting on the digits in healthy individuals.

In a more germane investigation to this one, Macgregor (2005) investigated the effect of stretching the skin over the patella on vasti muscles activity in people with PFP. Tape was applied to the skin directly over the patella with stretch applied in three different directions while subjects maintained an isometric knee extension contraction. Stretch applied to the skin over the patella increased VMO EMG and was greatest with the lateral skin stretch. The VL surface EMG activity was unchanged. The authors suggest that cutaneous stimulation may be one mechanism by which patella taping produces its clinical effect. Similarly, Christou (2004) found an increase in VMO activity after application of a placebo tape during an isokinetic leg press, though another author reports no EMG change in the vasti muscles from placebo tape during a stair stepping task (Cowan et al., 2006).

In summary, placebo taping at the shoulder is not well studied, though appears to have no effect on joint ROM. Consensus is lacking regarding whether or not placebo taping alters EMG activity at the knee. Thus, any studies investigating the effects of McConnell taping should incorporate this element into the research design.

CHAPTER III

MATERIALS AND METHODS

Subjects

We recruited volunteers for this study from flyers posted at Seton Hall University, the Seton Hall University student email broadcast and from flyers posted at The Hospital for Special Surgery cooperating physician's offices. The primary investigator interviewed fourteen volunteers via telephone to determine their appropriateness for inclusion in the study. Thirteen of those volunteers met the inclusion criteria and attended a follow up session for clinical instability testing. All thirteen subjects were enrolled in the study; however, one subject withdrew during testing secondary to discomfort from the wire electrodes. Therefore twelve subjects between the ages of 21 and 52 years (mean age 28.8, *SD*=) participated in this study. The subjects represented a sample of convenience and met the following inclusion criteria: 1) over 18 years of age; 2) one or more shoulder dislocations 3) currently experiencing symptoms; 4) positive result on the shoulder apprehension or relocation test (Farber et al., 2006; Farber, Castillo, Clough, Bahk, & McFarland, 2006); 5) previous diagnosis of ASI from an orthopedic doctor. Exclusion criteria for participation included: 1) pregnancy; 2) previous use of shoulder taping; 3) a documented rotator cuff tear; 4) pain precluding the ability to sustain the testing protocol; 5) a positive sulcus sign for multidirectional instability (Tzannes, Paxinos, Callanan, & Murrell, 2004). All subjects had a history of one or more full dislocations and incidences of multiple subluxations.

Table 1: Subject Demographics

Subject	Age (years)	Gender	Side tested	Arm dominance	Upper extremity sport[a]
1	29	Female	L	R	NA
2	21	Female	R	R	C
3	35	Male	R	R	NA
4	32	Female	R	R	NA
5	21	Male	R	R	R
6[b]					
7	35	Male	L	L	R
8	30	Male	L	R	R
9	53	Female	R	R	NA
10	26	Male	L	R	R
11	23	Male	L	L	C
12	21	Male	R	R	R
13	21	Male	R	R	R

[a]Recreational athlete; C, competitive athlete; NA,Non-athlete [b]Withdrew

As there are no previous studies of this nature, sample size was determined from a power analysis after the first five subjects. A priori sample size (α=.05, β= .80) was determined to be 12 subjects. Confidentiality was assured by assigning each subject a numeric code. All data were stored on a password protected computer at The Hospital for Special Surgery and on a thumb drive which was kept in a locked drawer. The study received approval by the Institutional Review Boards of The Hospital for Special Surgery and Seton Hall University. A written informed consent form was orally reviewed highlighting the possible risks and then signed by each subject.

Location

The study location was the Leon Root Motion Analysis Laboratory at The Hospital for Special Surgery, New York, New York.

Instrumentation

EMG Hardware:

The EMG signal was collected using a MA 300 EMG unit (Motion Lab Systems, Baton Rouge, LA). The MA 300 is comprised of two main components: the backpack multiplexor unit and the preamplifier electrode assemblies. The multiplexor houses the circuitry for sixteen variable gain EMG channels. This unit has a signal range of $\pm$5 volts (V) and contains a 10^{th} order low pass filter. The bandwidth capability of the multiplexor is10 Hz to 2,000 Hz. The multiplexor low pass filter was set to allow the maximum bandwidth of 2000 Hz.

There were two types of preamplifier assemblies. One houses two stainless steel discs positioned 18 mm apart for surface EMG detection. The second preamplifier type is designed with two thumb screws for attachment of the wire electrodes leads. Both preamplifier specifications include a bandwidth of 15Hz to 3,500 Hz (-3dB), a gain of 20dB, and a common mode rejection ratio (CMRR) of 100dB. The analog EMG signal was relayed from the preamplifier assembly to the multiplexor via standard cable leads. The cable leads terminated in either a snap clip for attachment to the surface electrodes, or in an alligator clip for interface with the wire electrodes. The EMG signal was transmitted from the multiplexor over a single coaxial cable to a 12 bit A-D converter (National Instruments, Austin, TX).

Because of the speed and amount of movement required by the arm during this protocol, the decision was made to use adhesive surface electrodes cabled to the preamplifiers for increased flexibility. The surface adhesive electrodes were unipolar silver-silver chloride (Ag/AgCl) solid gel electrodes with a 15 mm round detection surface. Two unipolar surface electrodes were used to create a bipolar arrangement. The inter-electrode distance was 20mm.

The fine wire electrodes were comprised of paired stainless steel wires, .08 mm in diameter. The last 2 mm of the wires are stripped for an exposed area of.51 mm^2 that serves as the detection surface. The wires were threaded through a 50 mm, 25 gauge hypodermic needle according to the technique of Basmajian (Basmajian, 1974).

Isokinetic Hardware:

Torque and position data were collected on a Biodex System 3 Multi-Joint Testing and Exercise Dynamometer (Biodex Corp., Shirley, N.Y.) This unit consists of a single chair with trunk stabilization straps and the mechanical dynamometer. Height, rotation, tilt and fore/aft position of both the chair and the dynamometer were adjustable. A Biodex analog signal interface device (Biodex Corp, Shirley, N.Y.) provided output of the Biodex torque and position signal to the A-D converter. Biodex signal output allowed for synchronization of position and torque with the EMG signal.

Software:

Cortex motion capture software (Motion Analysis Corp, Santa Rosa, CA) collected the EMG and Biodex signals. Visual 3D (C-Motion Inc, Germantown, MD) performed all signal processing.

SPSS Statistical Software (Armonk, N.Y.) performed the statistical analysis. G*Power (Olshausenstr, Germany) performed the statistical power calculations.

Dependent Variables

EMG Amplitude

Peak normalized EMG amplitude was calculated for each of the ten muscles, during the three isokinetic movement patterns (scaption, ER 45^o, ER 90^o) for the three taping conditions (No tape, base tape alone and McConnell tape). Subjects performed five repetitions of each isokinetic movement pattern. Each of the five repetitions was divided into three arcs of motion: 0-50^o, 50-75^o, and 75^o–maximum. The separation into three distinct arcs of motion allowed isolated analysis of the end ROM where the shoulder is most unstable. Accordingly, there were three peak EMG amplitudes per repetition (one for each arc of motion).

Peak Torque

Peak torque was calculated for each of the three isokinetic movement patterns for the three taping conditions. Table 2 summarizes the research variables.

Table 2: Research Design

Isokinetic Movement Pattern	Taping Condition	Dependent Variables
Scaption	No Tape Base Tape McConnell Tape	Peak EMG Amplitude 0°-50° 50°-75° 75°-max Peak Torque
ER 45° Abduction	No Tape Base Tape McConnell Tape	Peak EMG Amplitude 0°-50° 50°-75° 75°-max Peak Torque
ER 90° Abduction	No Tape Base Tape McConnell Tape	Peak EMG Amplitude 0°-50° 50°-75° 75°-max Peak Torque

Procedures:

Screening for inclusion criteria:

PROM testing: While supine on a plinth with hips and knees flexed, the primary investigator moved the subjects shoulder through the available ROM in three planes of motion. We noted any major restrictions in PROM and subject report of pain.

Apprehension testing: While supine the primary investigator placed the shoulder in 90º of abduction and moved it towards 90º of external rotation. If subjects reported perceptions of instability the test was considered positive (Farber et al., 2006).

Relocation Test: The investigator applied a posteriorly directed force to the humeral head with the patient positioned in the apprehension position as above. A decrease in apprehension or pain was a positive test (Farber et al., 2006).

ElectromyographicTesting:

The MA 300 EMG unit collected EMG from ten shoulder muscles using a combination of fine wire intramuscular electrodes and surface electrodes. Four muscles were tested with intramuscular fine wire electrodes: the supraspinatus, infraspinatus, upper subscapularis and lower subscapularis. EMG collection from the remaining six muscles: the clavicular head of the pectoralis major, latissimus dorsi, anterior and middle deltoid, serratus anterior and the biceps brachii utilized surface electrodes (table 3). Previous studies have validated the use of intramuscular and surface electrodes in parallel (Backus et al., 2011). Sampling at 5000 Hz converted the EMG signal from analog to digital form (A-D conversion). For the purposes of discussion the 10 muscles are divided into three groups: 1. rotator cuff muscles (supraspinatus, infraspinatus, upper and lower subscapularis) 2. humeral muscles (biceps brachii, anterior and middle deltoids) 3. trunk muscles (latissimus dorsi, serratus anterior and pectoralis major).

Table 3: Electrode Type by Muscle

Muscle	Electrode Type
Rotator Cuff Muscles	
Infraspinatus	Fine wire
Supraspinatus	Fine wire
Subscapularis, Lower	Fine wire
Subscapularis, Upper	Fine wire
Humeral Muscles	
Biceps Brachii	Surface
Deltoid, Anterior	Surface
Deltoid, Middle	Surface
Trunk Muscles	
Latissimus Dorsi	Surface
Pectoralis Major	Surface
Serratus anterior	Surface
Supraspinatus	Fine wire

All electrode placements were parallel to the orientation of the muscle and designed to be centered about the ideal electrode points as described by Perotto (Perotto & Delagi, 2005) and Cram (Cram, Kasman, & Holtz, 1998) (table 4).

Table 4: Electrode Placement for EMG Testing

Muscle	**Subject position**	**Electrode placement**
Biceps Brachii	Supine, arm extended	Midpoint between biceps tendon at the elbow and supraglenoid tubercle
Deltoid, Anterior	Supine, arm at side	Three fingerbreadths below the anterior margin of the acromion
Deltoid, Middle	Supine, arm at side	Halfway between the tip of the acromion and the deltoid tuberosity
Infraspinatus	Prone, arm abducted to 90^{o} and elbow flexed over edge of plinth	2.5 cm below the midpoint of the spine of the scapula
Latissimus Dorsi	Prone, arm at side, palm up	Three fingerbreadths distal to and along the posterior axillary fold
Pectoralis major	Supine	3.5 cm medial to the axillary fold
Serratus	Prone with arm dangling over edge of plinth	Just lateral to the inferior angle of the scapula
Subscapularis, Lower	Prone hand behind the back	5 cm below the spine of the scapula anteriorly
Subscapularis, Upper	Prone hand behind the back	3 cm above the spine of the scapula anteriorly
Supraspinatus	Prone, arm abducted to 90^{o} and elbow flexed over edge of the plinth	1.5 cm above the midpoint of the spine of the scapula

Insertion of fine-wire electrodes utilized clean technique. After needle removal the wire tips remained in the muscle bellies. The depth of insertion of the wire electrode ranges from 1.0 cm to 4.0 cm based upon the girth of the overlying musculature and amount of subcutaneous adipose tissue present in the subject. We taped the protruding wires to the skin and attached the proximal ends to the pre-amplifiers.

Skin preparation prior to application of the surface electrodes included cleaning with isopropyl alcohol to remove surface oils and lightly abrasion with a gauze pad to decrease skin impedance. The acromion of the opposite shoulder served as the placement site for the reference electrode. The multiplexor was secured to the Biodex chair via a Velcro belt.

Visual observation of muscle activity on the computer screen while the subject performed a muscle specific resisted motion confirmed the correct electrode placement. At this time, we adjusted the gains to ensure adequate visualization and to prevent signal saturation. After confirming adequate signal collection, the subjects performed a series of five second maximal voluntary isometric contractions (MVIC) for use in normalization. Previous research demonstrates the positions used (table 5) provide maximal activation of each muscle (Kelly, Kadrmas, Kirkendall, & Speer, 1996). The data acquired during EMG were expressed as a percentage of these MVIC contractions.

Table 5: MVIC Test Positions

Muscle	Action
Biceps Brachii	Resisted elbow flexion, shoulder at 0^{o}, elbow at 90^{o} flexion
Deltoid-Anterior	Resisted elevation in scapular plane, shoulder at 0^{o} rotation
Deltoid, Middle	Resisted abduction, shoulder at 0^{o} degrees rotation
Infraspinatus	Resisted external rotation, shoulder at 0^{o} rotation
Latissimus Dorsi	Resisted extension, shoulder at 90^{o} elevation in scapular plane
Pectoralis Major	Resisted horizontal adduction, shoulder at 90^{o} elevation in scapular plane
Serratus anterior	Shoulder protraction, shoulder at 90 elevation in scapular plane
Subscapularis, Lower	Resisted internal rotation, shoulder at 90^{o} elevation in scapular plane
Subscapularis, Upper	Resisted internal rotation , shoulder at 0^{o} elevation
Supraspinatus	Resisted forward flexion in scapular plane, shoulder at 90^{o} elevation and 0 degrees rotation

(Kelly et al., 1996)

Isokinetic Testing

Subjects performed three isokinetic movement patterns during which EMG and torque collection occurred: 1) scaption; 2) internal and external rotation in 45° of shoulder abduction and 3) internal and external in 90° of shoulder abduction. Figures 4-6 illustrate these patterns respectively.

Figure 4: Biodex Set Up Scaption

Figure 5: Biodex Set Up ER 45^{o} Abduction

Figure 6: Biodex Set Up ER 90^{o} Abduction

We randomized position order using a computer generated random order table (http://www.randomizer.org) to decrease the possibility of order bias (table 6). Due the length of the protocol, the last Biodex position for each taping condition served as the starting position of the next condition. This design decreased the number of Biodex position changes, and hence the total testing time as well as minimizing inter-trial variability. One of eight possible combinations of testing order were picked from a hat for each subject.

Table 6: Taping Randomization Table

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Scaption	Scaption	Scaption	Scaption	45	45	90	90
No Tape	45	45	90	90	90	90	45	45
	90	90	45	45	Scaption	Scaption	Scaption	Scaption
	90	90	45	45	Scaption	Scaption	Scaption	Scaption
Base Tape	45	45	90	90	45	90	45	90
	Scaption	Scaption	Scaption	Scaption	90	45	90	45
	Scaption	Scaption	Scaption	Scaption	90	45	90	45
McConnell	45	90	45	90	45	90	45	90
	90	45	90	45	Scaption	Scaption	Scaption	Scaption

As removing the tape between conditions dislodged the wire electrodes, rendering taping order randomization implausible. Therefore, the testing order was first no tape, then base tape tape alone, and lastly McConnell taping. The same investigator performed the EMG set up, McConnell shoulder taping and the isokinetic testing.

Subject set-up and positioning:

We performed setup and positioning according to the usual and customary Biodex guidelines described in the user’s manual. For all exercise patterns the subjects sat upright in the Biodex accessory chair reclined 10º. Pelvic and trunk stabilization straps restrained trunk movement. The dynamometer was located on the side to be tested with the height adjusted according to patient size.

Scaption:

The dynamometer was rotated 30^{o} toward the subject, tilted upwards 25^{o} and the chair rotated 15º away from the dynamometer. The lateral acromion process served as the shoulder axis location for alignment with the dynamometer. Subjects gripped the accessory handle in neutral wrist extension, neutral forearm rotation and full elbow extension.

External/internal rotation at 45° abduction:

The dynamometer position was height 0^o, rotation 20° towards the subject and upward tilt 50°. The Biodex chair was rotated 90°. The dynamometer axis was aligned with the longitudinal shaft of the humerus approximated through the olecranon in line with the acromion. The elbow and forearm were seated in the elbow cuff. Subjects gripped the accessory handle in neutral wrist extension, neutral forearm rotation and 90° elbow flexion.

External/internal rotation at 90° abduction:

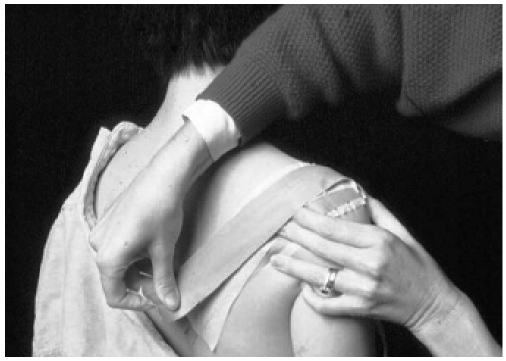
The Biodex dynamometer tilt and rotation were 0°. The Biodex chair was rotated 90^o. The dynamometer axis was aligned with the longitudinal shaft of the humerus approximated through the olecranon in line with the acromion. Subjects gripped the accessory handle in neutral wrist extension, neutral forearm rotation and 90° elbow flexion.

Taping Procedures:

Base Tape Taping Procedure: The subject sat in the Biodex chair with the arm relaxed at the side. The primary investigator applied a 10 inch piece of Coverall tape™ starting on the anterior aspect of the shoulder joint, running superiorly and posteriorly finishing just medially to the inferior border of the scapula.

McConnell Taping Procedure: We taped the shoulder in accordance with the McConnell technique (figure 5) (McConnell & McIntosh, 2009). We were careful in applying the tape over the wire electrodes so as to not dislodge them. The subject sat in the Biodex chair, with the arm relaxed at the side. Next we anchored a 10 inch piece of Leuko tape™ directly over the Coverall tape™ on the anterior shoulder. The thumb of the investigator's stabilizing hand applied a force up and back on the humeral head while the investigator's opposite hand pulled the tape superiorly and posteriorly across the shoulder joint. The tape finished just medial to the inferior border of the scapula directly over the coverall tape.

Figure 7: McConnell Taping Technique



(McConnell & McIntosh, 2009; McConnell et al., 2011)

Isokinetic Testing Protocol:

Before testing each movement pattern, we calibrated the Biodex dynamometer for position and performed gravity compensation. During gravity compensation the Biodex dynamometer takes a weight measurement of the arm while in the testing apparatus. Subtracting the weight of the limb offsets the limb weight's contribution to the overall torque measurement. In order to synchronize the Biodex position information with the Visual 3D software, we collected a static position calibration before each trial. We set the Biodex testing ROM according to subject comfort. Care was taken to avoid any reports of apprehension when setting the ER end ROM. A resting EMG was recorded prior to limb movement for each trial.

As an initial familiarization with isokinetic movements the subject performed a series of graded submaximal to maximal repetitions at an angular velocity of 90^o/second. The testing protocol consisted of five maximal isokinetic repetitions at 90^o/second in each of the three testing patterns for each of the three taping conditions. The investigator provided subjects with routine and standardized verbal encouragement without visual feedback. Approximately 5 minutes of rest between testing patterns was built into the protocol as the Biodex position required changing.

At the end of the testing protocol, we removed the wire electrodes cleaned the electrode insertion sites with hydrogen peroxide and inspected the wires to ensure they were intact and not broken during removal.

EMG Signal Processing:

The first level of signal processing was application of a lowpass filter at 700 Hz in order to limit the frequency spectrum. We chose to lowpass filter at 700 Hz based upon the findings of a power spectral analysis of the raw EMG signal. The 95% power frequency was calculated for each muscle across all conditions. The highest 95% power frequency for any muscle across all conditions for the 12 subjects was 475 Hz. Therefore, a conservative cut off frequency of 700 Hz was employed before further filtering the signal. Limiting the frequecy spectrum of the analog signal prior to further filtering decreased the possibility that high frequency artifact was included in the data. The signal was then highpass filtered with a (2nd order Butterworth filter) with a 20 Hz cutoff frequency. Next, the signal was rectified and lowpass filtered with a cut off frequency of 3.14 Hz (2nd order Butterworth filter) to create a linear envelope (Hillstrom & Triolo, 1994).

Biodex Signal Processing:

Raw torque and position output from the Biodex were lowpass filtered at 3.14 Hz to smooth the data. Next the signal was multiplied by the appropriate constant for conversion to units of degrees (position) and newton-meters (torque). The calibration offsets for position and torque collected during testing were applied.

Data Analysis

Visual 3D software calculated the mean EMG activity during the three arcs of motion (0°-50°, 50°-75°, 75°-Max) for each of the five repetitions for the three isokinetic movement patterns (scaption, ER 45° and ER 90°). For each of the three movement patterns, only those muscles performing a primary role were used for analysis. Only the upward elevation (scaption) and external rotation movements were used for analysis as these movements represent the ROM when the shoulder is most likely to be unstable.

Raw EMG was visually inspected for artifact including data spikes and saturation. The mean EMG amplitudes of the middle three repetitions were averaged for the three position arcs. If artifact or signal saturation corrupted the EMG signal of one of the middle three target repetitons, we discarded the mean for that repetition. The goal was to average the means of three repetitions. Therefore, if a mean from one of the middle three repetitions was disgarded secondary to a corrupt signal, we substituted the mean from one of the remaining two repetitions. The decision of which of the two remaining means to substitute was based upon which of them was closest in value to the other two means.

The results demonstrated that the change in mean EMG amplitude between taping conditions was bidirectional. Including both positive and negative data in the analysis causes them to cancel each other out, misrepresenting the magnitude of the change between conditions. Therefore, the absolute change scores between conditions was used for analysis.

Statistical Analysis

A paired samples T-test on the absolute value of the change scores tested the differences between the no tape condition and the McConnell taping condtion, between the no tape condition and the base tape taping condition and between the base tape condition and the McConnell taping condition. Significance was set at .0166 to account for multiple comparisons. Power was set at .80. Normality of data was tested using the Shapiro-Wilk test. We used a repeated measures ANOVA to test for differences between the peak torques. Noramlity and sphericity of data was tested using the Shapiro-Wilk and Mauchley's test respectively. Minimal detectable change (MDC) at the 95% confidence level was calculated using the following equation: MDC = 1.96 x SEM x square root of 2.

CHAPTER IV

RESULTS

Electromyographic Data

The change in EMG amplitudes expressed in percentage of maximum voluntary isometric contraction (%MVIC) between taping conditions increased in some subjects and decreased in others. This bidirectional EMG change found between conditions occurred across all muscles during all three isokinetic movement patterns. The distribution of subjects with positive change (increased activity) and negative change (decreased activity) did not show a strong association in one direction or another, although some directional tendencies arose. The direction of EMG change between the no tape-McConnell tape and the no tape-base tape conditions for scaption, ER 45 degrees and ER 90 degrees is summarized below.

Direction of EMG change during scaption (Figures 6-7)

For the purposes of discussion, the muscles for the scaption movement pattern are divided into three functional groups: group 1 consists of the humeral muscles including the anterior and middle deltoids and biceps; group 2 consists of the trunk muscles including the pectoralis major, latissimus dorsi and serratus anterior and group three the rotator cuff muscles including the supraspinatus, infraspinatus, upper and lower subscapularis muscles.

During the scaption movement pattern the distribution of subjects who demonstrated positive and those who demonstrated negative EMG change between the no tape-McConnell and no tape-base taping conditions was almost evenly distributed for the deltoids and biceps (figures 6a and 7a) as well as the pectoralis, latissimus and serratus (figures 6b and 7b). The subject distribution for EMG change of the rotator cuff muscles appeared to have stronger directional tendencies (figures 6c and 7c).

The lower subscapularis showed decreased activity (65%-80% of subjects decreased) during the no tape-McConnell tape condition. Conversely the upper subscapularis activity increased in 80% of subjects during the late range of motion in the no tape-McConnell tape, and in the early range during no tape-base tape condition. The infraspinatus activity increased in 70% of subjects during the later range of motion during the no tape-base tape condition only. The supraspinatus activity decreased in the early ROM (70% of subjects) during the no tape -base tape condition.

Figure 8a: Direction of EMG Change Scaption: No Tape-McConnell Tape

Humeral Muscles

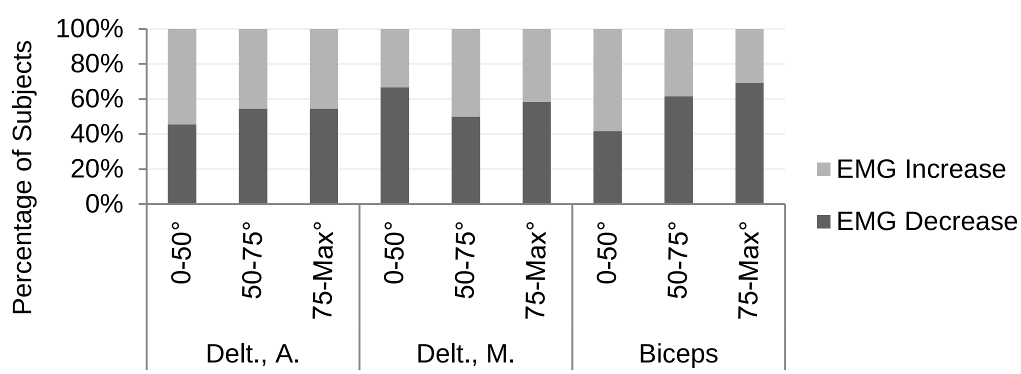


Figure 8b: Direction of EMG Change Scaption- No Tape-McConnell Tape

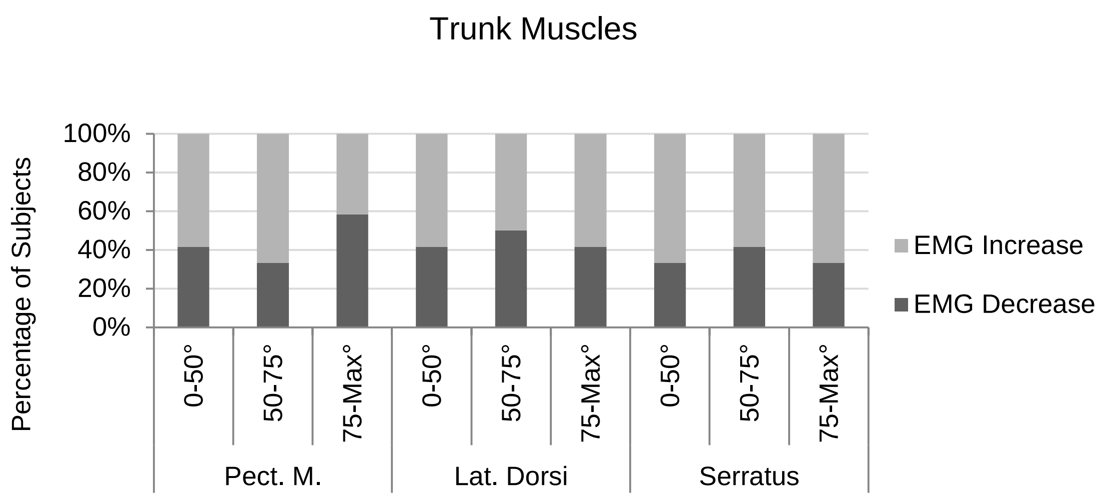


Figure 8c: Direction of EMG Change Scaption No Tape-McConnell Tape

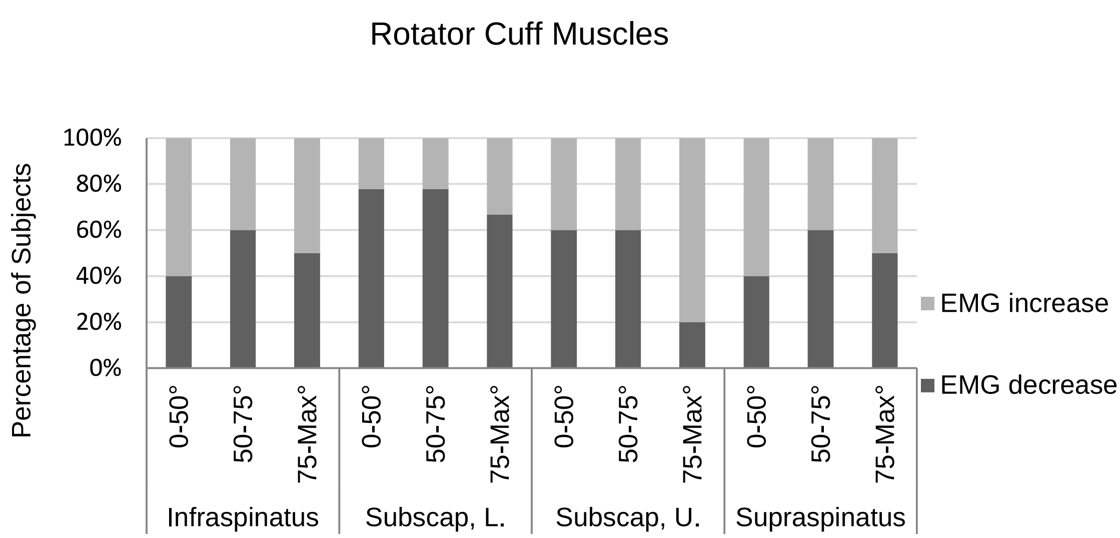


Figure 9a: Direction of EMG Change Scaption-No Tape-Base Tape

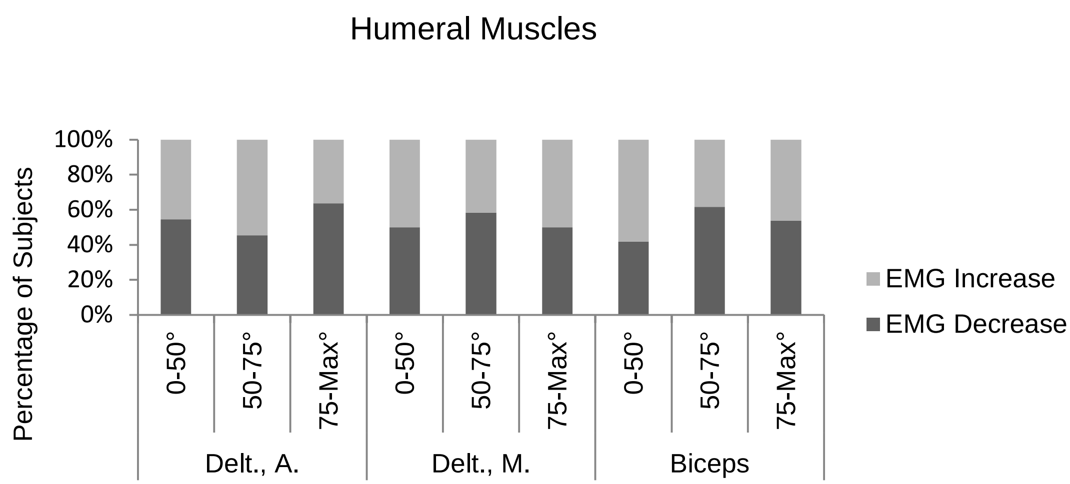


Figure9b: Direction of EMG Change Scaption-No Tape-Base Tape

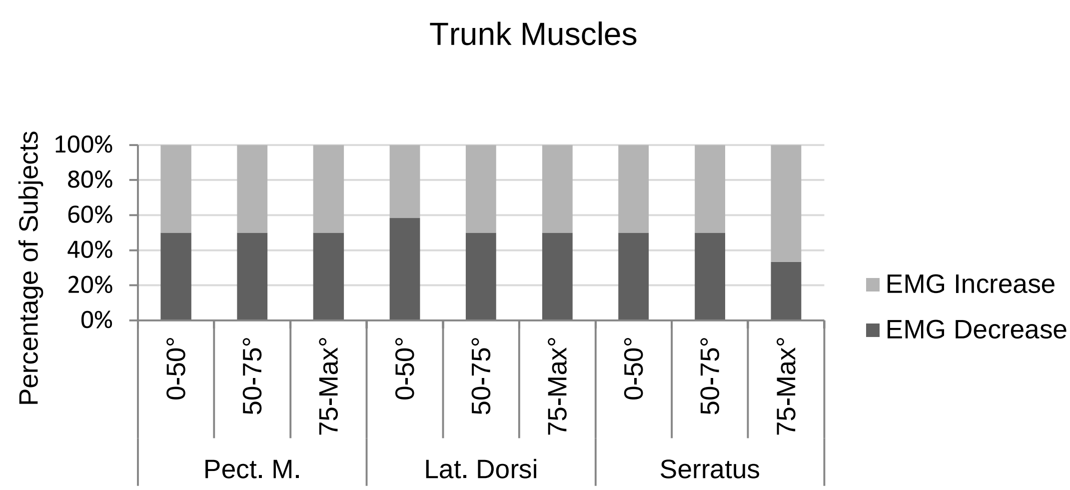
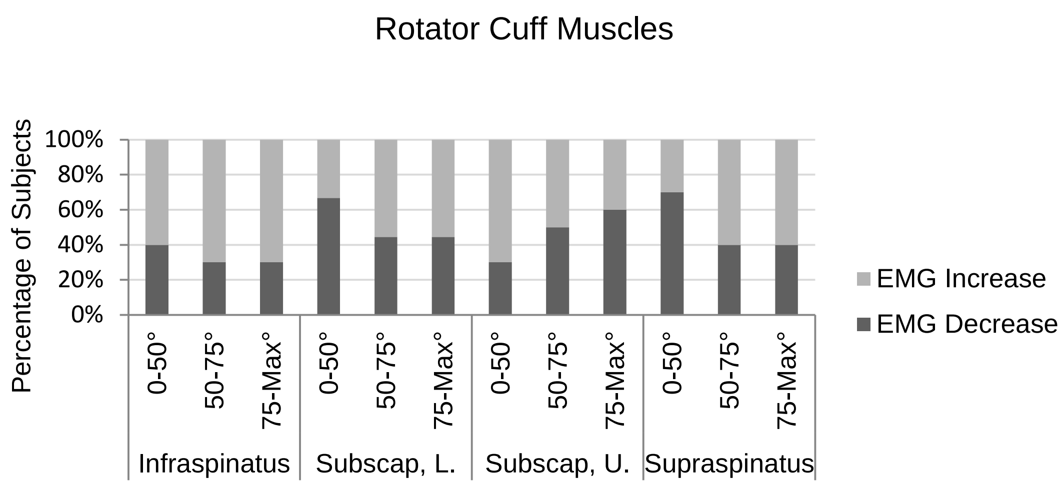


Figure 9c: Direction of EMG Change Scaption-No Tape-Base Tape



Direction of EMG change during ER 45° Abduction (Figures 8-9)

Infraspinatus activity decreased in 60-70% of subjects during the early range of motion for the no tape-McConnell condition and in the late ROM during the no tape-base tape condition. The lower subscapularis activity decreased in 70% of subjects in the early range for both taping conditions. The upper subscapularis also demonstrated decreased activity in the early ROM, though only during the no tape-base tape condition. The supraspinatus demonstrated decreased activity later in the range in the no tape to McConnell tape condition (70% of subjects) but conversely showed increased activity in the no tape-base taping condition.

Figure 10: Direction of EMG Change ER 45°-No Tape -McConnell Tape

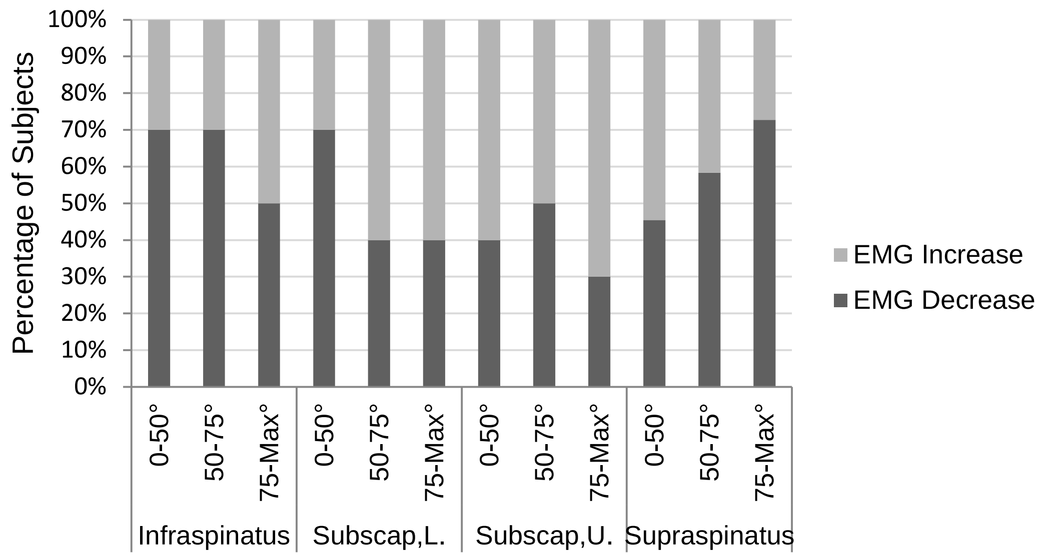
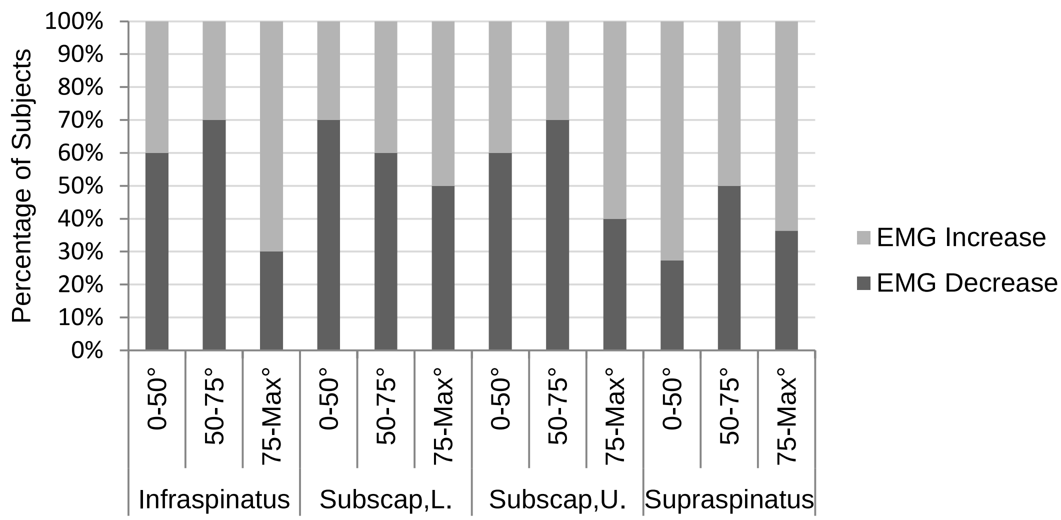


Figure 11: Direction of EMG Change ER 45°-No Tape to Base Tape



External Rotation at 90° Abduction (Figures 10-11)

Infraspinatus activity increased in 65-80% of subjects in the mid to late ROM for both taping conditions. The lower subscapularis demonstrated decreased activity in 70% of subjects in the no tape-McConnell tape condition only. More subjects (65%) decreased their supraspinatus muscle activity in the late ROM for both the no tape-McConnell and no tape- base tape conditions.

Figure 12: Direction of EMG Change ER 90°-No Tape-McConnell Tape

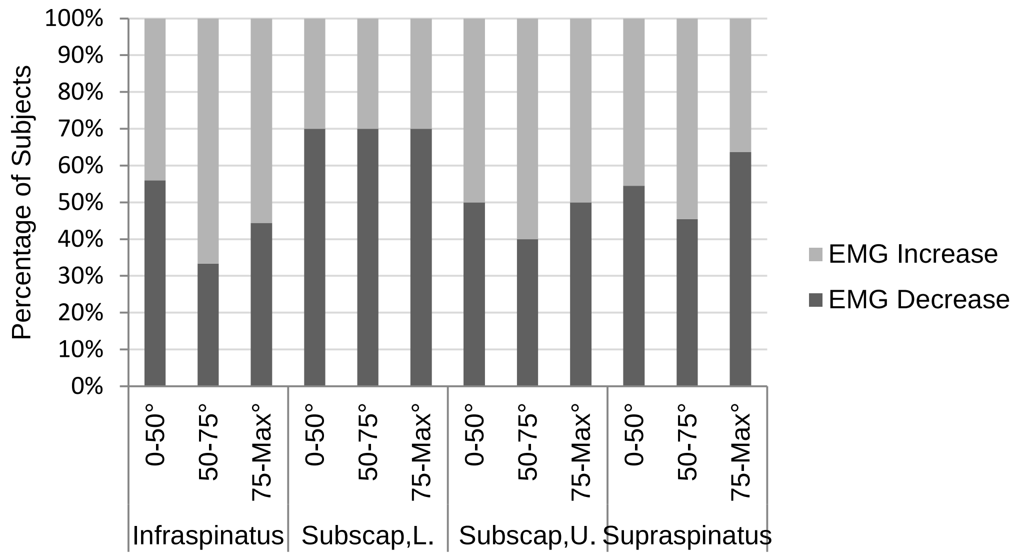
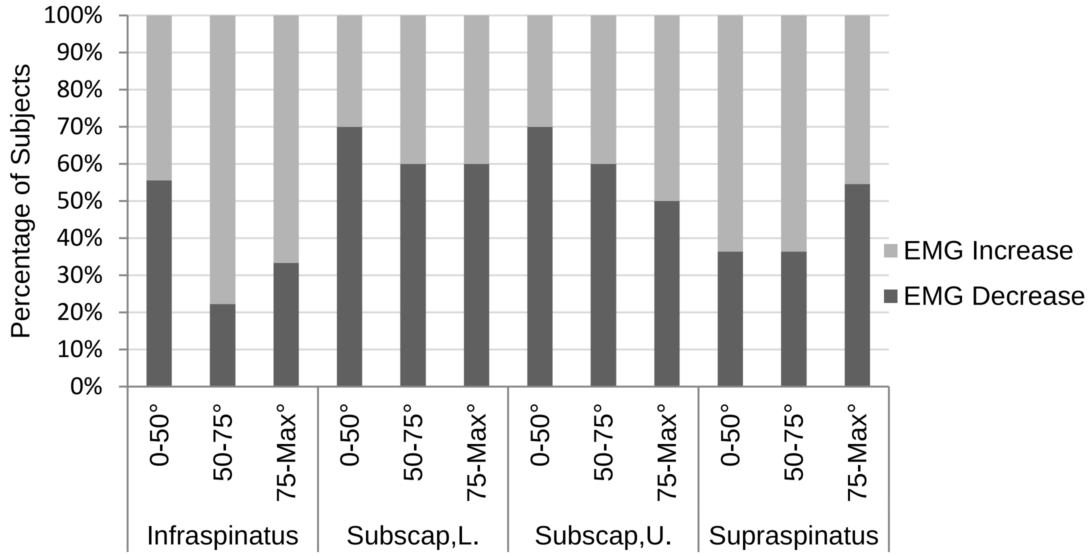


Figure13: Direction of EMG Change ER 90°-No Tape-Base Tape



The statistical analysis needed was influenced by the presence of bidirectional EMG change. As the inclusion of both positive and negative values in the statistical analyses would result in cancellation effects, we analyzed the absolute value of the change scores between taping conditions. Results, therefore, do not infer direction of EMG change, but rather the relative magnitude of change. Individual T-test results for the three movement patterns are presented below. Significance was set at $p < .0166$ to adjust for multiple comparisons.

Scaption

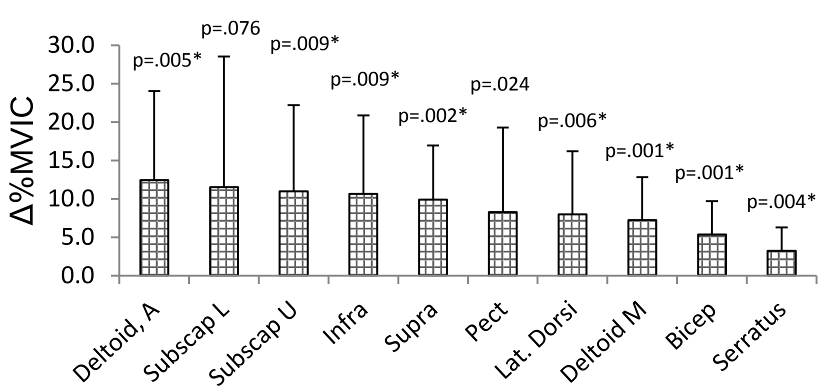
No Tape-McConnell Tape condition

Descriptive statistics and individual T-test results ($p<.0166$) for the change in EMG amplitude (%MVIC) for the no tape-McConnell tape condition are presented for the three arcs of motion in tables 7-9. Figures 12-14 display graphs of the mean EMG changes for the three arcs of motion in rank order with corresponding *p* values. Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decrease in the number of subjects for the analysis of the following muscles: anterior deltoid (n=11) upper subscapularis (n=11), lower subscapularis (n=9), and the infraspinatus and supraspinatus (n=10). Significant changes ($p<.0166$) in EMG activity are present across all three arcs of motion for the anterior and middle deltoid muscles, biceps, upper subscapularis, supraspinatus and the latissimus dorsi. The infraspinatus muscle showed significant EMG change in the first two arcs of motion but not the last. The lower subscapularis and pectoralis major showed no significant changes for any arc of motion. The serratus anterior was significant for only the 0-50° arc of motion. In general, the mean EMG changes for the anterior and middle deltoids, infraspinatus and supraspinatus muscles were larger than the remaining 6 muscles. Post hoc power tests of all non-significant results (α=.0166) revealed that 1-β was < .80. Computed sample sizes to achieve power for these results ranged from 21 to 27 subjects. The average calculated minimal clinical change (MDC) for all muscles across all three arcs of motion for scaption was 10.75 %.

Table 7
Change in EMG (%MVIC) No Tape- McConnell Tape
Scaption (0-50°)

			Test Value = 0					
							95% Confidence Interval of the Difference	
	n	*Mean Change*	*SD*	*t*	*df*	*p (2-tailed)*	*Lower*	*Upper*
Deltoid, A.	11	12.45	11.58	3.56	10	.005	4.66	20.23
Subscap., L	9	11.53	16.99	2.04	8	.076	-1.53	24.59
Subscap., U	11	11.00	11.17	3.27	10	.009	3.49	18.51
Infra	10	10.65	10.22	3.30	9	.009	3.34	17.97
Supra	10	9.88	7.06	4.43	9	.002	4.84	14.93
Pect. Major	12	8.28	10.99	2.61	11	.024	1.30	15.26
Lat. Dorsi	12	7.97	8.23	3.35	11	.006	2.74	13.20
Deltoid M.	12	7.22	5.58	4.48	11	.001	3.68	10.77
Biceps	12	5.36	4.34	4.27	11	.001	2.60	8.12
Serratus	12	3.22	3.03	3.69	11	.004	1.30	5.15

Figure 14: Δ EMG No Tape -McConnell Tape Scaption (0-50°)



**p<.0166*

Table 8
Change in EMG (%MVIC) No Tape- McConnell Tape
Scaption (50-75°)

		Test Value = 0						
	n	*Mean Change*	*SD*	*t*	*df*	*p (2-tailed)*	*95% Confidence Interval of the Difference Lower*	*Upper*
Infra	10	17.53	15.57	3.56	9	0.006	6.39	28.67
Deltoid, M	12	16.85	9.76	5.98	11	0.000	10.65	23.06
Subscap. L	9	13.30	18.96	2.10	8	0.068	-1.27	27.88
Deltoid, A	11	12.42	8.80	4.68	10	0.001	6.51	18.34
Supra	10	10.59	11.15	3.00	9	0.015	2.62	18.57
Lat. Dorsi	12	9.68	9.24	3.63	11	0.004	3.81	15.55
Biceps	12	9.11	7.89	4.00	11	0.002	4.10	14.12
Pect. Major	11	8.11	11.13	2.42	10	0.036	0.64	15.59
Subscap. U	11	6.04	5.20	3.86	10	0.003	2.55	9.54
Serratus	12	4.56	6.77	2.33	11	0.040	0.26	8.86

Figure 15: Δ EMG No Tape-McConnell Tape Scaption (50-75°)

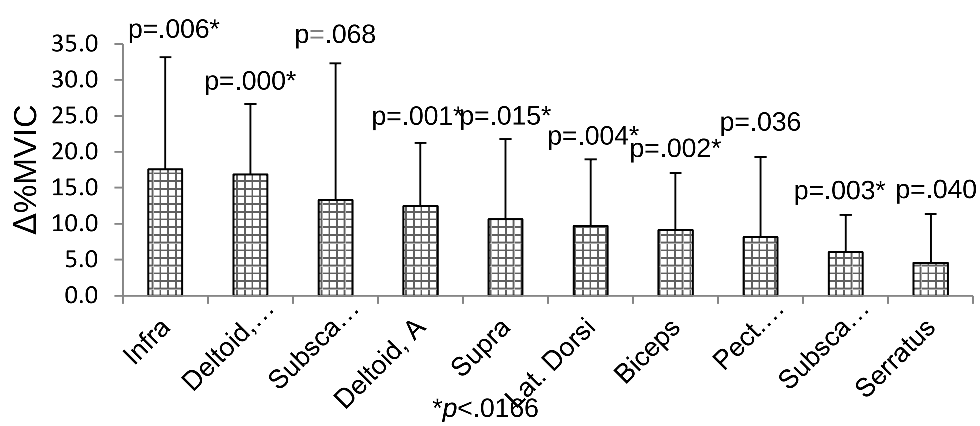
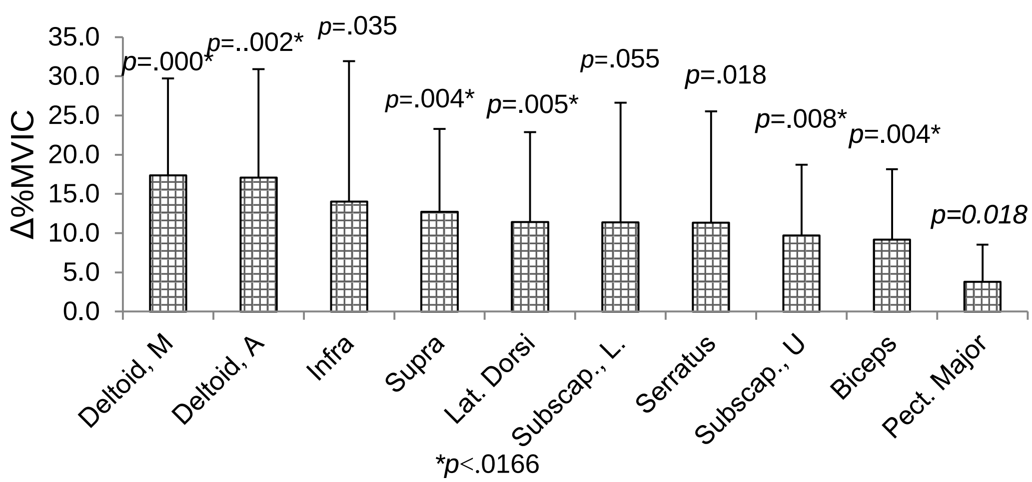


Table 9
Δ EMG (%MVIC) No Tape- McConnell Tape
Scaption (75°-Max)

				Test Value = 0				
							95% Confidence Interval of the Difference	
Muscle	n	Mean Change	*SD*	t	df	p (2-tailed)	Lower	Upper
Deltoid, M	12	17.39	12.35	4.88	11	0.000	9.55	25.24
Deltoid, A	11	17.09	13.80	4.11	10	0.002	7.82	26.36
Infra	10	14.03	17.91	2.48	9	0.035	1.21	26.84
Supra	10	12.74	10.56	3.82	9	0.004	5.19	20.30
Lat. Dorsi	12	11.43	11.43	3.46	11	0.005	4.17	18.69
Subscap. L	9	11.39	15.25	2.24	8	0.055	-0.33	23.12
Serratus	12	11.36	14.18	2.78	11	0.018	2.35	20.37
Subscap. U	11	9.73	8.99	3.42	10	0.008	3.30	16.16
Biceps	12	9.20	8.96	3.56	11	0.004	3.51	14.89
Pect. Major	12	3.79	4.74	2.77	11	0.018	0.78	6.80

Figure 16: Δ EMG No tape-McConnell tape Scaption (75°-Max)



No Tape-Base Tape Condition

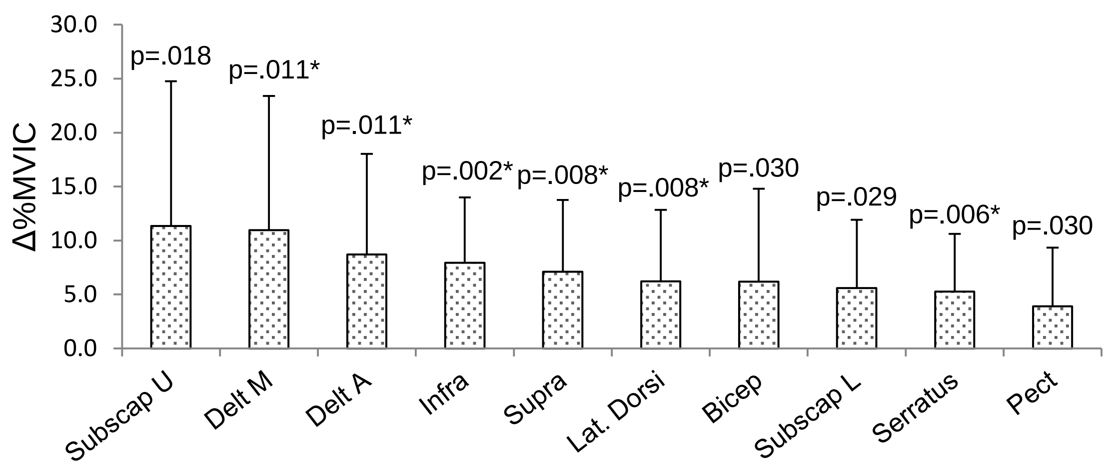
Descriptive statistics and t-test results of the change in EMG amplitude (%MVIC) for the no tape-base tape condition for the three arcs of motion are presented in tables 10-12. Figures 15-17 display the graphs of the mean EMG changes for the three arcs in rank order with corresponding *p* values. Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decrease in the sample size for the analysis of the following muscles: supraspinatus (n=10), infraspinatus (n=10), anterior deltoid (n=11), lower subscapularis (n=9), pectoralis major (n=10), and the upper subscapularis (n=10).

Significant changes ($p<.0166$) in EMG activity are present across all three arcs of motion for the anterior and middle deltoid muscles and the serratus anterior. Significant changes in mean EMG amplitudes during the no tape-base tape condition were seen for other muscles more randomly over the three arcs of motion. Post hoc testing of all non-significant results ($\alpha=.0166$) revealed that $1-\beta$ was < .80. Computed sample sizes to achieve power for these results ranged from 17 to 32 subjects. The average MDC for all muscles across all three movement patterns was 9.26%.

Table 10
ΔEMG (%MVIC) No Tape - Base Tape
Scaption (0-50°)

				Test Value = 0				
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*p (2-tailed)*	*Lower*	*Upper*
Subscap. U	11	11.37	13.40	2.81	10	0.018	2.37	20.37
Deltoid, M	12	10.97	12.42	3.06	11	0.011	3.07	18.86
Deltoid, A	10	8.72	9.32	3.10	10	0.011	2.46	14.98
Infra	10	7.94	6.06	4.15	9	0.002	3.61	12.27
Supra	10	7.13	6.64	3.40	9	0.008	2.38	11.88
Lat. Dorsi	12	6.22	6.61	3.26	11	0.008	2.02	10.42
Biceps	12	6.21	8.61	2.50	11	0.030	0.74	11.67
Subscap. L	9	5.61	6.32	2.66	8	0.029	0.76	10.47
Serratus	12	5.28	5.33	3.43	11	0.006	1.89	8.66
Pect. Major	12	3.91	5.44	2.49	11	0.030	0.45	7.36

Figure 17: Δ EMG No Tape to Base Tape Scaption (0-50°)



*p<.0166

Table 11
Δ EMG (%MVIC) No Tape - Base Tape
Scaption (50-75°)

				Test Value = 0				
	n	*Mean Change*	*SD*	*t*	*df*	*p (2-tailed)*	*95% Confidence Interval of the Difference* Lower	*Upper*
Deltoid, M	12	14.35	13.12	3.79	11	0.003	6.01	22.69
Infra	10	13.16	16.81	2.47	9	0.035	1.13	25.18
Biceps	12	11.47	15.11	2.63	11	0.023	1.86	21.07
Deltoid, A	10	8.49	7.82	3.60	9	0.005	3.23	13.74
Supra	10	8.28	9.49	2.76	9	0.022	1.49	15.08
Subscap. U	11	7.12	9.52	2.48	10	0.033	0.72	13.52
Subscap. L	9	6.03	5.63	3.22	8	0.012	1.71	10.36
Serratus	12	5.24	6.20	2.92	11	0.014	1.29	9.18
Lat. Dorsi	12	5.07	5.28	3.33	11	0.007	1.72	8.43
Pect. Major	12	4.23	5.11	2.74	11	0.021	0.80	7.66

Figure: 18: Δ EMG No Tape-Base Tape Scaption (50-75°)

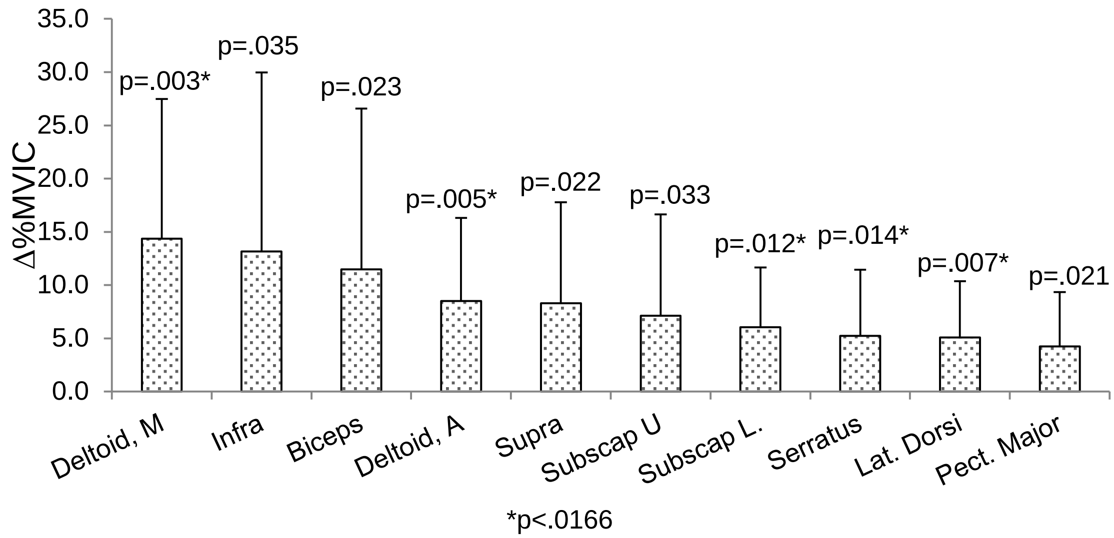
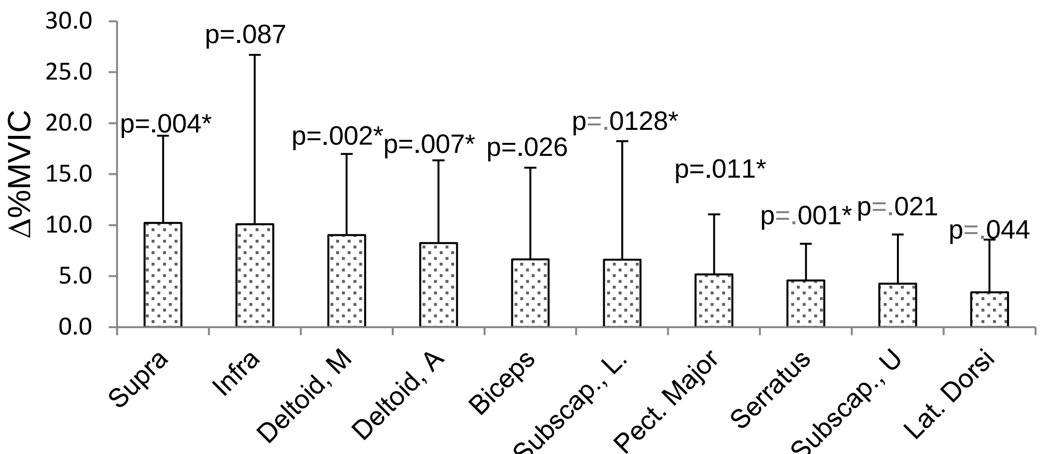


Table 12
Δ EMG (%MVIC) No Tape- Base Tape
Scaption (75°-Max)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*p (2-tailed)*	*Lower*	*Upper*
Supra	10	10.21	8.56	3.77	9	0.004	4.09	16.33
Infra	10	10.09	16.61	1.92	9	0.087	-1.80	21.97
Deltoid, M	12	9.02	7.97	3.92	11	0.002	3.95	14.08
Deltoid, A	11	8.22	8.14	3.35	10	0.007	2.75	13.69
Biceps	12	6.65	8.98	2.56	11	0.026	0.94	12.35
Subscap. L	9	6.59	11.64	1.70	8	0.128	-2.36	15.54
Pect. Major	10	5.17	5.89	3.04	11	0.011	1.43	8.91
Serratus	12	4.57	3.59	4.41	11	0.001	2.29	6.85
Subscap. U	10	4.25	4.82	2.79	9	0.021	0.80	7.70
Lat. Dorsi	12	3.40	5.18	2.27	11	0.044	0.11	6.69

Figure 19: Δ EMG No Tape to Base Tape Scaption (75°-Max)



*p<.0166

<u>McConnell Tape -Base Tape Conditions</u>

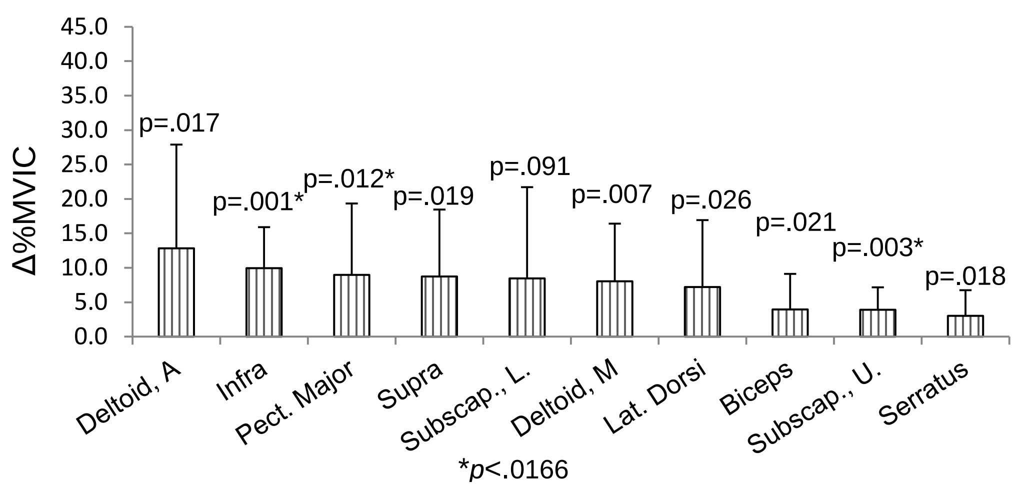
Because the change in EMG amplitude (%MVIC) after application of the base tape alone was significant for several muscles, we employed a T-test to determine if the change from the McConnell tape was significantly different from that of the base tape alone. Descriptive statistics and t-test results for the change in EMG amplitude (%MVIC) between the McConnell tape and the base tape only conditions for the three arcs of motion are presented in tables 13-15. Figures 18-20 display the graphs of the mean EMG changes for the three arcs in rank order with corresponding *p* values.

Significant changes ($p<.0166$) in EMG activity are present across all three arcs of motion for the infraspinatus, middle deltoid, and upper subscapularis. The anterior deltoid, supraspinatus and latissimus dorsi muscles were all significant during the last two arcs of motion. With respect to the terminal ROM (75-Max) all but the lower subscapularis and the serratus anterior demonstrated a significant difference ($p<.0166$) between the base tape and the McConnell taping condition. Post hoc testing of all non-significant results ($\alpha=.0166$) revealed that $1-\beta$ was $< .80$. Computed sample sizes to achieve power for these results ranged from 16 to 29 subjects.

Table 13
Δ EMG (%MVIC) McConnell Tape - Base Tape
Scaption (0-50°)

				Test Value = 0				
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Deltoid, A	11	12.84	15.05	2.83	10	0.017	2.72	22.95
Infra	10	9.94	5.95	5.28	9	0.001	5.68	14.20
Pect. Major	12	8.97	10.39	2.99	11	0.012	2.37	15.57
Supra	10	8.76	9.68	2.86	9	0.019	1.84	15.68
Subscap., L.	9	8.48	13.23	1.92	8	0.091	-1.70	18.65
Deltoid, M	12	8.05	8.35	3.34	11	0.007	2.74	13.36
Lat. Dorsi	12	7.19	9.71	2.57	11	0.026	1.02	13.36
Biceps	12	3.97	5.12	2.69	11	0.021	0.72	7.23
Subscap., U.	11	3.92	3.26	3.99	10	0.003	1.73	6.11
Serratus	12	3.01	3.76	2.78	11	0.018	0.62	5.40

Figure 20: Δ EMG McConnell Tape -Base Tape Scaption (0-50°)

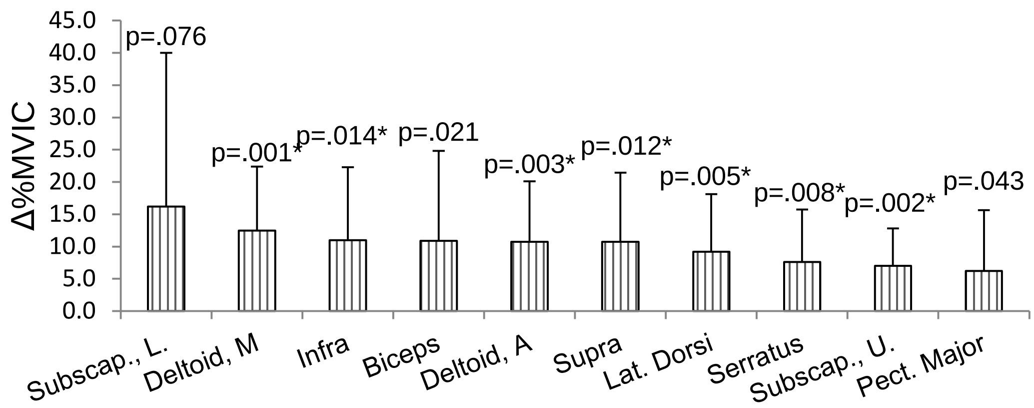


*p<.0166

Table 14
Δ EMG McConnell Tape to Base Tape
Scaption (50-75°)

						Test Value = 0	95% Confidence Interval of the Difference	
Muscle	n	Mean change	SD	*t*	*df*	*p* *(2 tailed)*	Lower	Upper
Subscap., L.	9	16.17	23.82	2.04	8	0.076	-2.14	34.48
Deltoid, M	12	12.45	9.92	4.35	11	0.001	6.15	18.75
Infra	10	10.96	11.32	3.06	9	0.014	2.86	19.05
Biceps	12	10.86	13.94	2.70	11	0.021	2.00	19.72
Deltoid, A	11	10.74	9.36	3.81	10	0.003	4.45	17.02
Supra	10	10.70	10.73	3.15	9	0.012	3.02	18.38
Lat. Dorsi	12	9.17	8.93	3.56	11	0.005	3.49	14.85
Serratus	12	7.57	8.17	3.21	11	0.008	2.38	12.76
Subscap., U.	11	7.02	5.79	4.02	10	0.002	3.13	10.91
Pect. Major	12	6.22	9.43	2.28	11	0.043	0.23	12.21

Figure 21: Δ EMG McConnell Tape to Base Tape Scaption (50-75°)

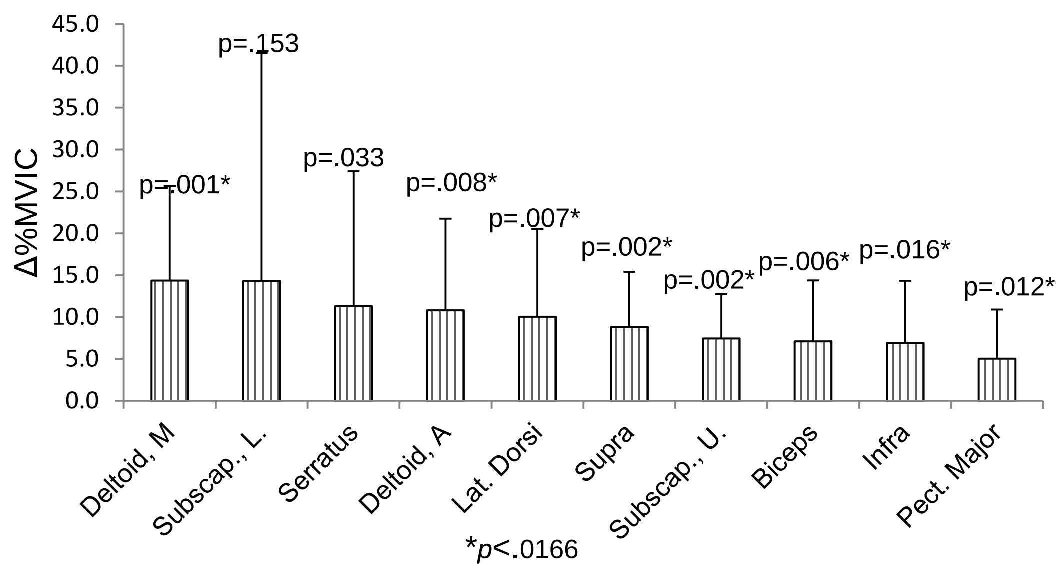


**p*<.0166

Table 15
Δ EMG Base Tape - McConnell Tape
Scaption (75°-Max)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Deltoid, M	12	14.37	11.29	4.409	11	.001	7.20	21.54
Subscap., L.	9	14.33	27.18	1.581	8	.153	-6.57	35.22
Serratus	12	11.32	16.07	2.439	11	.033	1.11	21.53
Deltoid, A	11	10.80	10.96	3.266	10	.008	3.43	18.16
Lat. Dorsi	12	10.05	10.46	3.327	11	.007	3.40	16.69
Supra	10	8.85	6.54	4.276	9	.002	4.17	13.52
Subscap., U.	10	7.46	5.26	4.482	9	.002	3.70	11.23
Biceps	12	7.11	7.25	3.397	11	.006	2.50	11.72
Infra	10	6.93	7.41	2.954	9	.016	1.62	12.23
Pect. Major	12	5.05	5.84	2.995	11	.012	1.34	8.76

Figure 22: Δ EMG Base Tape - McConnell Tape Scaption (75°Max)



External Rotation at 45° Abduction

No Tape- McConnell Tape Conditions

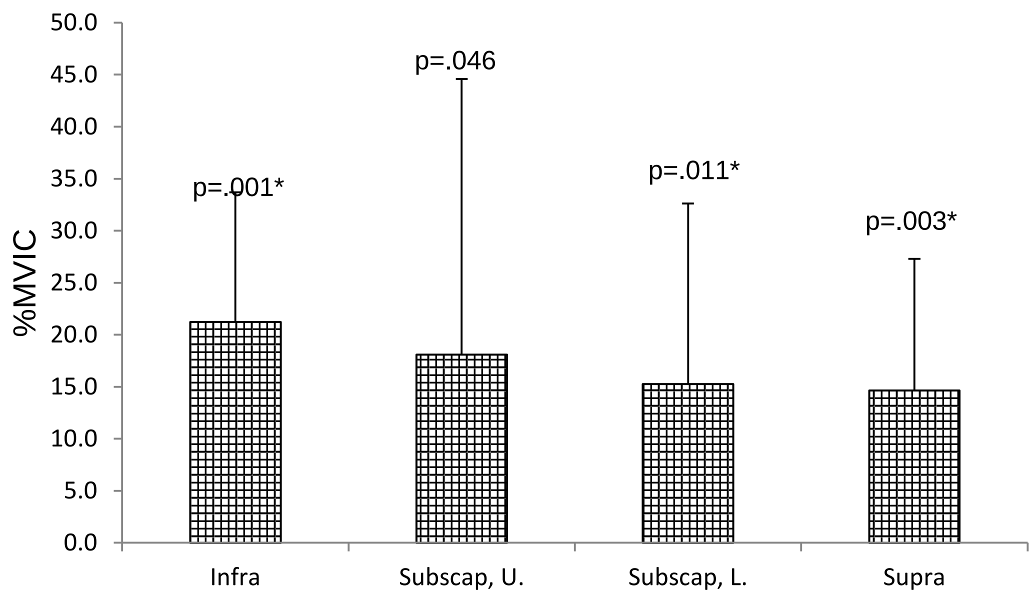
Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decrease in the sample size for analysis of the infraspinatus (n=9) and supraspinatus (n=11). Descriptive statistics and t-test results for the change in EMG amplitude (%MVIC) are presented for the three arcs of motion in tables 16-18. Figures 21-23 display the graphs of the mean EMG changes in rank order with corresponding *p* values.

Significant differences ($p<.0166$) of the absolute value of the mean EMG amplitudes (%MVIC) are seen for the infraspinatus and supraspinatus muscles across all three arcs of motion. The lower subscapularis demonstrated a significant change in the terminal ROM (75°-max) and the upper subscapularis in the mid range (50-75°). Post hoc power analysis revealed a $1-\beta <.80$ for all non-significant results. Computed sample sizes to achieve power for these results ranged from 17-22 subjects. The average MDC score for all muscles over all three arcs of motion was 10.9%.

Table 16
Δ EMG (%MVIC) No Tape - McConnell Tape
ER 45 (0-50°)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Infra	9	21.24	12.46	5.113	8	0.001	11.66	30.81
Subscap, U.	12	18.10	26.49	2.266	11	0.047	0.30	35.89
Subscap, L.	12	15.26	17.35	3.045	11	0.011	4.23	26.28
Supra	11	14.66	12.64	3.846	10	0.003	6.17	23.15

Figure 23: Δ EMG No Tape-McConnell Tape ER 45º (0-50º)

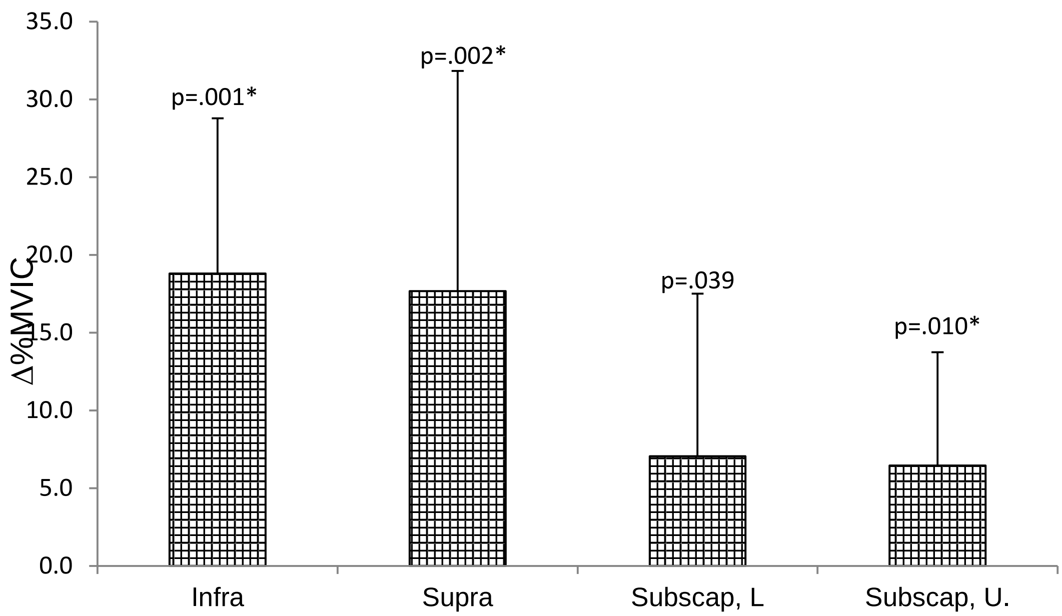


*p<.0166

Table:17
Δ EMG (%MVIC) No Tape- McConnell Tape
ER 45° (50-75°)

Muscle	n	Mean change	SD	t	df	p (2 tailed)	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
				Test Value = 0				
Infra	9	18.80	9.98	5.33	8	0.001	10.46	27.14
Supra	11	17.68	14.15	4.14	10	0.002	8.17	27.19
Subscap, L.	12	7.07	10.45	2.34	11	0.039	0.43	13.71
Subscap, U.	12	6.47	7.27	3.08	11	0.010	1.85	11.09

Figure 24: Δ EMG No Tape-McConnell Tape ER 45° (50-75°)

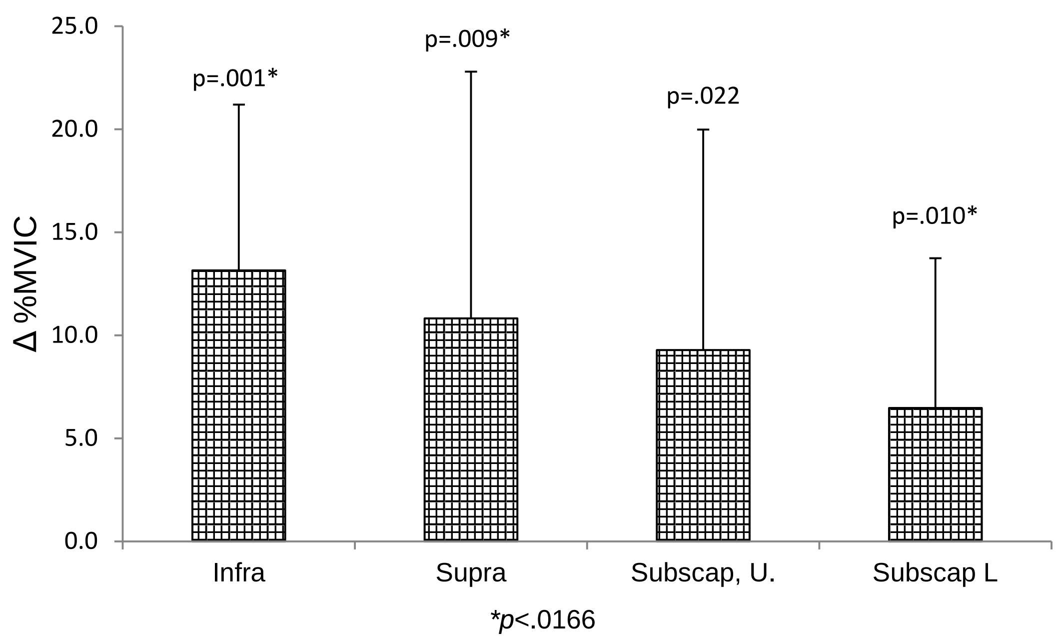


*p<.0166

Table 18
∆ EMG (%MVIC) No Tape - McConnell Tape
ER 45° (75°-Max)

				Test Value = 0				
							Confidence Interval of the Difference	
Muscle	n	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Infra	9	13.15	8.05	4.901	8	0.001	6.96	19.33
Supra	11	10.82	11.97	3.133	10	0.010	3.22	18.43
Subscap, U.	12	9.27	10.71	2.737	11	0.023	1.61	16.94
Subscap, L.	12	6.47	7.27	3.081	11	0.010	1.85	11.09

Figure 25: Δ EMG No Tape to McConnell Tape ER 45 (75°-Max)



No Tape-Base Tape Conditions

Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decrease in the sample size for the analysis of the upper subscapularis (n=11), supraspinatus (n=11) and infraspinatus (n=9). Descriptive statistics and T-test results for the change in EMG amplitude (%MVIC) for the three arcs of motion are presented in tables 19-21. Figures 24-26 display the graphs of the mean EMG changes for the three arcs of motion in rank order with corresponding *p* values.

Significant differences (p<.0166) of the absolute value of the mean EMG amplitudes (%MVIC) are seen for the supraspinatus and infraspinatus in the early (0-50°) and late (75°-max) portion of the ROM, the upper subscapularis during mid range (50-75°) and the lower subscapularis during the late ROM (75°-max). Post hoc power analysis revealed a 1- β <.80 for all non-significant results. Computed sample sizes to achieve power for these results ranged from 18 to 41 subjects. The average MDC value across all muscles and all three arcs of motion for scaption was 13.3.

Table 19
Δ EMG (%MVIC) No Tape-Base Tape
ER 45° (0-50°)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Subscap, U.	11	11.48	16.61	2.29	10	0.045	0.32	22.64
Supra	11	9.55	9.21	3.44	10	0.006	3.36	15.74
Infra	9	9.31	6.09	4.59	8	0.002	4.63	13.99
Subscap, L	12	8.38	10.80	2.69	11	0.021	1.52	15.24

Figure 26: Δ EMG No Tape to Base Tape ER 45° (0-50°)

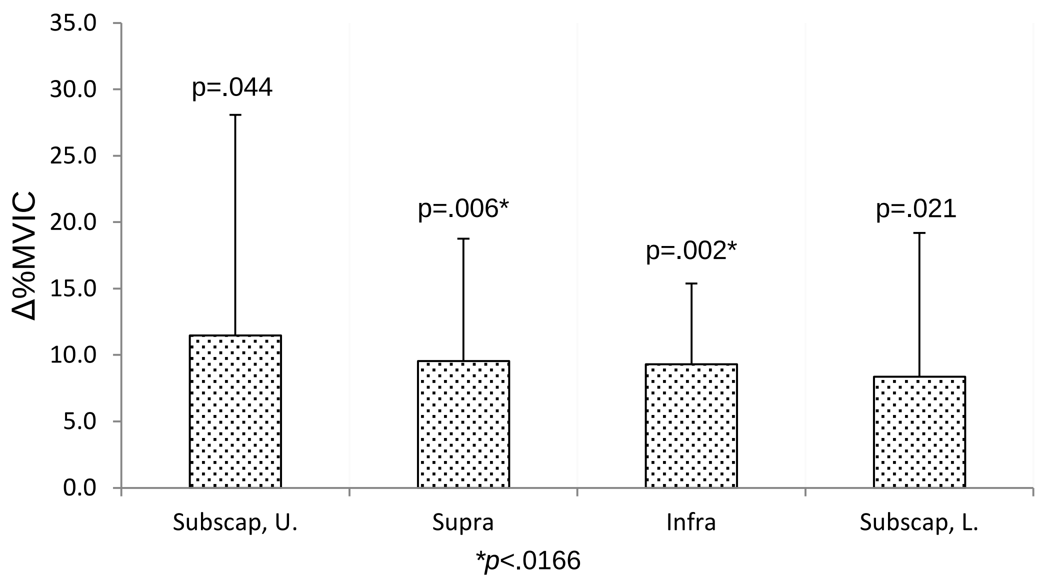
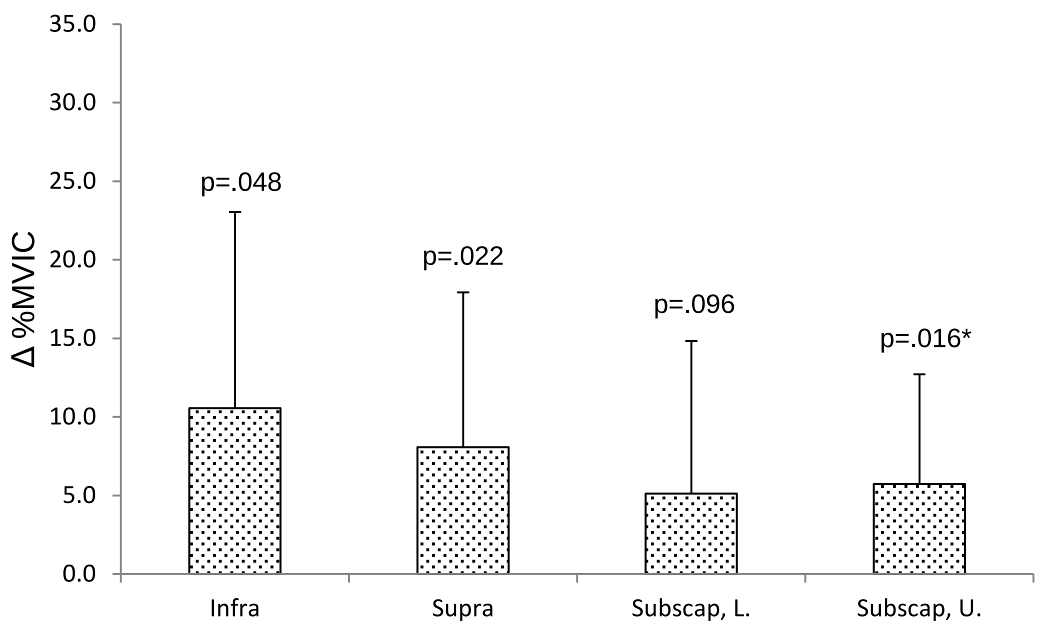


Table 20
Δ EMG (%MVIC) No Tape - Base Tape
ER 45° (50-75°)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	n	*Mean Change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Infra	9	10.56	12.49	2.390	8	0.048	0.11	21.00
Supra	11	8.07	9.86	2.715	10	0.022	1.45	14.69
Subscap, U.	11	5.73	6.98	2.847	10	0.017	1.30	10.16
Subscap, L.	12	5.11	9.72	1.822	11	0.096	-1.06	11.29

Figure 27: Δ EMG No Tape to Base Tape ER 45° (50-75°)

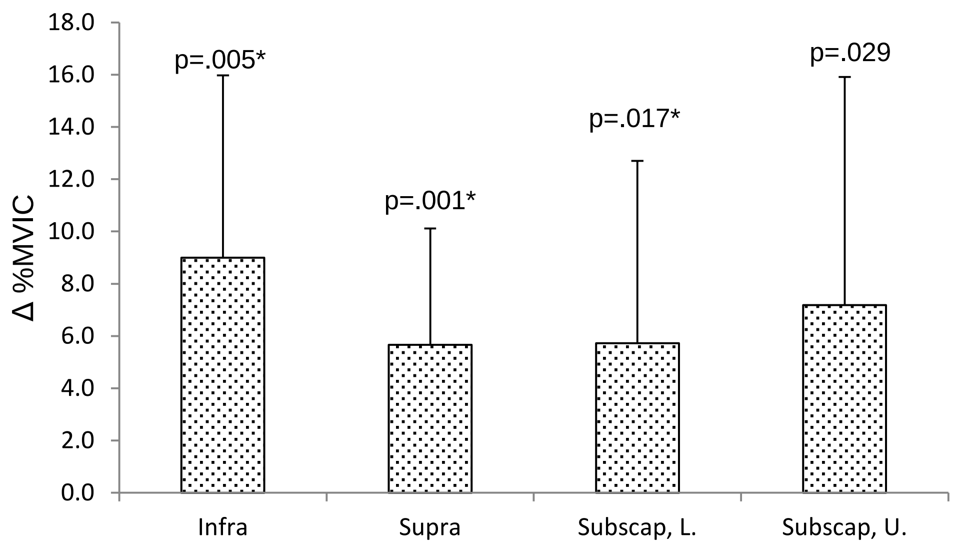


*p<.0166

Table 21
Δ EMG (%MVIC) No Tape - Base Tape
ER 45° (75°-Max)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*(2-tailed) p*	*Lower*	*Upper*
Infra	9	8.99	6.98	3.865	8	0.005	3.63	14.36
Supra	12	5.66	4.45	4.405	11	0.001	2.83	8.49
Subscap, L	11	5.73	6.98	2.847	10	0.017	1.30	10.16
Subscap, U.	11	7.19	8.73	2.605	10	0.029	0.95	13.43

Figure 28: Δ EMG No Tape to Base Tape ER 45° (75°-Max)



*p<.0166

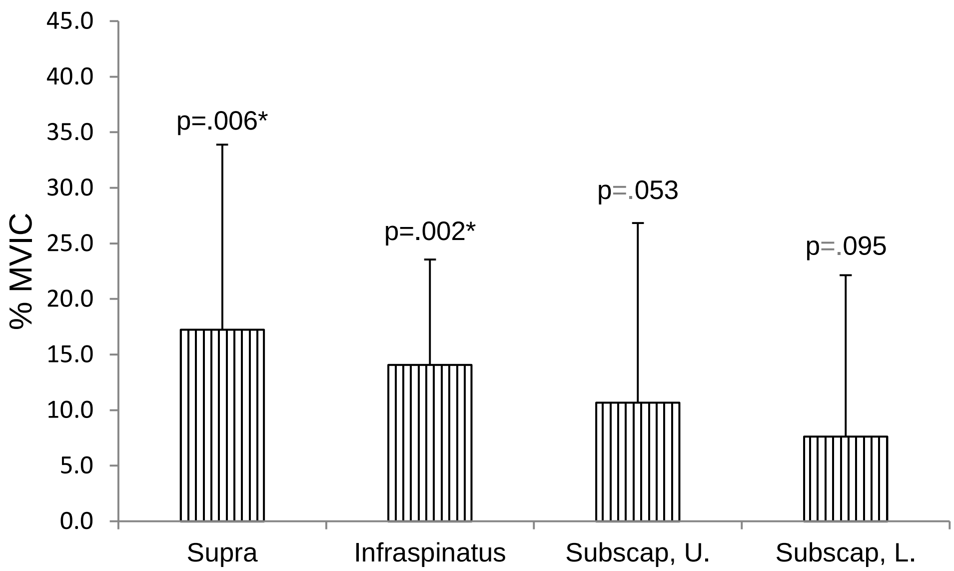
McConnell Tape -Base Tape Conditions

The change in EMG amplitude (%MVIC) after application of the base tape alone was significant for several muscles therefore a t-test was employed to determine if the change from the McConnell tape was significantly different from that of the base tape alone. Descriptive statistics and t-test results for the change in EMG amplitude (%MVIC) for the McConnell tape - base tape only conditions are presented for the three arcs of motion in tables 22-24. Figures 27-29 display the graphs of the mean EMG changes in rank order for the three arcs of motion with corresponding *p* values. Significant differences ($p<.0166$) of the absolute value of the mean EMG amplitudes (%MVIC) are seen for the supraspinatus and the infraspinatus for all three arcs of motion, and for the upper and lower subscapularis muscles during the 2nd two arcs of motion. Post hoc power analysis revealed a $1-\beta <.80$ for all non-significant results. Computed sample sizes to achieve power for these results ranged from 27-41 subjects.

Table 22
Δ EMG (%MVIC) McConnell Tape - Base Tape
ER 45 (0-50°)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*(2-tailed) P*	*Lower*	*Upper*
Supra	11	17.25	16.63	3.439	10	0.006	6.07	28.42
Infra	9	14.08	9.46	4.463	8	0.002	6.80	21.35
Subscap, U.	11	10.67	16.16	2.191	10	0.053	-0.18	21.53
Subscap, L.	12	7.63	14.51	1.822	11	0.096	-1.59	16.85

Figure 29: Δ EMG McConnell - Base Tape ER 45° (0-50°)

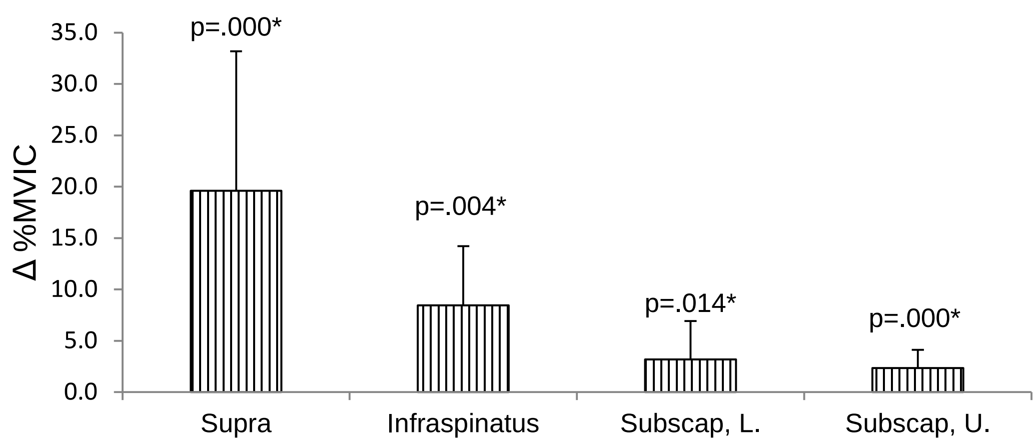


*p<.0166

Table 23
Change in EMG (%MVIC) McConnell Tape - Base Tape
ER 45° (50-75°)

				Test Value = 0				
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean*	*SD*	*t*	*df*	*p* (2 tailed)	*Lower*	*Upper*
Supra	11	19.60	13.60	4.778	10	0.001	10.46	28.73
Infra	8	8.46	5.75	4.160	7	0.004	3.65	13.27
Subscap L.	12	3.17	3.74	2.933	11	0.014	0.79	5.55
Subscap U.	12	2.34	1.77	4.595	11	0.001	1.22	3.46

Figure 30: Δ EMG McConnell Tape - Base Tape ER 45 (50-70°)

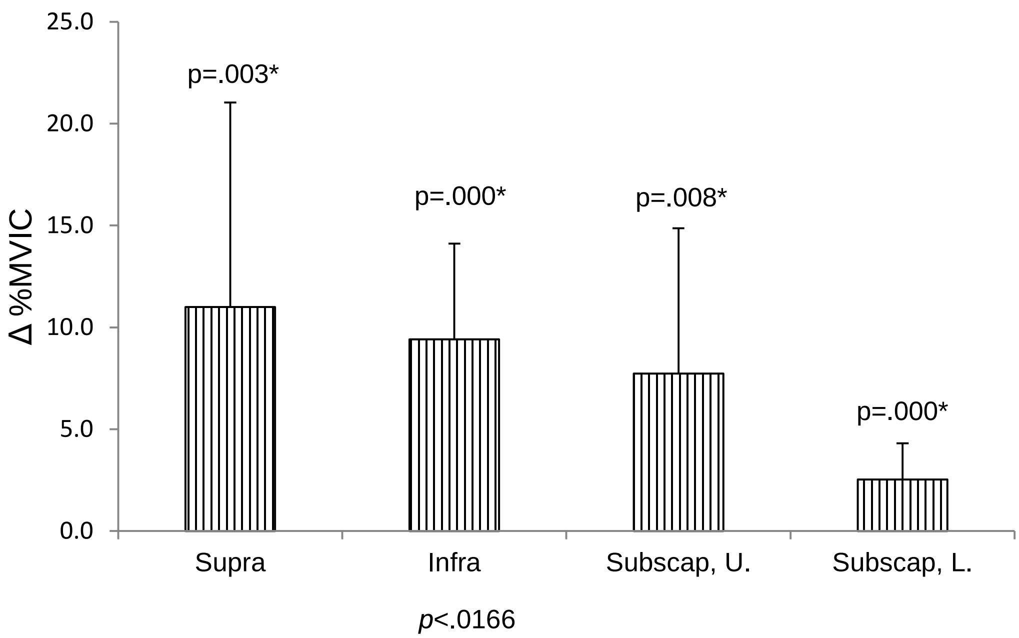


*p<.0166

Table 24
Δ in EMG (%MVIC) McConnell Tape - Base Tape
ER 45° (75°-Max)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	N	Mean	SD	t	df	p (2 tailed)	Lower	Upper
Supra	12	11.00	10.04	3.80	11	0.003	4.62	17.38
Infra	9	9.42	4.69	6.03	8	0.000	5.82	13.02
Subscap, U	10	7.73	7.13	3.43	9	0.008	2.63	12.83
Subscap, L.	12	2.53	1.78	4.93	11	0.000	1.40	3.66

Figure 31: Δ EMG McConnell Tape - Base Tape ER 45 (75-Max°)



External Rotation 90° Abduction

No Tape to McConnell Tape Conditions

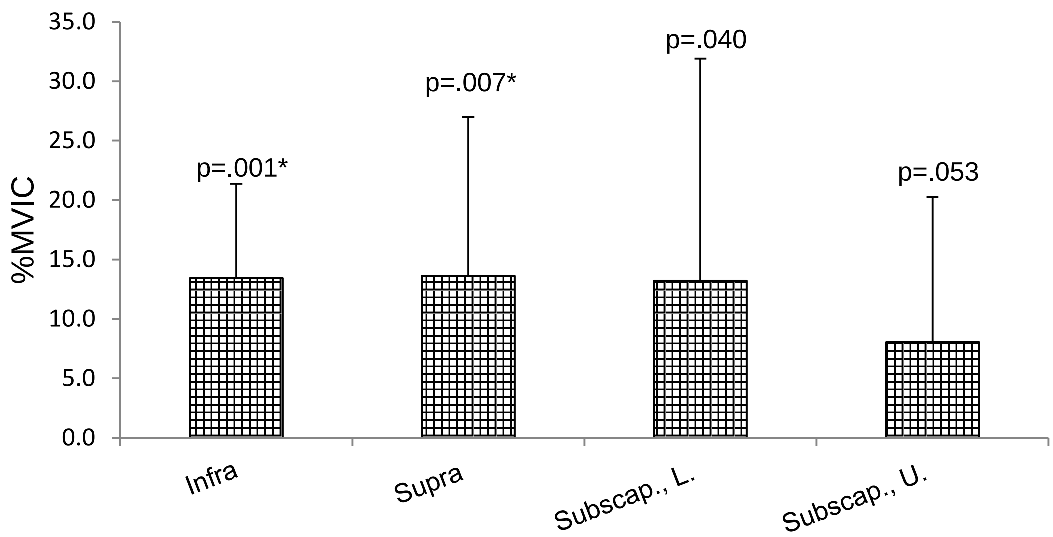
Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decreased sample size for analysis of the upper subscapularis (n=11), supraspinatus (n=11) and infraspinatus (n=9). Descriptive statistics and t-test results for the change in EMG amplitude (%MVIC) for the three arcs of motion are presented in tables 25-27. Figures 30-33 display the graphs of the mean EMG changes in rank order for the three arcs of motion with corresponding *p* values.

Significant differences (p<.0166) of the mean EMG amplitudes (%MVIC) are seen for the infraspinatus and supraspinatus muscles across all three arcs of motion and both the upper and lower subscapularis for the 75°-max arc of motion. The mean changes in EMG amplitudes were highest in the infraspinatus and supraspinatus muscles. Post hoc power analysis revealed a 1- β <.80 for all non-significant results. Computed sample sizes to achieve power for these results ranged from 18-28 subjects. The average MDC value for all muscles across all three arcs of motion was 9.3%.

Table 25
Δ in EMG (%MVIC) No Tape - McConnell Tape
ER 90° (0-50°)

			Test Value = 0					
	n	*Mean Change*	*SD*	*t*	*df*	*p (2tailed)*	*95% Confidence Interval of the Difference Lower*	*Upper*
Infra	9	13.44	7.92	5.09	8	.001	7.36	19.53
Supra	11	13.62	13.36	3.38	10	.007	4.64	22.60
Subscap., L.	11	13.23	18.66	2.35	10	.041	.69	25.76
Subscap., U.	11	8.05	12.21	2.19	10	.053	-.15	16.25

Figure 32: Δ EMG No Tape to McConnell Tape ER 90° (0-50°)

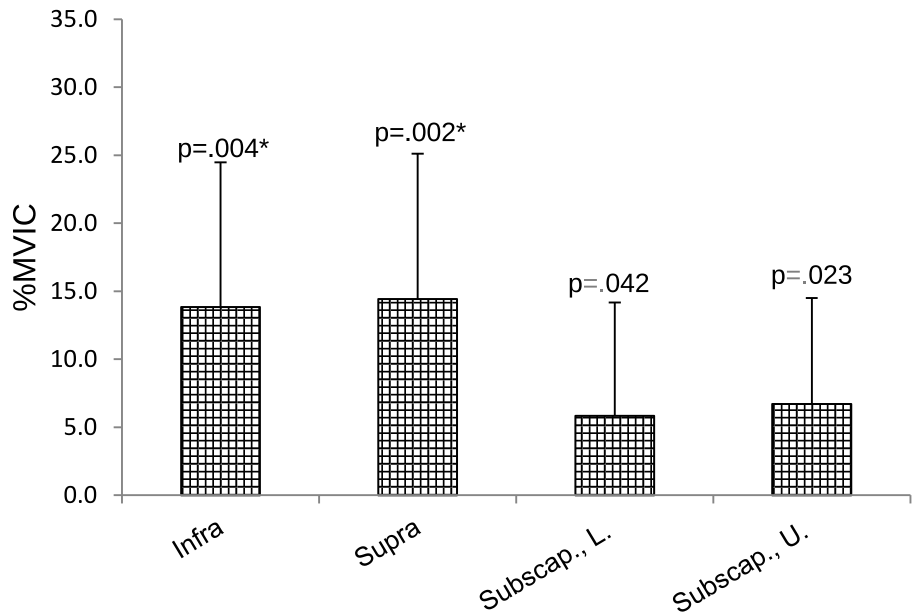


p<.0166

Table 26
Δ EMG (%MVIC) No Tape- McConnell Tape
ER 90° (50-75°)

		Test Value = 0						
	n	*Mean Change*	*SD*	*t*	*df*	*p (2 tailed)*	*95% Confidence Interval of the Difference Lower*	*Upper*
Infra	9	13.84	10.63	3.91	8	.005	5.67	22.02
Supra	11	14.42	10.70	4.47	10	.001	7.24	21.61
Subscap., L.	11	5.84	8.33	2.33	10	.042	.25	11.44
Subscap., U.	11	6.71	7.80	2.72	10	.024	1.13	12.29

Figure 33: Δ EMG No Tape - McConnell ER 90° (50-75°)

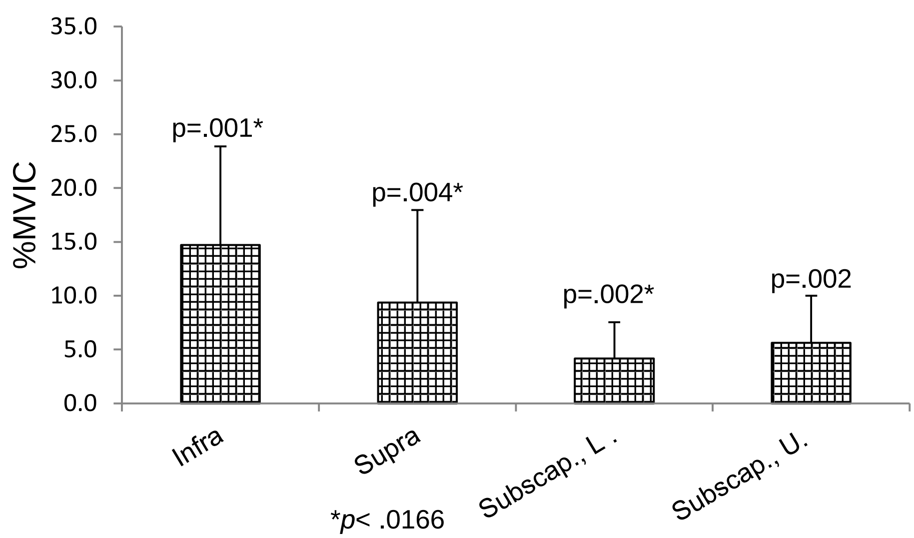


*p <.0166

Table 27
Δ in EMG (%MVIC) No Tape-McConnell Tape
ER 90° (75-Max)

							95% Confidence Interval of the Difference	
			Test Value = 0					
	N	Mean Change	SD	t	df	(2 tailed) *p*	Lower	Upper
Infra	9	14.72	9.16	4.82	8	.0013	7.68	21.76
Supra	11	9.39	8.58	3.63	10	.0046	3.63	15.15
Subscap., L .	11	4.18	3.36	4.13	10	.0020	1.92	6.44
Subscap., U.	11	5.64	4.35	4.30	10	.0016	2.72	8.56

Figure 34: Δ EMG No Tape-McConnell Tape ER 90° (75°-Max)



No Tape-Base Tape Conditions

Loss of EMG data due to saturation or corruption of the EMG signal resulted in a decrease in the number of subjects for analysis of the upper subscapularis (n=11), supraspinatus (n=11) and infraspinatus (n=9). Descriptive statistics and T-test results for the change in EMG amplitude (%MVIC) for the three arcs of motion are presented in tables 28-30. Figures 33-35 display the graphs of the absolute values of the mean EMG changes for the three arcs of motion in rank order with corresponding *p* values.

Significant differences ($p<.0166$) of the mean EMG amplitudes (%MVIC) are seen for the infraspinatus and supraspinatus muscles over all three arcs of motion. With the exception of the upper subscapularis during the last arc of motion, neither of the subscapularis muscles demonstrated a significant change in EMG.

Post hoc power analysis revealed a $1-\beta <.80$ for all non-significant results. Computed sample sizes to achieve power for these results ranged from 19 to 26 subjects. The average MDC value for all muscles across all three movement patterns was 8.2%.

Table 28
Δ EMG (%MVIC) No Tape-Base Tape
ER 90° (0-50°)

							Test Value = 0	
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Subscap L	11	12.04	16.40	2.43	10	0.035	1.02	23.06
Subscap, U.	11	10.55	15.52	2.25	10	0.048	.13	20.98
Supra	11	9.84	9.48	3.45	10	0.006	3.48	16.21
Infra	9	9.21	8.77	3.15	8	0.014	2.47	15.96

Figure 35: Δ EMG No Tape- Base Tape ER 90 (0-50°)

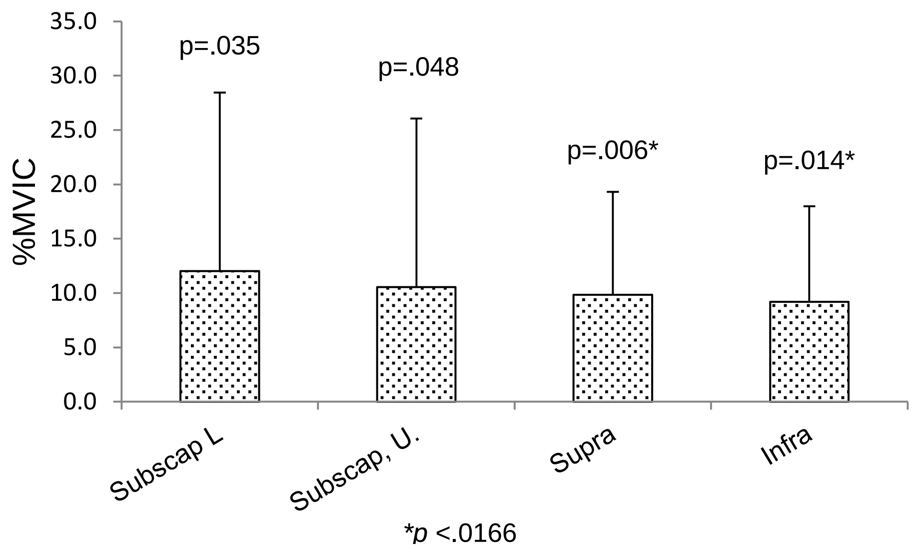


Table 29
Δ EMG (%MVIC) No Tape- Base Tape
ER 90° (50-75°)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Supra	11	12.24	8.72	4.66	10	0.001	6.38	18.09
Subscap, U.	11	11.53	15.90	2.29	10	0.048	.154	22.90
Infra	9	10.36	9.94	3.13	8	0.014	2.72	18.00
Subscap L	11	4.02	4.89	2.72	10	0.021	.730	7.30

Figure 36: Δ EMG No Tape-Base Tape ER 90° (50-75°)

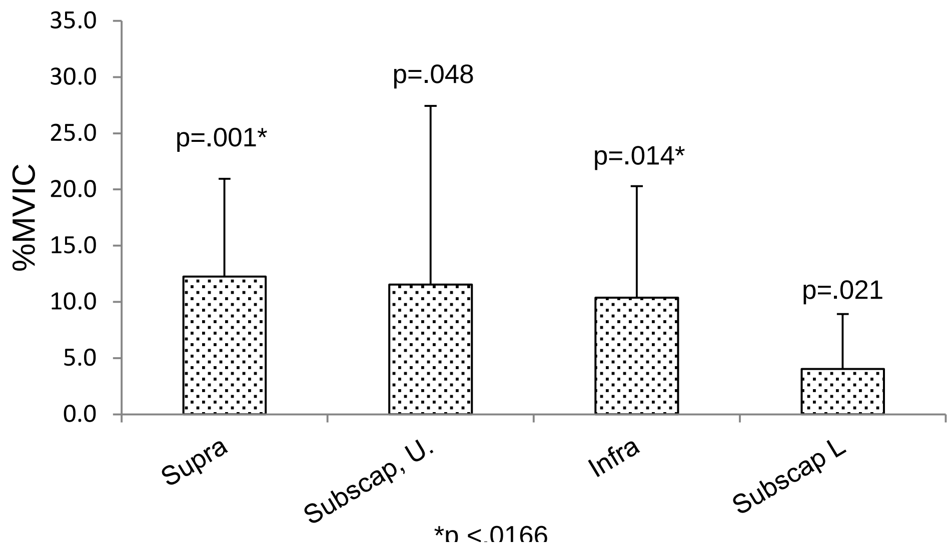
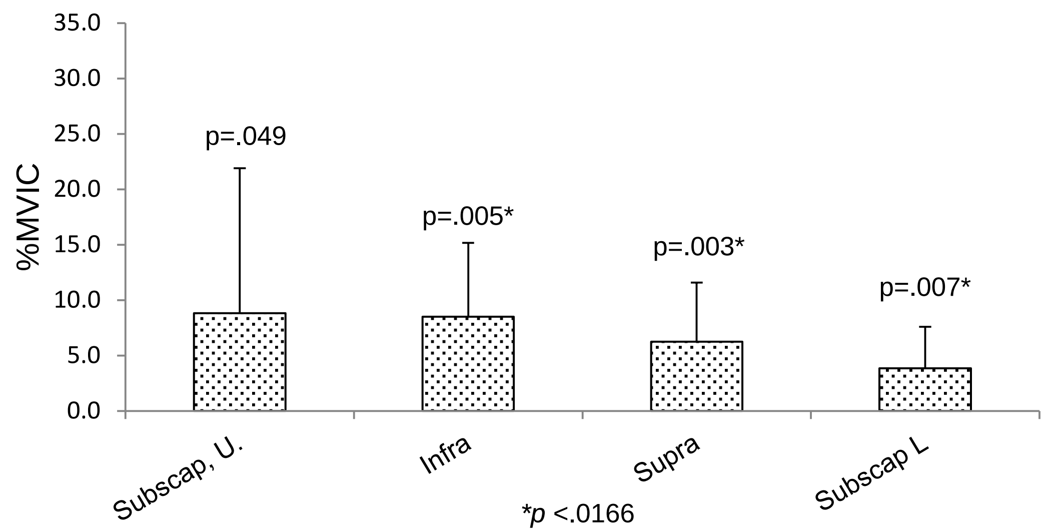


Table 30
Δ EMG (%MVIC) No Tape-Base Tape
ER 90° (75°-Max)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Subscap, U.	11	8.83	13.07	2.24	10	0.049	.047	17.61
Infra	9	8.49	6.68	3.81	8	0.005	3.36	13.62
Supra	11	6.25	5.35	3.87	10	0.003	2.65	9.84
Subscap L	11	3.84	3.75	3.40	10	0.007	1.33	6.36

Figure 37: Δ EMG No Tape-Base Tape ER 90° (75°-Max)



McConnell Tape-Base Tape Conditions

A change in EMG amplitude (%MVIC) after application of the base tape alone was significant for several muscles, therefore a t-test to determine if the change from the McConnell tape was significantly different from that of the base tape alone was performed. Descriptive statistics and t-test results for the change in EMG amplitude (%MVIC) between the McConnell tape and the base tape only conditions are presented for the three arcs of motion in tables 31-33. Figures 36-38 display the graphs of the absolute values of the mean EMG changes for the three arcs of motion in rank order with corresponding *p* values. Significant differences ($p<.0166$) of the absolute value of the mean EMG amplitudes (%MVIC) are seen for the supraspinatus during the second two arcs of motion, and the infraspinatus and the lower subscapularis during the early (0-50) and late (75-max) part of the ROM. The upper subscapularis muscle did not demonstrate significant changes in EMG activity during any part of the ROM. Post hoc power analysis revealed a $1- \beta <.80$ for all non-significant results. Computed sample sizes to achieve power for these results ranged from 15 to 24 subjects.

Table 31
Δ EMG (%MVIC) McConnell Tape-Base Tape
ER 90° (0-50°)

						Test Value = 0		
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean Change*	*SD*	*t*	*df*	*(2-tailed) p*	*Lower*	*Upper*
Supra	11	15.58	19.23	2.69	10	.023	2.66	28.50
Subscap, U.	11	10.33	14.44	2.37	10	.039	.632	20.03
Infra	9	9.67	6.49	4.47	8	.002	4.68	14.66
Subscap L	11	4.50	4.24	3.51	10	.006	1.65	7.35

Figure 38: Δ McConnell Tape to Base Tape ER 90° (0-50°)

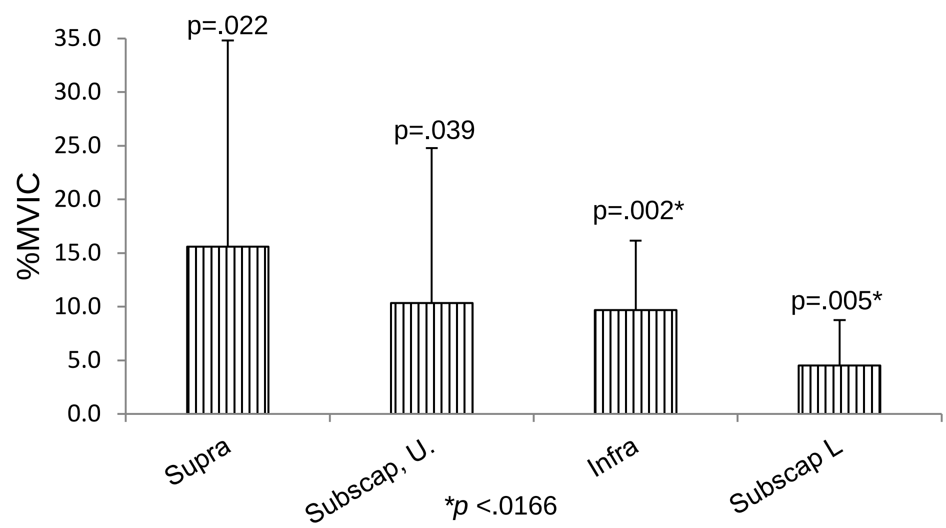


Table 32
Δ EMG (%MVIC) McConnell Tape-Base Tape
ER 90° (50-75°)

				Test Value = 0				
							95% Confidence Interval of the Difference	
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Supra	11	18.81	18.08	3.45	10	.006	6.66	30.96
Infra	9	9.51	10.10	2.83	8	.022	1.75	17.28
Subscap, U.	11	8.96	10.11	2.80	10	.021	1.73	16.20
Subscap L	11	3.60	5.08	2.35	10	.041	.18	7.01

Figure 39: Δ EMG McConnell Tape- Base Tape ER 90° (50-75°)

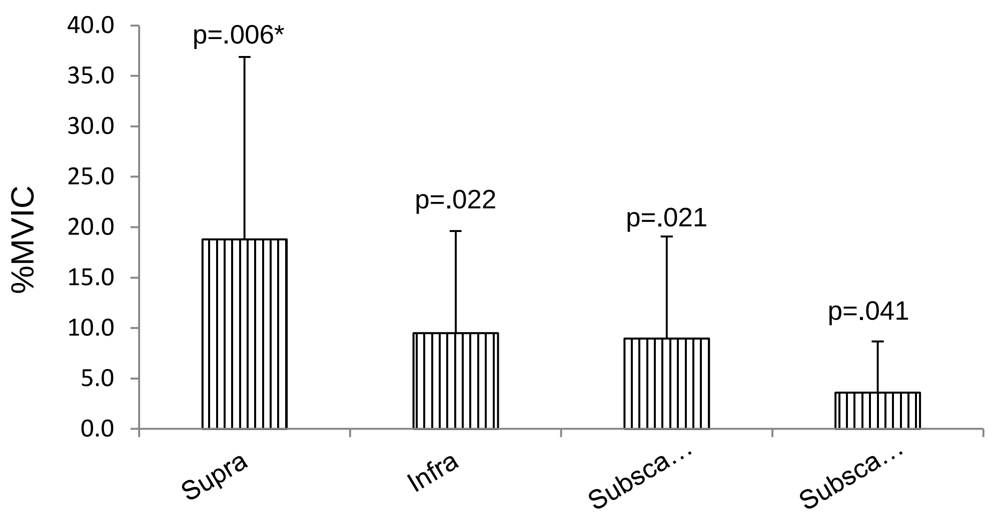
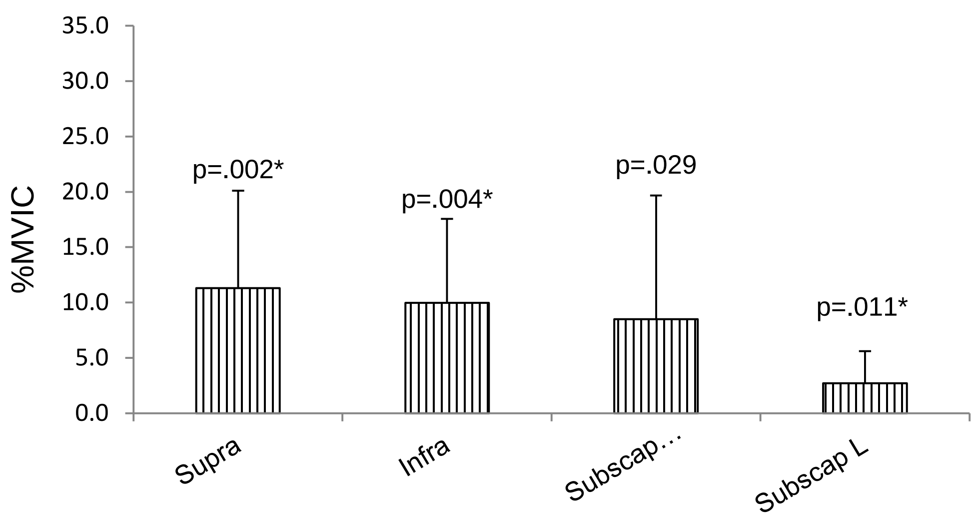


Table 33
Δ EMG (%MVIC) McConnell Tape-Base Tape
ER 90° (75°-Max)

							95% Confidence Interval of the Difference	
		Test Value = 0						
Muscle	*n*	*Mean change*	*SD*	*t*	*df*	*p (2 tailed)*	*Lower*	*Upper*
Supra	11	11.29	8.81	4.25	10	.002	5.37	17.21
Infra	9	9.97	7.59	3.94	8	.004	4.14	15.80
Subscap, U.	11	8.51	11.14	2.53	10	.030	1.03	16.00
Subscap L	11	2.71	2.89	3.11	10	.011	.77	4.65

Figure 40: ΔEMG McConnell Tape- Base Tape ER 90° (75°-Max)



Torque

Descriptive statistics for the mean torques for scaption, ER 45° and ER 90° are presented in tables 34, 36 and 38 respectively and in figures 39-41. Results of the within subject effects (tables 35, 37 and 39) demonstrate no main effect for taping condition for peak torque (Nm) for any of the three isokinetic movement patterns.

Table 34

Descriptive Statistics Scaption Torques (Nm)

Taping Condition	n	Mean (Nm)	SD
No Tape	12	13.73	6.95
McConnell Tape	12	14.15	6.14
Base Tape	12	13.92	5.8

Table 35

ANOVA Results Scaption Torques (Nm)

Factor		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Tape	Sphericity Assumed	1.077	2	.538	.143	.867	.013

Figure 41: Δ Torques (Nm) Scaption

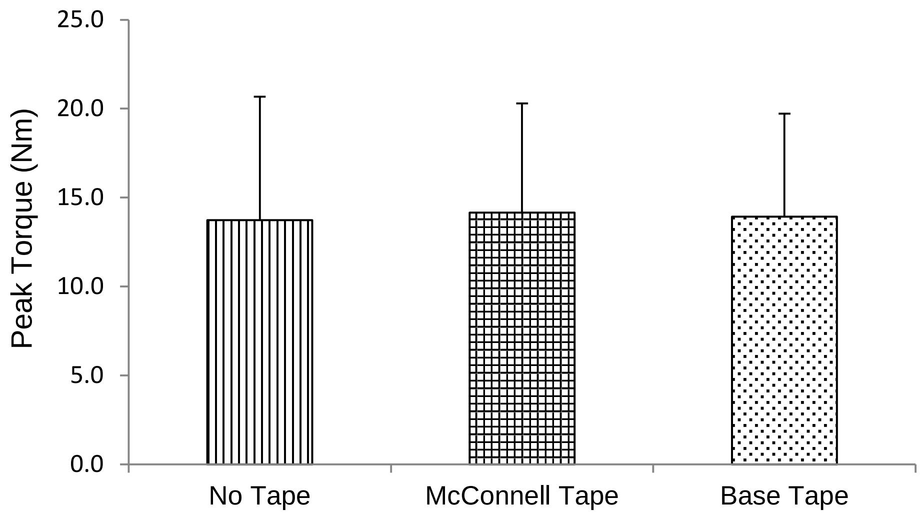


Table 36

Descriptive Statistics ER 45° Torques (Nm)

Taping Condition	n	Mean (Nm)	SD
No Tape	12	9.03	3.52
McConnell Tape	12	9.18	3.69
Base Tape	12	8.47	2.89

Table 37

ANOVA Tests of Within Subjects Effects Torques-ER 45°

Factor		Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Tape	Sphericity Assumed	3.367	2	1.68	0.524	0.60	0.05

Figure 42: Δ Torques (Nm) ER 45°

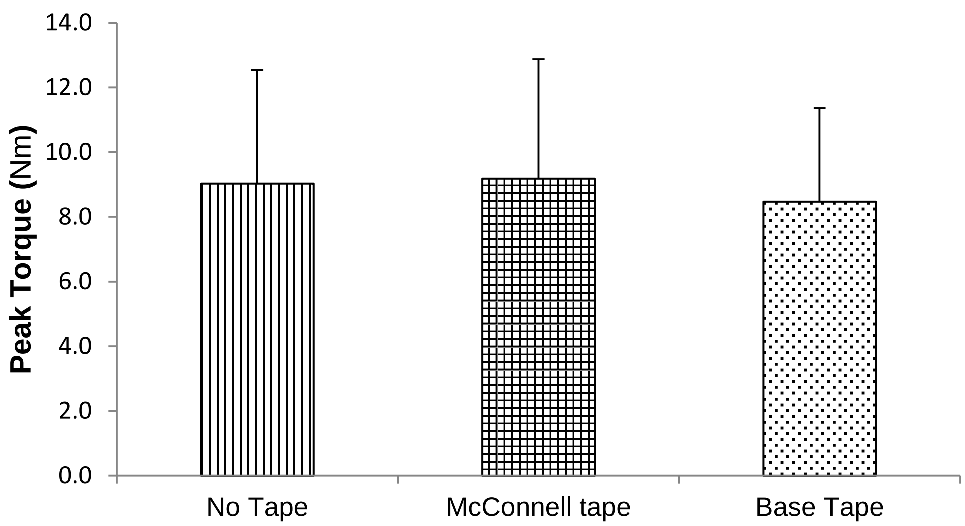


Table 38

Descriptive Statistics ER 90° Torques (Nm)

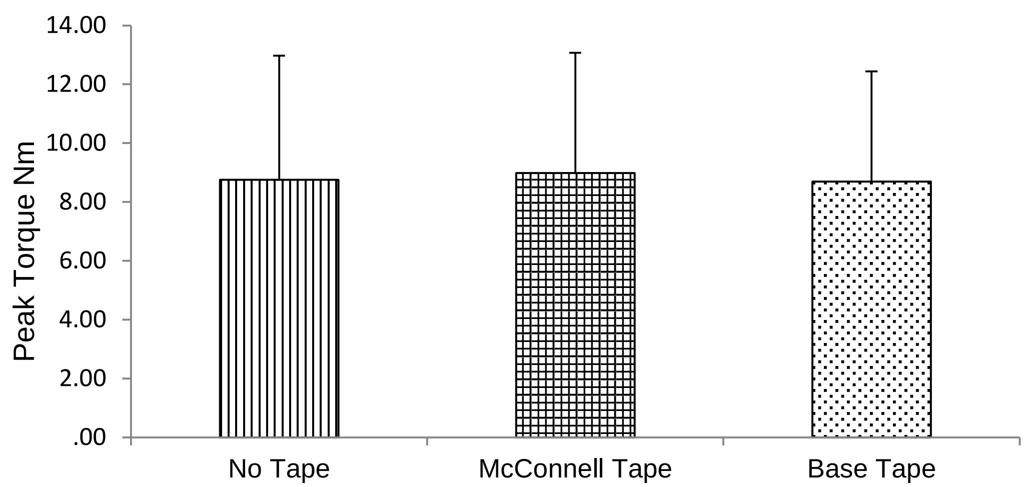
Taping Condition	n	Mean (Nm)	SD
No Tape	12	8.75	4.22
McConnell Tape	12	8.98	4.09
Base Tape	12	8.69	3.75

Table 39

ANOVA Tests of Within Subjects Effects Torques-ER 90°

Factor		Type III Sum of Squares	df	Mean Square	F	sig.	Partial Eta Squared
Tape	Sphericity Assumed	.564	2	.282	.159	.854	.014

Figure 43: Torques (Nm) ER 90°



Chapter V

DISCUSSION AND CONCLUSIONS

McConnell taping for anterior shoulder instability is a clinically important intervention despite a lack of evidence to support its use. While studies report the effect of McConnell tape at the patellofemoral joint, this repeated measures investigation is the first to date to examine the effects of McConnell corrective taping and base taping alone on the electromyographic activity and torque production of the shoulder muscles. Consistent with the patellofemoral taping literature, we found that the EMG activity between conditions increased in some subjects but decreased in others. This variability in EMG change occurred across all three arcs of motion, for all three movement patterns. Our statistical procedures used change scores to determine significant differences. In an effort to limit results that may be attributed to measurement error, we calculated MDC for all muscles across all movement patterns in all taping conditions. The muscles' MDC scores ranged from 8.2% to 13.3%. In absence of any universally accepted approach, we chose a value just under half of the highest MDC to serve as a conservative estimate for demarcating meaningful change. Accordingly, changes in %MVIC less than 6% will be considered not to be clinically meaningful and are excluded from the discussion.

The primary purpose of McConnell taping for shoulder instability is to alter humeral head position in order to influence activity of the rotator cuff muscles. The rotator cuff muscles through concavity compression are the primary dynamic restraint to unwanted anterior translation of the humeral head on the glenoid (Lippitt et al., 1993). In this study three rotator cuff muscles (supraspinatus, infraspinatus and upper subscapularis) demonstrated a significant change in EMG activity during the 75° to max arc of motion during ER at 90°. This finding, consistent with our hypothesis, is critical as this is the position where the greatest anterior translation occurs in unstable shoulders (von Eisenhart-Rothe et al., 2005). The lower subscapularis did not demonstrate a relevant change in EMG in the 75° to max position during ER 90°. This finding may be partially explained by the fact that the lower subscapularis is reported to be more active in lower ranges of abduction (Decker, Tokish, Ellis, Torry, & Hawkins, 2003), though the work of Kadaba and colleagues (1992) does not support that finding.

The changes in muscle activity of the rotator cuff muscles during the McConnell taping condition may be owed to the tape moving the humeral head more posteriorly, presumably altering the muscle's length-tension relationship. Research has demonstrated that the optimal length of a muscle facilities optimal muscle contraction (Soderberg, 1997). The more posterior re-alignment of the humeral head after taping may restore a more optimal length by reducing the position between the origin and insertion. This concept was elucidated by Greenfield (1990) who found that shoulder external rotation strength increased when moving the shoulder from the coronal plane into the plane of the scapula where the length tension relationship of the rotator cuff is more optimal.

The ability to influence the length tension relationship during the vulnerable abduction and ER position has important implications for the use of McConnell taping during rehabilitation. If we are able to effect a change in muscle activity of the primary shoulder stabilizers in the apprehension position we can perhaps incorporate more strengthening exercises in this functionally important position returning patients to play more quickly. Often persons with ASI cannot perform strength training in full ER and abduction because of apprehension and pain, creating a significant functional deficit because this is the position of the arm during an overhead throw.

In addition to showing significant changes in the apprehension position, the supraspinatus and infraspinatus muscles also demonstrated significant change during the other two arcs of motion, across all three movement patterns. Additionally these muscles demonstrated the greatest amount of change in EMG activity compared to the other muscles. The upper and lower subscapularis muscles demonstrated greater variability in their EMG response and acted independently of each other. For instance, the change in upper subscapularis EMG activity was significant over all three arcs of motion during scaption while the change in lower subscapularis EMG was not significant at all. The less consistent EMG change of the subscapularis muscles when compared to the supraspinatus and infraspinatus may be partially attributed to the technical difficulties of wire placement in these muscles. Access to these muscles is challenging as the arm must be fully internally rotated with the hand placed behind the back. As experienced in our study, internal rotation in injured shoulders is frequently limited (Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1990) making the hand behind the back position difficult to obtain. It is possible that because of the difficulty in wire placement, the ideal motor point was not achieved. Additionally, during the rotation tasks, the subscapularis was contracting eccentrically where as the supraspinatus and infraspinatus were contracting concentrically. The stretched position of the subscapularis during an eccentric contraction may cause greater displacement of the wires, increasing EMG variability. This may also be a factor in the high standard deviations seen for the subscapularis muscles.

Like the rotator cuff, the deltoids and biceps serve as primary stabilizers of the glenohumeral joint and are reported to decrease anterior translation of the humeral head in unstable shoulders (Itoi et al., 1994; Rodosky et al., 1994;Pagnani et al., 1996; Kido et al., 2003). The deltoids in our study demonstrated significant EMG changes over all three arcs of motion for scaption, whereas, the biceps over the last two arcs only. The literature demonstrates increased EMG activity of the biceps in shoulders with ASI (Kim et al., 2001) and decreased activity of the deltoids in shoulders with multidirectional instability (Kronberg, Brostrom, & Nemeth, 1991) so the ability to alter the activity of these muscles through taping has important clinical implications.

While the rotator cuff muscles provide primary concavity compression, the trunk muscles act as secondary shoulder joint stabilizers only because their insertions are further from the joint axis of motion. In our study the latissimus dorsi demonstrated a significant change in EMG over all three arcs of motion during scaption, yet the pectoralis major activity remained unaffected. The role of the pectoralis major in the unstable shoulder is not well understood. Some investigators suggest that because of the anterior pull of the pectoralis major it may actually decrease stability of the glenohumeral joint (Arciero & Cruser, 1997; Labriola, Lee, Debski, & McMahon, 2005). In a controlled laboratory experiment, Labriola found that simulated activity of the pectoralis major increased anteriorly directed shoulder forces 1180% (Labriola et al., 2005). Our study supports the idea that the pectoralis major may not play a significant role in stabilizing the unstable shoulder.

In this study, our results also do not support the effectiveness of McConnell tape in producing significant EMG changes in the serratus anterior. Several authors documented changes in serratus anterior activity in unstable subjects during throwing (Glousman et al., 1988) and shoulder elevation (McMahon et al., 1996). In our study, McConnell tape application did not create a significant change in serratus anterior muscle EMG. Perhaps without a direct attachment onto the humerus serratus anterior is not affected by humeral head repositioning.

Overall application of McConnell tape produced key changes in the EMG activity of the rotator cuff and deltoids consistent with the types of changes seen after repositioning of the patella with tape. Several authors report changes in VMO EMG activity after realigning the patella more medially with tape. Ng and Cheng (2002), using a functional test, examined the effects of patellar taping on the EMG activity ratio of the VMO to the VL. The authors reported a decrease in VMO activity after taping and attributed this to a decreased demand on the VMO to pull the patella medially. Christou et al (2004) investigated the influence of patellar taping on the EMG activity of the VMO and VL. Their EMG findings after patellar taping showed increases in VMO activity, whereas VL activity did not differ between groups. Cowan and Hodges (2006) investigated the effects of patellar taping of subjects performing a stair based functional task. These authors reported that the EMG amplitudes of the vasti muscles increased in some subjects but decreased in others. The presence of both increased and decreased EMG activity in the patellofemoral literature is similar to the results in the present study.

This variable pattern of subject EMG response in both the patella taping literature and the present study raises the possibility that different individuals use different neuromuscular strategies to cope with shoulder instability. Shoulder subluxation directly influences motor performance. Individuals with ASI note apprehension in their functional activities, which may also be painful (Tsai et al., 1991). Over time people with ASI may develop individual neuromuscular strategies to cope with this apprehension and pain. Several factors may play a role in the diversity of the subject response seen here, including length of time from initial injury or the type of upper extremity athletics the subject performs.

Several historical theories explain the neuromuscular system's response to pain or the threat of pain. The first, the vicious cycle theory, proposes that there is a uniform increase in the activity of muscles that produce movement within a painful joint (Johansson & Sojka, 1991). In subjects with ASI for example, this theory dictates that there might be an increase in rotator cuff muscle activity to help stabilize the joint. A differing neuromuscular theory explaining muscle activity patterns around a painful joint is the pain adaptation theory. This model proposes that the activity of muscles that act as antagonists to a movement are uniformly decreased (Lund, Donga, Widmer, & Stohler, 1991). An example of this might be a decrease in quadriceps muscle activity in a person with patellofemoral pain. The purpose of the pain adaptation response is to decrease displacement, velocity or force at the painful site (Hodges, 2011). While these two theories help shed light on our EMG findings, more recently Hodges (2011) proposed that rather than a uniform increase or decrease of motor activity in response to pain, motor adaptation varies between individuals and tasks. He argues the possibility of each individual develops a protective strategy that is uniquely based on his or her experience. Hodges' model helps to explain the bidirectional EMG change found between subjects in this study.

Based on these theories one could surmise that each subject entered this study with unique motor strategies to cope with their instability and pain and therefore responded differently to tape application. Subjects who increased their EMG activity may have had an initial suppression of motor activity (pain adaptation theory). In these subjects repositioning the humeral head through taping may optimize the length-tension relationship, facilitating contraction. Subjects who demonstrated decreased EMG activity after tape application possibly experienced initial muscular hyperactivity (vicious cycle theory). Stabilizing the joint through tape may decrease the need for this muscular hyperactivity, thus decreasing the EMG activity in these subjects with ASI. Other EMG findings of subjects with unstable shoulders confirm this variability in muscle response between our subjects. Glousman (1988) studied throwers with ASI and found increased supraspinatus activity in the late cocking phase but decreased infraspinatus in the early cocking phase. McMahon (2002) however, found that supraspinatus activity decreased during abduction and scaption, whereas infraspinatus activity remained unchanged. Despite the different functional activities used in these two studies, it is evident that muscle activity varies in subjects with ASI.

Sensory effects from tape applied to the skin cannot be discounted. To ensure that our findings controlled for the potential influence on cutaneous afferents from the presence of tape touching the skin, we examined the EMG activity after the application of base tape alone. The literature supports changes in motor activity from stimulation of cutaneous afferents in the overlying skin of the foot (Aniss et al., 1992) and the hand (McNulty et al., 1999). In the taping literature, Macgregor (2005) used tape to apply a stretch to the skin over the patella and found an increase in EMG activity of the VMO (Macgregor et al., 2005). Similarly, Christou (2004) found that during isokinetic leg presses subjects demonstrated increases in VMO activity after application of a placebo tape. Consistent with these studies, and our hypothesis, we found base tape alone caused a significant change in EMG activity for multiple muscles across all three movement patterns. Interestingly, in McNulty's (1999) investigation of reflex coupling in the hand, stimulation of the cutaneous afferents caused both excitatory and inhibitory EMG response of the muscles in the digits. Given our findings, this may help to explain why bidirectional EMG changes occurred after the application of base tape alone. Not surprisingly, the muscles directly underling the tape demonstrated the greatest change in % MVIC after base tape application. These included the deltoids, infraspinatus and supraspinatus muscles. Interestingly, the latissimus dorsi, biceps and upper subscapularis muscles not directly under the tape also demonstrated significant EMG change after application of the base tape. These were the latissimus dorsi, biceps and upper subscapularis. One explanation for these muscle changes may be that the tape tractioned the skin over the C4-T2 dermatomes thereby altering cutaneous afferent activity and subsequent reflex motor activity for theses muscles. It appears then from the results of this study and the aforementioned literature that some of the effect of taping may be attributed to stimulation of the cutaneous afferents in the skin.

In addition to the significant changes noted in EMG for the two taping conditions separately, we analyzed the differences found between the no tape to McConnell tape with the no tape to base tape conditions. We found that for many muscles these two taping conditions were also statistically different. Overall the supraspinatus, infraspinatus and deltoids demonstrated significant changes between the McConnell tape condition and the base tape condition relative to the baseline. After application of the base tape, we documented an added effect from application of the McConnell corrective tape. Thus the full treatment effect from McConnell taping then may be achieved partially from a sensory effect from stimulation of the cutaneous afferents and partially from the presumed mechanical realignment of the humeral head through the corrective tape. This pilot study supports this theoretical concept of McConnell taping at the shoulder in subjects with ASI. However further investigations are warranted.

While this study identified many significant EMG changes, no statistically different changes in peak torque between taping conditions occurred. As muscle force is proportional to the total cross sectional area of the muscle (Soderberg, 1997) it may be that skeletal adaptation is required to see a change in force production. If this is the case, perhaps changes in torque cannot be seen in just one session but require several weeks of training. Again, our results indicate that additional studies looking at the use of McConnell taping in context of a rehabilitation program for individuals with ASI are needed.

Study Limitations

There were several limitations of this study. Although 12 subjects were recruited, we did not have complete data for all individual analyses due to saturation of a few muscle's EMG signals. The ranges of values entered into data analyses ranged from ten to twelve. The use of a repeated measures design required fewer subjects reducing some of the variability, however the resulting smaller sample size then did not allow us to group subjects according to direction of their EMG change. Additionally, because of the small sample size some of the non-significant results were underpowered rendering them inconclusive.

A second limitation to be considered addresses the analyses using absolute values for the change scores since we were not able to determine the direction of EMG change, only the magnitude. Lastly, we could not randomize the taping order, as removing the tape between conditions dislodged the indwelling electrodes. For this reason we cannot eliminate the chance that there was an additional learning effect as subjects performed the testing three times during the single session.

Conclusions and Future Directions

This is the first experimental study on the use of McConnell shoulder taping on the EMG activity of the shoulder muscles and shoulder joint peak torque in subjects with ASI. This study documented changes in EMG activity of several muscles during three different functional movement patterns after application of both McConnell shoulder taping and base layer taping alone. Most significantly, three of the rotator cuff muscles demonstrated significant EMG change in the apprehension position of 90 degrees abduction and full external rotation. The ability to affect a change in muscle activity of the primary stabilizing muscles within this functional position lends efficacy to the use of tape during rehabilitation of people with ASI.

Because we found bidirectional EMG change between subjects, future studies with an increased sample size are needed size in order to allow grouping of subjects by direction of EMG change. Additionally as we identified muscles that had no EMG change from the use of McConnell tape, a shorter protocol with fewer muscles studied can be used.

References

Aniss, A. M., Gandevia, S. C., & Burke, D. (1992). Reflex responses in active muscles elicited by stimulation of low-threshold afferents from the human foot. *Journal of Neurophysiology, 67*(5), 1375-1384.

Arciero, R. A., & Cruser, D. L. (1997). Pectoralis major rupture with simultaneous anterior dislocation of the shoulder. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons , 6*(3), 318-320.

Backus, S. I., Tomlinson, D., Vanadurongwan, B., Lenhoff, M. W., Cordasco, F. A., Chehab, E., Hillstrom, H. J. (2011). A spectral analysis of rotator cuff musculature electromyographic activity: Surface and indwelling. *HSS Journal: The Musculoskeletal Journal of Hospital for Special Surgery, 7*(1), 21-28.

Baker, C. L., Uribe, J. W., & Whitman, C. (1990). Arthroscopic evaluation of acute initial anterior shoulder dislocations. *The American Journal of Sports Medicine, 18*(1), 25-28.

Basmajian, J. V. (1974). Chapter 3: Description and analysis of the EMG signal. In J. V. Basmajian (Ed.), *Muscles alive: Their functions revealed by electromyography* (3d ed., pp. 65). Baltimore: Williams & Wilkins.

Blasier, R. B., Guldberg, R. E., & Rothman, E. D. (1992). Anterior shoulder stability: Contributions of rotator cuff forces and the capsular ligaments in a cadaver model. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons 1*(3), 140-150.

Boettcher, C. E., Ginn, K. A., & Cathers, I. (2008). Standard maximum isometric voluntary contraction tests for normalizing shoulder muscle EMG. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society, 26*(12), 1591-1597.

Burden, A. (2010). How should we normalize electromyograms obtained from healthy participants? what we have learned from over 25 years of research. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology, 20*(6), 1023-1035.

Cain, P. R., Mutschler, T. A., Fu, F. H., & Lee, S. K. (1987). Anterior stability of the glenohumeral joint. A dynamic model. *The American Journal of Sports Medicine, 15*(2), 144-148.

Christou, E. A. (2004). Patellar taping increases vastus medialis oblique activity in the presence of patellofemoral pain. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology, 14*(4), 495-504.

Conway, A., Malone, T., & Conway, P. (1992). Patella alignment/tracking alteration: Effect on force output and perceived pain. *Journal of Isokinetic Exercise Science, 2*, 9.

Copay, A. G., Subach, B. R., Glassman, S. D., Polly, D. W., Jr, & Schuler, T. C. (2007). Understanding the minimum clinically important difference: A review of concepts and methods. *The Spine Journal: Official Journal of the North American Spine Society, 7*(5), 541-546.

Cowan, S. M., Hodges, P. W., Crossley, K. M., & Bennell, K. L. (2006). Patellar taping does not change the amplitude of electromyographic activity of the vasti in a stair stepping task. *British Journal of Sports Medicine, 40*(1), 30-34.

Cram, J. R., Kasman, G. S., & Holtz, J. (1998a). Chapter 14: Electrode placements. In J. R. Cram, G. S. Kasman & J. Holtz (Eds.), *Introduction to surface electromyography* (pp. 237). Gaithersburg, Md.: Aspen Publishers.

Cram, J. R., Kasman, G. S., & Holtz, J. (1998). Chapter 3:Instrumentation. In J. R. Cram, G. S. Kasman & J. Holtz (Eds.), *Introduction to surface electromyography* (pp. 43). Gaithersburg, Md.: Aspen Publishers.

Cram, J. R., Kasman, G. S., & Holtz, J. (1998c). Glossary of terms: Appendix A. In J. R. Cram, G. S. Kasman & J. Holtz (Eds.), *Introduction to surface electromyography* (pp. 390). Gaithersburg, Md.: Aspen Publishers.

Curl, L. A., & Warren, R. F. (1996). Glenohumeral joint stability. selective cutting studies on the static capsular restraints. *Clinical Orthopaedics and Related Research,*(330), 54-65.

Decker, M. J., Tokish, J. M., Ellis, H. B., Torry, M. R., & Hawkins, R. J. (2003). Subscapularis muscle activity during selected rehabilitation exercises. *The American Journal of Sports Medicine, 31*(1), 126-134.

DeLuca, C. J. (2002). In DeLuca C. J. (Ed.), *Fundamental concepts in EMG signal acquisition* (2.1st ed.). Boston, MA: DelSys Inc.

DeLuca, C. J. (2006). Electromyography. In J. G. Webster (Ed.), *Encyclopedia of medical devices and instrumentation* (2nd ed., pp. 98). Hoboken, NJ: Wiley-Interscience.

Dodson, C. C., & Cordasco, F. A. (2008). Anterior glenohumeral joint dislocations. *The Orthopedic Clinics of North America, 39*(4), 507-18, vii.

Fallon, J. B., Bent, L. R., McNulty, P. A., & Macefield, V. G. (2005). Evidence for strong synaptic coupling between single tactile afferents from the sole of the foot and motoneurons supplying leg muscles. *Journal of Neurophysiology, 94*(6), 3795-3804.

Farber, A. J., Castillo, R., Clough, M., Bahk, M., & McFarland, E. G. (2006). Clinical assessment of three common tests for traumatic anterior shoulder instability. *The Journal of Bone and Joint Surgery. American Volume, 88*(7), 1467-1474.

Glousman, R. E., Jobe, F., Tibone, J., Moynes, D. R., Antonelli, D. J., & Perry, J. (1988). Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *The Journal of Bone and Joint Surgery. American Volume, 70*(2), 220-226.

Greenfield, B. H., Donatelli, R., Wooden, M. J., & Wilkes, J. (1990). Isokinetic evaluation of shoulder rotational strength between the plane of scapula and the frontal plane. *The American Journal of Sports Medicine, 18*(2), 124-128.

Handfield, T., & Kramer, J. (2000). Effect of McConnell taping on perceived pain and knee extensor torques during isokinetic exercises performed by patients with patellofemoral pain. *Physiotherapy Canada. Physiothérapie Canada,* 39.

Henry, J. H., & Genung, J. A. (1982). Natural history of glenohumeral dislocation--revisited. *The American Journal of Sports Medicine, 10*(3), 135-137.

Herrington, L., Malloy, S., & Richards, J. (2005). The effect of patella taping on vastus medialis oblique and vastus laterialis EMG activity and knee kinematic variables during stair descent. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology, 15*(6), 604-607.

Hillstrom, H. J., & Triolo, R. J. (1994). EMG theory. In R. Craik, & C. A. Oatis (Eds.), *Gait analysis: Theory and application* (1st ed., pp. 271). St. Louis: Mosby.

Hodges, P. W. (2011). Pain and motor control: From the laboratory to rehabilitation. *Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology, 21*(2), 220-228.

Hovelius, L. (1999). The natural history of primary anterior dislocation of the shoulder in the young. *Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association, 4*(4), 307-317.

Itoi, E., Newman, S. R., Kuechle, D. K., Morrey, B. F., & An, K. N. (1994). Dynamic anterior stabilisers of the shoulder with the arm in abduction. *The Journal of Bone and Joint Surgery. British Volume, 76*(5), 834-836.

Jaggi, A., & Lambert, S. (2010). Rehabilitation for shoulder instability. *British Journal of Sports Medicine, 44*(5), 333-340.

Jaggi, A., Noorani, A., Malone, A., Cowan, J., Lambert, S., & Bayley, I. (2012). Muscle activation patterns in patients with recurrent shoulder instability. *International Journal of Shoulder Surgery, 6*(4), 101-107.

Jobe, F. W., Moynes, D. R., & Brewster, C. E. (1987). Rehabilitation of shoulder joint instabilities. *The Orthopedic Clinics of North America, 18*(3), 473-482.

Jobe, F. W., & Pink, M. (1993). Classification and treatment of shoulder dysfunction in the overhead athlete. *The Journal of Orthopaedic and Sports Physical Therapy, 18*(2), 427-32.

Johansson, H., & Sojka, P. (1991). Pathophysiological mechanisms involved in genesis and spread of muscular tension in occupational muscle pain and in chronic musculoskeletal pain syndromes: A hypothesis. *Medical Hypotheses, 35*(3), 196-203.

Kadaba, M. P., Cole, A., Wootten, M. E., McCann, P. D., Reid, M., Mulford, G. Bigliani, L. U. (1992). Intramuscular wire electromyography of the subscapularis. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society, 10*(3), 394-397.

Kelly, B. T., Kadrmas, W. R., Kirkendall, D. T., & Speer, K. P. (1996). Optimal normalization tests for shoulder muscle activation: An electromyographic study. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society, 14*(4), 647-653.

Kido, T., Itoi, E., Lee, S. B., Neale, P. G., & An, K. N. (2003). Dynamic stabilizing function of the deltoid muscle in shoulders with anterior instability. *The American Journal of Sports Medicine, 31*(3), 399-403.

Kim, S. H., Ha, K. I., Kim, H. S., & Kim, S. W. (2001). Electromyographic activity of the biceps brachii muscle in shoulders with anterior instability.

Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association, 17(8), 864-868.

Kronberg, M., Brostrom, L. A., & Nemeth, G. (1991). Differences in shoulder muscle activity between patients with generalized joint laxity and normal controls. *Clinical Orthopaedics and Related Research, (269)*(269), 181-192.

Labriola, J. E., Lee, T. Q., Debski, R. E., & McMahon, P. J. (2005). Stability and instability of the glenohumeral joint: The role of shoulder muscles. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons, 14*(1 Suppl S), 32S-38S.

Lippitt, S., & Matsen, F. (1993). Mechanisms of glenohumeral joint stability. *Clinical Orthopaedics and Related Research, (291)*(291), 20-28.

Lippitt, S. B., Vanderhooft, J. E., Harris, S. L., Sidles, J. A., Harryman, D. T.,2nd, & Matsen, F. A.,3rd. (1993). Glenohumeral stability from concavity-compression: A quantitative analysis. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons, 2*(1), 27-35.

Lund, J. P., Donga, R., Widmer, C. G., & Stohler, C. S. (1991). The pain-adaptation model: A discussion of the relationship between chronic musculoskeletal pain and motor activity. *Canadian Journal of Physiology and Pharmacology, 69*(5), 683-694.

Macgregor, K., Gerlach, S., Mellor, R., & Hodges, P. W. (2005). Cutaneous stimulation from patella tape causes a differential increase in vasti muscle activity in people with patellofemoral pain. *Journal of Orthopaedic Research : Official Publication of the Orthopaedic Research Society, 23*(2), 351-358.

Matsen, F. A.,3rd, Harryman, D. T.,2nd, & Sidles, J. A. (1991). Mechanics of glenohumeral instability. *Clinics in Sports Medicine, 10*(4), 783-788.

McConnell, J. (1986). The management of chondromalacia patella: A long term solution. *Australian Journal of Physiotherapy, 32*, 215.

McConnell, J., Donnelly, C., Hamner, S., Dunne, J., & Besier, T. (2011). Effect of shoulder taping on maximum shoulder external and internal rotation range in uninjured and previously injured overhead athletes during a seated throw. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society, 29*(9), 1406-1411.

McConnell, J., Donnelly, C., Hamner, S., Dunne, J., & Besier, T. (2012). Passive and dynamic shoulder rotation range in uninjured and previously injured overhead throwing athletes and the effect of shoulder taping. *PM & R: The Journal of Injury, Function, and Rehabilitation, 4*(2), 111-116.

McConnell, J., & McIntosh, B. (2009). The effect of tape on glenohumeral rotation range of motion in elite junior tennis players. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine, 19*(2), 90-94.

McMahon, P. J., Jobe, F. W., Pink, M. M., Brault, J. R., & Perry, J. (1996). Comparative electromyographic analysis of shoulder muscles during planar motions: Anterior glenohumeral instability versus normal. *Journal of Shoulder & Elbow Surgery, 5*(2 Pt 1), 118-123.

McMahon, P. J., & Lee, T. Q. (2002). Muscles may contribute to shoulder dislocation and stability. *Clinical Orthopaedics and Related Research, (403 Suppl)*(403 Suppl), S18-25.

McNulty, P. A., Turker, K. S., & Macefield, V. G. (1999). Evidence for strong synaptic coupling between single tactile afferents and motoneurones supplying the human hand. *The Journal of Physiology, 518 (Pt 3)*(Pt 3), 883-893.

Ng, G. Y., & Cheng, J. M. (2002). The effects of patellar taping on pain and neuromuscular performance in subjects with patellofemoral pain syndrome. *Clinical Rehabilitation, 16*(8), 821-827.

Nordin, M., & Frankel, V. H. (2001). Biomechanics of the shoulder. (3rd ed., pp. 318-339). Philadelphia: Lippincott Williams & Wilkins.

Norlin, R. (1993). Intraarticular pathology in acute, first-time anterior shoulder dislocation: An arthroscopic study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy*

Association of North America and the International Arthroscopy Association, 9(5), 546-549.

O'Brien, S. J., Neves, M. C., Arnoczky, S. P., Rozbruch, S. R., Dicarlo, E. F., Warren, R. F., Wickiewicz, T. L. (1990). The anatomy and histology of the inferior glenohumeral ligament complex of the shoulder. *The American Journal of Sports Medicine, 18*(5), 449-456.

O'Brien, S. J., Schwartz, R. S., Warren, R. F., & Torzilli, P. A. (1995). Capsular restraints to anterior-posterior motion of the abducted shoulder: A biomechanical study. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons, 4*(4), 298-308.

Owens, B. D., Nelson, B. J., Duffey, M. L., Mountcastle, S. B., Taylor, D. C., Cameron, K. L., DeBerardino, T. M. (2010). Pathoanatomy of first-time, traumatic, anterior glenohumeral subluxation events. *The Journal of Bone and Joint Surgery. American Volume, 92*(7), 1605-1611.

Pagnani, M. J., Deng, X. H., Warren, R. F., Torzilli, P. A., & O'Brien, S. J. (1996). Role of the long head of the biceps brachii in glenohumeral stability: A biomechanical study in cadavera. *Journal of Shoulder and Elbow Surgery / American Shoulder and Elbow Surgeons, 5*(4), 255-262.

Perotto, A., & Delagi, E. F. (2005). Shoulder joint. *Anatomical guide for the electromyographer: The limbs and trunk* (4th ed., pp. 117). Springfield, IL: Charles C Thomas.

Perrin, D. H. (1993). *Isokinetic exercise and assessment* (1st ed.). Champaign, Illinois: Human Kinetics Publishers.

Robinson, C. M., Howes, J., Murdoch, H., Will, E., & Graham, C. (2006). Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. *The Journal of Bone and Joint Surgery.American Volume, 88*(11), 2326-2336.

Rodosky, M. W., Harner, C. D., & Fu, F. H. (1994). The role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder. *The American Journal of Sports Medicine, 22*(1), 121-130.

Soderberg, G. L. (1997b). Shoulder. In G. L. Soderberg (Ed.), *Kinesiology: Application to pathological motion* (2nd ed., pp. 143). Baltimore: Williams & Wilkins.

Soderberg, G. L. (1997c). Tissue structure and function: Chapter 2. In G. L. Soderberg (Ed.), *Kinesiology: Application to pathological motion* (2nd ed., pp. 29). Baltimore: Williams & Wilkins.

Soderberg, G. L., & Knutson, L. M. (2000). A guide for use and interpretation of kinesiologic electromyographic data. *Physical Therapy, 80*(5), 485-98.

Taber, C. W. (1997). *Taber's cyclopedic medical dictionary*. Philadelphia, Pa.: F.A. Davis Co.

Tsai, L., Wredmark, T., Johansson, C., Gibo, K., Engstrom, B., & Tornqvist, H. (1991). Shoulder function in patients with unoperated anterior shoulder instability. *The American Journal of Sports Medicine, 19*(5), 469-473.

Tzannes, A., Paxinos, A., Callanan, M., & Murrell, G. A. (2004). An assessment of the interexaminer reliability of tests for shoulder instability. *Journal of Shoulder & Elbow Surgery, 13*(1), 18-23.

von Eisenhart-Rothe, R., Hinterwimmer, S., Braune, C., Jager, A., Mayr, H., Vogl, T., Graichen, H. (2005). MR-based 3D-analysis of the pathomechanics of traumatic and atraumatic shoulder instability. [MR-basierte 3D-Analyse der Pathomechanik der traumatischen und atraumatischen Schulterinstabilitat] *Zeitschrift Fur Orthopadie Und Ihre Grenzgebiete, 143*(4), 461-467. doi:10.1055/s-2005-836747

Warner, J. J., Micheli, L. J., Arslanian, L. E., Kennedy, J., & Kennedy, R. (1990). Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *The American Journal of Sports Medicine, 18*(4), 366-375.

Webster, J. G. (2006). *Encyclopedia of medical devices and instrumentation* (2nd ed.). Hoboken, N.J.: Wiley-Interscience.

Werner, S., Knutsson, E., & Eriksson, E. (1993). Effect of taping the patella on concentric and eccentric torque and EMG of knee extensor and flexor muscles in patients with patellofemoral pain syndrome. *Knee Surgery,* *Sports Traumatology, Arthroscopy : Official Journal of the ESSKA, 1*(3-4), 169-177.

Winter, D. A., & Winter, D. A. (1990). Kinesiological electromyography. In D. A. Winter, & D. A. Winter (Eds.), *Biomechanics and motor control of human movement* (2nd ed., pp. 196). New York: Wiley.

Wuelker, N., Schmotzer, H., Thren, K., & Korell, M. (1994). Translation of the glenohumeral joint with simulated active elevation. *Clinical Orthopaedics and Related Research, (309)*(309), 193-200.

Appendix A

Definitions

Abduction: Lateral movement of the limbs away from the median line of the body (Taber, 1997)

Afferent: Carrying inward to a central organ or section, as nerves that conduct impulses from the periphery of the body to the brain or spinal cord (Taber, 1997)

Amplitude: The quantity that expresses the magnitude of a signal's activity (DeLuca, 2002).

Analog filter: a filter found in the electronic circuitry of the hardware (EMG) (DeLuca, 2002).

Analog- to- digital conversion (A-D): Conversion of the raw (analog) EMG signal into a mathematical signal through the process of sampling (DeLuca, 2002).

Bandwidth: A range of EMG signal frequencies (DeLuca, 2002)

Bipolar electrodes: Two recording surfaces used side by side (Cram, Kasman, & Holtz, 1998).

Common mode rejection: During amplification, the signal that is the same at both recording electrodes is identified as noise and eliminated (Cram, Kasman, & Holtz, 1998c).

Common Mode Rejection Ratio (CMRR): The measure of the ability of the amplifier to eliminate the signal that is the same at both recording electrodes (common mode signal) (DeLuca, 2006).

Concavity Compression: The stability afforded a convex object that is pressed into a concave surface(S. Lippitt & Matsen, 1993).

Concentric muscle contraction: Muscle activity generated as a muscle shortens in length (Cram, Kasman, & Holtz, 1998c).

Cross talk: When the signal from a distant muscle reaches the electrodes placed over another muscle site (Cram, Kasman, & Holtz, 1998).

Cut off frequency: The designated point that defines the limits of a filter's frequency range (Cram, Kasman, & Holtz, 1998c).

Dermatome: The area of skin supplied with afferent nerve fibers by a single posterior spinal root (Taber, 1997).

Differential Amplification: A characteristic of the amplifier in which the EMG signal reaching both recording electrodes is compared to that of the reference electrode and only the signal that is different is passed on for further amplification (Cram, Kasman, & Holtz, 1998c).

Digital EMG signal: The processed EMG signal expressed as a sequence of numbers (DeLuca, 2002). The digitation of a signal allows for mathematical manipulation of the signal to be performed.

Dislocation: A complete separation of the joint surfaces where immediate, spontaneous relocation of the shoulder does not occur (Dodson & Cordasco, 2008).

Eccentric muscle contraction: Muscle activity generated as a muscle increases in length (Cram, Kasman, & Holtz, 1998c).

Electrode: The electrical conductor or recording surface for EMG signal detection(DeLuca, 2002).

Electromyography (EMG): The electrical manifestation of the neuromuscular activation associated with a contracting muscle (DeLuca, 2006; Webster, 2006)

External rotation (ER): Movement of the shoulder in the transverse plane so that the hand moves away from the midline of the body.

Fast fourier transformation (FFT): The mathematical process of decomposing an EMG signal into the frequency components in order to obtain the power spectrum(Cram, Kasman, & Holtz, 1998).

Filter: a device designed to attenuate specific ranges of frequencies while allowing others to pass (DeLuca, 2002)

Filtering: The manipulation of a signal's frequency (DeLuca, 2002)

Filter order: The magnitude of attenuation of the input signal's frequency. The higher the order of the filter, the more frequency attenuation occurs (DeLuca, 2002).

Fine wire electrode: An EMG electrode that is inserted into the muscle. Consists of 2 wires threaded through a hollow core needle(Cram, Kasman, & Holtz, 1998).

Frequency: The number of repetitions per unit time of a complete waveform (Webster, 2006).

Gain: Amplification of a signal. The amount of gain determines how large or small the signal appears on the visual display (Cram, Kasman, & Holtz, 1998).

High pass filter: Frequencies lower than the specified filter frequency are attenuated (higher frequencies are passed) (Hillstrom & Triolo, 1994) .

Instant center of rotation: the location of a point resulting from the construction of an intersection of two axes perpendicular to the plane of motion (Soderberg, 1997a).

Internal rotation (IR): Movement of the shoulder in the transverse plane so that the hand moves towards the midline of the body.

Isokinetic exercise: Movement of the limb at a constant rate. (Perrin, 1993).

Isometric muscle contraction: Muscle activity in which the muscle length and joint angle are kept constant (Cram, Kasman, & Holtz, 1998c).

Late cocking: A phase of the overhead throw when maximal external rotation and abduction of the arm is attained (Glousman et al., 1988).

Length-Tension relationship: The relationship between the length of a muscle and the contractile force the muscle is able to generate (Soderberg, 1997c).

Linear envelope: Smoothing a signal by low pass filtering the rectified signal (Winter & Winter, 1990).

Maximal Voluntary Isometric Contraction (MVIC): A muscle contraction used as a reference for normalization of electromyographic activity (Boettcher, Ginn, & Cathers, 2008) .

Mechanoreceptor: A receptor that receives mechanical stimuli such as pressure from sound or touch (Taber, 1997).

Minimal detectable change: The smallest change that can be considered above the measurement error with a given level of confidence (95% confidence level) (Copay, Subach, Glassman, Polly, & Schuler, 2007).

Movement artifact: Large deflections/distortion of a raw signal recording due to motion of the electrodes or the cables (Cram, Kasman, & Holtz, 1998).

Noise: Any unwanted signal contained in a signal that may possibly mask the true signal of interest (DeLuca, 2002).

Normalization (EMG): Conversion of the EMG signal to a scale that is common to all measurement occasions. Allows for comparison between subjects. Normalization is performed by dividing the EMG by a standard factor derived from a reference muscle contraction (Burden, 2010). In this study the MVIC was used as the reference muscle contraction

Nyquist theorem (sampling theorem): Sampling frequency for any signal should be at least twice the value of the highest frequency component in the signal (DeLuca, 2002).

Peak EMG Amplitude: The highest amplitude measured during the EMG activity (DeLuca, 2002).

Peak Torque: The highest muscular torque produced at any point during an activity (Perrin, 1993)

Power Spectrum: The distribution of frequencies contained within a signal (Backus et al., 2011).

Raw EMG: The analog, unprocessed EMG signal (Cram, Kasman, & Holtz, 1998).

Reference electrode: An electrode which maintains a neutral electric potential to provide a common reference for the recording electrodes during differential amplification (DeLuca, 2002).

Resistance/Impedance: A measure of how difficult it is for charges to flow in the form of an electric current (Hillstrom & Triolo, 1994) .

Rectification (full wave): The negative portion of the EMG signal that resides below the zero point is made positive by artificially placing it above the zero crossing line (Cram, Kasman, & Holtz, 1998).

Sampling frequency: The number of samples of the EMG signal collected per second (DeLuca, 2002).

Saturation: Over amplification of the EMG signal causes the output signal to exceed the maximum output voltage capability of the recording system (DeLuca, 2002). Visually the signal appears to be clipped at the peak and maximum amplitude is not represented.

Scaption: Elevation of the arm in a plane of motion 30^{o} forward to the abduction plane (Greenfield, Donatelli, Wooden, & Wilkes, 1990).

Signal Range: The maximum output voltage a device is capable of sustaining (DeLuca, 2002).

Signal to noise ratio: The ratio of energy in a signal to the energy in the noise signal (DeLuca, 2002).

Smoothing: A digital filtering technique that decreases the number of high frequencies contained in the signal (Soderberg & Knutson, 2000). Visually the signal appears to have the sharper peaks “smoothed out” (Cram, Kasman, & Holtz, 1998)

Subluxation: Partial separation of joint surfaces wherein spontaneous relocation occurs (Dodson & Cordasco, 2008).

Surface Electrode: An EMG electrode that sits on the skin over the muscle of interest (Cram, Kasman, & Holtz, 1998)

Torque: Force measured about a joint’s axis of rotation. Torque = force x distance (Perrin, 1993).