MEASURING HUMERAL HEAD TRANSLATION AFTER SUPRASCAPULAR

NERVE BLOCK

by

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   Subacromial impingement syndrome is the most common disorder of the shoulder. Abnormal superior translation of the humeral head is believed to be one of the major causes of this pathology. The overall purpose of this study was to better understand glenohumeral kinematics in normal healthy individuals using fluoroscopy to help comprehend the mechanism of shoulder impingement. This research was divided into three sections: a validation study to measure humeral head translation, a comparison between dynamic and static arm elevation and lastly, humeral head translation after a suprascapular nerve block.

   In the first study, fluoroscopy was used to take images of human cadaver shoulders. Scapular orientation was manipulated in different positions while the humerus was at 90 degrees of elevation. Humeral head translation was measured using two

methods and was compared to the known translation. Additionally, the accuracy of the contour registration method to measure 2-D scapular rotations was assessed.

For the second study, subjects elevated their dominant arm while fluoroscopic images were taken. An edge detection software was utilized to digitize points on both the humeral head and glenoid. Humeral head translation and scapular upward rotation were measured using a contour registration method with respect to the glenoid during arm elevation. Five different arm elevation angles were investigated to measure differences in humeral head translation between trials. There was no difference found between humeral head translation and scapular upward rotation between static and dynamic shoulder elevation.

For the third study, humeral head translation was measured before and after a suprascapular never block. The humeral head was superiorly located and the scapula was more upwardly rotated after the block. The differences were observed during mid range of motion. This result showed that there was a compensatory increase in both humeral head translation and scapular upward rotation due to the nerve block. These results suggest that increasing muscular strength and endurance of the supraspinatus and infraspinatus muscle could prevent any increased superior humeral head translation. This may be beneficial in preventing shoulder impingement or rotator cuff tear over time.

This dissertation includes unpublished co-authored materials.

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CHAPTER I

INTRODUCTION

Superior translation of the humeral head is believed to be one of the major causes of subacromial impingement syndrome (SAIS) (Deutsch et al., 1996, Sharkey and Marder, 1995, Wong et al., 2003). An increase in superior translation of the humeral head, possibly due to rotator cuff fiber disruption, can increase shear and compressive forces on the rotator cuff tendons that can eventually result in rotator cuff rupture (Halder et al., 2001). As a result, rotator cuff tears are a common shoulder problem (Soslowsky et al., 1997, Ludewig and Cook, 2002, Flatow et al., 1994).

An arthroscopic visualization of the subacromial space affords a complete view of the coracoacromial arch, the acromiclavicular (AC) joint, the superficial surface of the rotator cuff, and the subacromial and subdeltoid bursae. The subacromial space is defined by humeral head, bursal surface of the cuff (floor of the subacromial space), the anterior surface of the acromion, the AC joint and the coracoacromial ligament (anterior wall and medial-most aspect of the space) (Neer, 1972, Rockwood et al., 2004). The tissues that occupy the subacromial space are the supraspinatus tendon, subacromial bursa, long head of the biceps brachii tendon, and the capsule of the shoulder joint (Michener et al., 2003).

The width of the subacromial space is determined by measuring the distance between the inferior side of the acromion and the apex of the humeral head (acromio-humeral distance-AH) (Lochmuller et al., 1997). Numerous studies have measured AH distance in normal subjects and reported that it ranges from 6 – 14 mm (Graichen et al., 2001, Golding, 1962, Graichen et al., 1999a, Graichen et al., 1999b, Cotton and Rideout, 1964, Weiner and Macnab, 1970, Werner et al., 2006). As mentioned above, various tissues occupy the subacromial space so a reduction of its width plays an important role in the pathology of SAIS (Burns and Whipple, 1993, Bigliani et al., 1991, Neer, 1972). SAIS is characterized by a mechanical compression of the soft tissues in the subacromial space with symptoms that typically include shoulder pain, stiffness, tenderness, and weakness (Karduna et al., 2005).

There are two predominating mechanistic theories as to the cause of narrowing subacromial space in SAIS: intrinsic and extrinsic. Intrinsic impingement is caused by intrinsic factors such as: osteophytes, acromial changes, muscle imbalances and weakness. Intrinsic impingement, theorizes that degenerative process that occurs over time with overuse, tension or trauma of the tendons leads to partial or full thickness tendon tear. On the other hand, extrinsic factors such as faulty posture, altered scapular or GH (GH) kinematics, posterior capsular tightness, and acromial or coracoacromial arch pathology may lead to extrinsic impingement (Michener et al., 2003). Extrinsic impingement ensues when inflammation and degeneration of the tendon occur as a result of mechanical compression by some structure external to the tendon.

Intrinsic Factors

The rotator cuff muscles, especially the supraspinatus, surrounding the GH joint act through force couples and serve as its primary stabilizers (Halder et al., 2001). The rotator cuff serves to maintain congruency between the humeral head and glenoid fossa by producing a compressive force during GH movements (Michener et al., 2003). In addition to the rotator cuff, latissimus dorsi and teres major help in the depression of the humeral head to prevent excessive superior translation of the humeral head (Halder et al., 2001). The rotator cuff also functions with the deltoid muscles to produce a smooth trajectory of the humerus during all phases of GH elevation (Alpert et al., 2000, McMahon et al., 1995). However, after the initial phase of elevation of approximately the first 30 - 60°, the rotary contribution of the supraspinatus declines significantly (Reddy et al., 2000). This may be due to a change in the length-tension relationship and decrease in the moment arm of the supraspinatus with increasing elevation (Kuechle et al., 1997, Reddy et al., 2000). Patients diagnosed with SAIS are known to experience dysfunctional or weak rotator cuff musculature (Leroux et al., 1994, Hawkins and Dunlop, 1995, Reddy et al., 2000). Due to weak rotator cuff musculature, the deltoid will be forced to increase its contribution during GH elevation (Payne et al., 1997). Moreover, an increase in superior translation of the humeral head had been observed in an artificially induced disruption in the force-couple of the deltoid and supraspinatus (Sharkey and Marder, 1995, Deutsch et al., 1996, Paletta et al., 1997, Chen et al., 1999). This change may have resulted in a decreased subacromial space.

In addition, SAIS involves a degree of inflammation of the tendons or bursa of the subacromial space (Fu et al., 1991, Ogata and Uhthoff, 1990, Bigliani and Levine, 1997). This inflammation will cause a decrease in the overall volume of the subacriomal space, potentially leading to the increased compression of the tissues against the borders of the subacromial space (Michener et al., 2003). Degeneration of the tendons of the subacromial space has been demonstrated in patients with SAIS, which may result from the inflammatory process or tension overload during shoulder activities (Banas et al., 1995, Ogata and Uhthoff, 1990, Paletta et al., 1997).

Tumors specifically acromial echondroma was seen in a patient with SAIS (Lopez-Martin et al., 2005). In addition, subacromial osteophytes have reportedly been seen in patients suffering from SAIS which decreases the subacromial space (Williamson et al., 1994). The tumor and the osteophytes eventually caused a decrease in subacromial space leading to the compression of the tendon.

Moreover, in a study comparing active versus passive arm elevation, the authors reported that there was a significant increase in superior translation of the humeral head from $0 - 150°$ (1.58 mm – 0.36 mm) during passive elevation and 1 mm increase in superior translation during active elevation at $60°$ but at between $90 - 120°$ it translated back to the center (Graichen et al., 2000). This result showed that when the muscles (i.e. rotator cuff muscles, anterior deltoid) involved in centralization of the humeral head in the glenoid were not active during shoulder elevation, it caused an increase in superior translation of the humeral head. During active elevation we would suspect that there is going to be minimal if any no superior translation because the muscles responsible for

depressing the humeral head into the glenoid are active. However, the result of this study demonstrated that there was an increase in translation. The authors speculated that the superiorly positioned humeral head at 60° may be caused by the dominance of the deltoid with its cranial force direction, while at 90° and 120° the rotator cuff muscles with their centralizing effect are more active (Graichen et al., 2000, Graichen et al., 1999b). This increase in superior translation of the humeral head can lead to a decrease in subacromial space.

Different muscle activity during shoulder movement can influence the kinematics of the GH joint which can decrease the subacromial space. In a study done by Graichen et al. (2005), the authors compared abducting and adducting muscle activity and its effect on subacromial space width in-vivo. They found out that activation of the abductor muscles of the arm, during arm abduction, produced an increased superior translation of the humeral head (Graichen et al., 2005).

Extrinsic Factors

The primary extrinsic cause of subacromial impingement is believed by most authors to be related to the morphology of the anterior acromion, AC joint and coracoacromial ligament (Rockwood et al., 2004). In a cadaveric study, Bigliani et al. identified three types of acromial morphology, with type I (flat), type II (curved), type III (hook) as viewed in sagittal cross section (Bigliani, 1986). Studies have noted that type III acromion is associated with rotator cuff tearing (Bigliani, 1986, Bigliani and Levine, 1997, Toivonen et al., 1995, Tuite et al., 1995). Acromial geometry has also been linked to changes in subacromial pressure and abnormal contact with the tissues of the

subacromial space. An increase in subacromial pressure was observed in cadavers having hooked acromia compared to flat or curved (Payne et al., 1997). In addition, the tendons of the rotator cuff had greater contact on the acromion throughout the range of motion (Flatow et al., 1994). Another cause of a decrease subacromial space is the thickening of coracoacromial ligament. The lateral band, which is the region most likely to impinge on the rotator cuff, was shorter and had a larger cross-sectional area in specimens with rotator cuff tears (Soslowsky et al., 1994, Ogata and Uhthoff, 1990). However in a more recent study, researchers reported that cuff tear patients have the same coracoacromial ligament fiber architecture compared to normal patients and the changes were more affected by age (Takase and Yamamoto, 2005).

Posterior capsular tightness can alter GH kinematics which can lead to SAIS (Michener et al., 2003). In a study done in cadavers, surgically inducing posterior capsular tightness resulted in increased superior and anterior humeral head translation during passive humeral flexion (Harryman et al., 1990). In a similar study, surgical tightening of the GH joint capsule resulted in an increase in superior and anterior humeral head translation (Werner et al., 2004). An increase in superior and anterior humeral head translation can lead to a decrease in subacromial space which can then lead to mechanical compression of the subacromial structures (Flatow et al., 1994).

Glenohumeral joint kinematics can also be a contributing factor in the pathogenesis of SAIS. Since the apex of the humeral head is the inferior border of the subacromial space, any abnormal superior translation of the humeral head during shoulder motion may lead to decreased subacromial space width and can develop into

SAIS. Additionally, the increase in superior translation of the humeral head during shoulder abduction increases shear and compressive forces on the rotator cuff tendons which can eventually result in fiber disruption (Halder et al., 2001).

Studies that examined superior migration of the humeral head compared normal healthy subjects with rotator cuff patients. They reported an increase in humeral head superior translation during shoulder abduction between $0 - 30°$ and $30 - 60°$ of about $1 - 5$ mm in subjects with rotator cuff tear (Deutsch et al., 1996, Poppen and Walker, 1976, Yamaguchi et al., 2000). In addition, an increased anterior translation of the humeral head (3 mm) has been observed with patients suffering from shoulder impingement which is consistent with possible reductions in available subacromial space (Ludewig and Cook, 2002).

The amount of excessive anterior and superior displacement for rotator cuff and shoulder impingement patients ranges from $1 - 5$ mm. This seems too small to even consider. However, the normal subacromial width in healthy subject's ranges from $6 - 14$ mm so if there is an excessive superior or anterior translation of the humeral head this could be a potential factor for impingement due to a decrease subacromial space and increase mechanical compression to the underlying tissues.

As mentioned above, acromial morphology is one candidate for SAIS. Acromion is part of the scapula so any abnormal kinematics of the scapula could affect the subacromial space. The scapula demonstrates a pattern of upward rotation, external rotation and posterior tilting during GH elevation (van der Helm and Pronk, 1995). Alterations of the scapular movement patterns have been found to be associated with

muscle weakness, fatigue, and paralysis (Karduna et al., 2005). In addition, altered scapular kinematics have been demonstrated in patients with SAIS (Ludewig and Cook, 2000, Warner et al., 1992). The SAIS may be due to a decrease in subacromial space due to altered scapular kinematics.

In a study done by Ebaugh et al. (2005) looking at scapulothoracic motion during active and passive arm elevation, they found that decreased level of muscle activity resulted in altered scapulothoracic kinematics. The greatest effect was noted for upward rotation of the scapula through the mid range of arm elevation (Ebaugh et al., 2005b). In addition, Tsai et al. (2003) and Ebaugh et al. (2005) in their fatigue study showed that muscular fatigue resulted in an increase in scapular posterior tilting and upward rotation of the scapula respectively (Ebaugh et al., 2005a, Tsai et al., 2003). Moreover, Meskers et al (2005) examined scapular kinematics in patients with hemiplegia due to stroke and determined that posterior spinal tilt decreased during external rotation in the frontal plane. Ludewig et al. (2000) performed a study examining scapular kinematics in people with symptoms of shoulder impingement and observed that there was a decrease in scapular upward rotation in subjects with symptoms of shoulder impingement (Ludewig and Cook, 2000).

In the past, increasing scapular upward rotation and posterior tilting was believed to be an important scapular motion to consider in preventing impingement in the subacromial space (Flatow et al., 1994). This makes sense because if we think of it upward rotation elevates the acromion and posterior tilting elevates the anterior portion of the acromion, so increasing these two rotations during humeral elevation would increase

subacromial space. However, in a recent study done on cadavers, the authors established that an increase in upward rotation of the scapula leads to a decrease in subacromial clearance and posterior tilting had no effect on subacromial clearance (Karduna et al., 2005).

Current studies that collected images of the shoulder complex were either taken statically or during dynamic shoulder elevation. Bezer et al (2005), used plain radiographs to measure superior excursion of the humeral head to help them determine the location and size of the cuff tear preoperatively. In more recent studies, Teyhen and colleagues (2008) measured GH migration during dynamic arm elevation using fluoroscopy and investigated the effect of rotator cuff fatigue. Additionally, Bey et al (2008) utilized bi-planar x-ray to measure 3D GH joint kinematics dynamically in patients who had undergone rotator cuff repair.

Specific Aim and Hypotheses

Since patient data are rarely available before the development of cuff tears, it is not known whether abnormal decentralization of the humeral head is causal or compensatory in nature. Therefore, the purpose of this project was to assess the effect of suprascapular nerve block on measured humeral head translation and scapular upward rotation during dynamic elevation trials. In addition, we want to assess muscle activation patterns of GH muscles that are associated in centralizing the humeral head and elevating the arm before and after its paralysis.

This project was divided into three research studies. The first project was to validate a technique on measuring humeral head translation using fluoroscopy. Second,

was to measure in-vivo humeral head translation and scapular upward rotation using fluoroscopy and compare the differences between static and dynamic shoulder elevation. Last, was to use suprascapular nerve block to mimic supraspinatus and infraspinatus dysfunction and compare humeral head and scapular upward rotation prior to and after nerve block.

The current studies hypotheses are as follows:

1. I hypothesize that there will be an increase in measured humeral head translation and scapular upward rotation during dynamic trials on both weighted and non-weighted condition.

2. I hypothesize that a suprascapular nerve block will result in a compensatory increase in superior translation of the humeral head and more scapular upward rotation during dynamic shoulder elevation.

3. I hypothesize that a suprascapular nerve block will result in a compensatory increase in the deltoid muscle group and latissimus dorsi after nerve block.

Bridge

Numerous techniques have been employed to monitor humeral head translation due to its involvement with several shoulder pathologies. However, most of the techniques were not validated. The objective of this study was to compare the accuracy of manual digitization and contour registration in measuring superior translation of the humeral head.

Chapter II describes two techniques in measuring humeral head translation using 2-D images. This study will help establish a technique that will be utilized in measuring

humeral head translation and scapular upward rotation for the succeeding in-vivo
projects.

CHAPTER II

MEASURING HUMERAL HEAD TRANSLATION USING FLUOROSCOPY: A

VALIDATION STUDY

INTRODUCTION

Shoulder impingement syndrome and rotator cuff tears are among the most

common chronic shoulder injuries in the general population (Flatow et al., 1994,

Ludewig and Cook, 2002, Soslowsky et al., 1997, Wong et al., 2003). Superior

translation of the humeral head is believed to be one of the causes of shoulder

impingement syndrome (Deutsch et al., 1996, Sharkey and Marder, 1995, Wong et al.,

2003). An increase from normal superior translation of the humeral head, possibly due

to rotator cuff fiber disruption, can increase shear and compressive forces on the rotator

cuff tendons that can eventually result in rotator cuff rupture (Halder et al., 2001).

The majority of the research investigating translations of the humeral head

during shoulder abduction have utilized x-rays (Yamaguchi et al., 2000, Poppen and

Walker, 1976, Paletta et al., 1997, Deutsch et al., 1996). Numerous techniques have

been utilized to quantify humeral head translation during shoulder elevation, ranging

from manual digitization of key landmarks to computer assisted contour recognition

(Graichen et al., 2000, Hallstrom and Karrholm, 2006, Pfirrmann et al., 2002, Poppen

and Walker, 1976, Bey et al., 2006). With the exception of Bey and colleagues

(2006), to our knowledge, none of these methods have been validated against a gold standard. In the present study, two methods were used to quantify humeral head translation. Both methods were based on digitized landmarks on the humeral head and glenoid. The first method was based on Poppen and Walker (1976) and is termed Manual Digitization (MD) in the current study. The second method was developed by Crisco et.al. (1995), named Contour Registration (CR) for this paper, and quantifies both translation and rotation through image contour registration. The purpose of this study was to compare the accuracy of two different methods in measuring superior translation of the humeral head.

METHODS

Specimens and instrumentation

Eight GH joints were obtained from four cadavers (74 ± 14 years old), two females and two males. The scapula and the humerus were harvested and the majority of soft tissues were removed. The bones were boiled and scraped to remove any excess soft tissue. The bones were stabilized on a shoulder jig that was situated 40 cm away from the image intensifier (Figure 2.1). This device allowed the scapula to be manipulated with three degrees of rotational freedom. The humerus was secured to a translation device in order to displace it superiorly. A calibration object with a known length was positioned on the superior aspect of the subscapular fossa to help in scaling the digital image. The superior humeral head translation was recorded using a GE (OEC) 9800 fluoroscopy unit (Figure 2.1) set at the standard automatic mode (49-51 kVp, 0.49-0.54 mA) .

Protocol

The bone pairs were situated so that the anterior surface of the scapula was perpendicular to the beam of the fluoroscope in order to reduce projection error. Data were collected at four humeral angles: 30, 60, 90, and 120 degrees of elevation in the scapular plane. The scapula was placed in a predetermined neutral position set to mimic the orientation of the scapula *in-vivo* (McClure et al., 2006) while the humerus was positioned at the aforementioned humeral elevation angle (Table 2.1). In addition, at 90° of humeral elevation, the scapula was manipulated into different degrees of rotation, one standard deviation from the neutral position, while maintaining the other degrees of rotation in neutral (McClure et al., 2006). Fluoroscopic images were taken at a neutral position and again after 2 mm (A) and 4 mm (B) of superior translation for each set of humeral and scapular angles, which are within the range reported in the literature (Bezer et al., 2005, Deutsch et al., 1996, Graichen et al., 2005, Poppen and Walker, 1976).
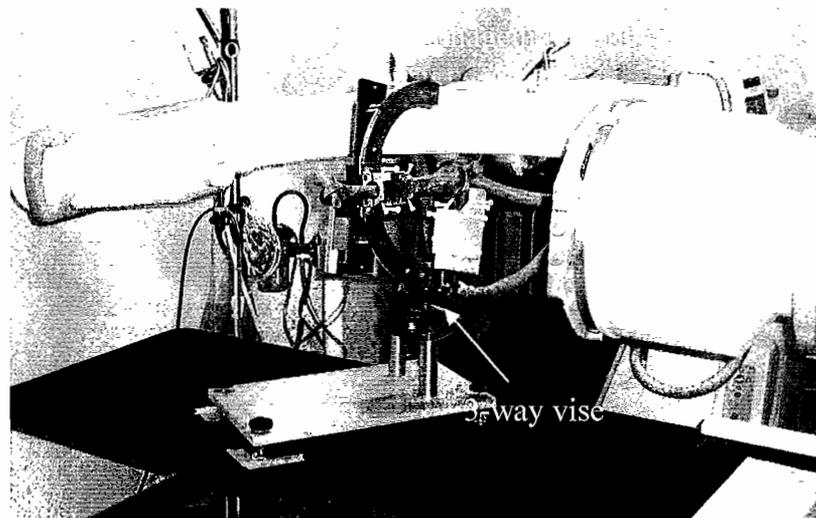
Figure 2.1. Shoulder jig used to secure the scapula and humerus positioned in the middle of the fluoroscopy unit.

Table 2.1. Neutral scapular orientation at different humeral elevation angles in the scapular plane.

Humeral Elevation (°)	Scapular Orientation (°)		
	Posterior Tilt	Upward Rotation	Internal Rotation
30	3	1	25
60	6	5	26
90*	0	2	17
90[‡]	7	15	25
90*	14	28	33
120	10	28	22

[‡]Indicates the mean scapular orientation at 90° of humeral elevation.

*Denotes ± one standard deviation from the mean scapular orientation position at 90° of humeral elevation.

Image analysis

The images were first analyzed by digitizing points on the humeral head and the glenoid using edge detection software, Space (Lewis Center for Neuroimaging, University of Oregon, Eugene, http://lcni.uoregon.edu/%7Emark/Space_program.html). The humeral head coordinates were then used to calculate the geometric center of the humeral head by using a curve fitting, non-linear regression analysis to fit a circle to the humeral head coordinate data and then calculating the center point (Figure 2.2) using a customized LabVIEW (National Instruments Corporation, Austin, TX) program.

Humeral translation was defined as net translation of the humeral head, using both x and y components. Humeral head net translation was calculated using two methods. The first method (MD) involved digitizing points on the superior and inferior aspect of the glenoid and finding the center of a line connecting the two points. The center of the line served as the origin of the glenoid coordinate system (Deutsch et al., 1996, Poppen and Walker, 1976). The net translation was then calculated using the geometric center of the humeral head with respect to the glenoid coordinate system. The second method (CR) entailed digitizing points on the entire glenoid face and employing the image contour registration procedure described by Crisco et al. (1995). Using the geometric center of the humeral head and the transformation matrix that was generated based on the contour registration between images; the net translation of the humerus was calculated. Root mean square (RMS) errors were calculated. Additionally, a two-way mixed model Intraclass Correlation Coefficient (ICC) was used to assess the intrarater reliability of the contour registration method on two separate days.

Further image analysis at 90° of humeral elevation was performed to assess the validity of the image contour registration method in calculating scapular rotational angles (Crisco et al., 1995). Images were rotated by 10° using Photoshop CS2 (Adobe, San Jose, CA). Using contour registration, the angle between the initial position and rotated image was calculated. Additionally, the angle between the upward (UR) and downward (DR) scapular rotation was calculated. The resulting angle was then compared to the known value of the scapular angle between UR and DR that was 26 degrees. The

scapular angle was based on the position of the scapula, one standard deviation from

neutral, when the humerus was at 90° of elevation (McClure et al., 2006).

Figure 2.2. Digital image with points and digitized contours used for both MD and CR
methods.

RESULTS

A trial from one of the specimen, during 90 degrees of humeral elevation and

scapula in external rotation, had to be excluded due to mechanical disruption during

testing. The ICC value for the CR method was 0.81.

For the MD, neutral scapular position had a RMS error of 0.28 mm – 0.34 mm (14% - 17% error). The CR method in neutral scapular position had a RMS error of 0.22 – 0.23 mm, (11% - 12% error). Comparing the two different methods, the RMS error difference for A and B was 0.11mm and 0.06 mm respectively (Table 2.1). MD had the greatest error when the scapula was upwardly rotated (0.41mm) during the first translation and posteriorly tilted (0.43 mm) at the second translation. The CR had the greatest error when the scapula was externally rotated (0.3 mm and 0.4 mm).

Method MD showed lesser error at 60° and 120° of humeral elevation (Figure 2.3). For the scapular angle calculation, only the CR method was used as it can measure rotational angles. The RMS error between scapular UR and DR was 2.4°. The RMS error between known scapular angle and rotated image was 0.7°.
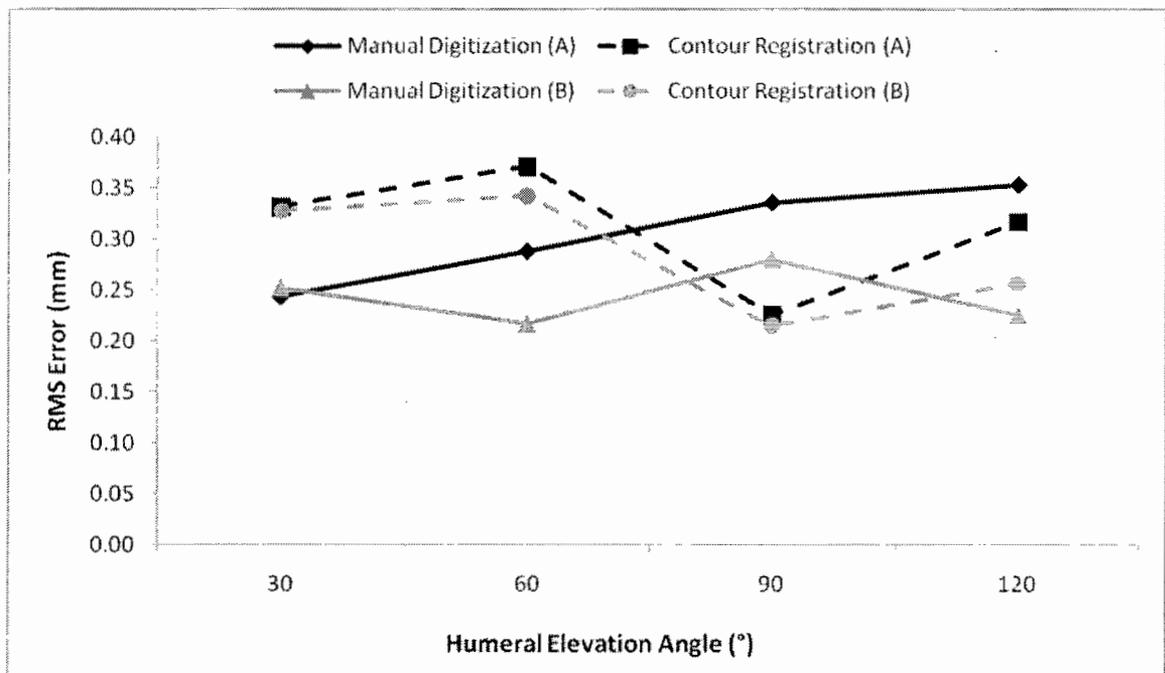
Figure 2.3. Superior translation RMS error between the two methods during neutral scapular position at 30, 60, 90, and 120 degrees of humeral elevation.

DISCUSSION

Both methods showed reasonably low errors in measuring humeral head translation. The image contour registration method of Crisco et. al. (1995) had lower measurement error after 60°of humeral elevation compared to the technique used by Poppen and Walker (1976) in measuring superior humeral head translation in the present study. In a recent study, Bey and colleagues (2006) validated a new 3D model based tracking technique using biplane x-ray measuring GH joint kinematics. Our mean RMS errors of 0.34 mm for MD and 0.23 mm for CR compare favorably to their reported error of approximately ± 0.5 mm (Bey et al., 2006).

One of the advantages of the CR technique compared to MD was that it allowed more points to be digitized on the glenoid that could provide an accurate representation of the surface geometry. In addition, the subjective nature of digitizing two points on the glenoid face used for the MD method was avoided, which could add to the error associated with the measurement. The CR method was also able to take into account any rotational motion of the glenoid during the trials which could be beneficial in an *in-vivo* study.

For the present study, the projection error was controlled by ensuring that the anterior surface of the scapula was directly perpendicular to the beam of the fluoroscope during all the scapular neutral position. One of the major concerns with the use of two dimensional (2-D) medical imaging (i.e. single plane radiograph) is the potential for out of plane motion (Bey et al., 2006, Dennis et al., 2005). The results of the present study showed that when the scapula was not positioned perpendicular to the fluoroscope, the

RMS error increased. The MD method had the highest error when the scapula was placed in a posteriorly tilted position compared to neutral. This higher measurement error may be due to the fact that the distance between the superior and inferior glenoid changed because the superior portion of the glenoid was farther away from the fluoroscope compared to the inferior portion which could influence the origin of the image. There are several limitations that need to be addressed for the current study. First, the study was performed in-vitro with no soft tissues intact and only the bones were utilized. As a result, the digital x-ray images analyzed in the present study might have a better quality compared to images taken in-vivo. Using the CR method in-vivo might create problems when digitizing the glenoid contour due to poor image quality. In addition, gleno-humeral kinematics is a 3-D motion and the current study is using a 2-D imaging technique to monitor humeral motion so out of plane movement is a concern.

BRIDGE

The first study showed that the contour registration method showed lower errors after 60° of humeral elevation compared to manual digitization in measuring humeral head translation. Moreover, the contour registration technique enables me to objectively measure upward rotation of the scapula that could potentially avoid errors associated with subjectively picking points on the glenoid face. The contour registration technique will be utilized to measure humeral head translation and scapular upward rotation for both studies 2 and 3. The purpose of the second study was to examine the effect of shoulder movements (i.e. static & dynamic) on humeral head translations and scapular upward

rotation in healthy individuals. Chapter III describes the differences between static and

dynamic arm elevation in 14 healthy subjects.

CHAPTER III

MEASURING IN-VIVO HUMERAL HEAD TRANSLATION USING

FLUOROSCOPY: A COMPARISON OF STATIC AND DYNAMIC POSITIONING

INTRODUCTION

Altered GH joint kinematics are a contributing factor in the pathogenesis of

subacromial impingement syndrome (Deutsch et al., 1996). An increase in superior and

anterior humeral head translation can lead to a decrease in subacromial space that can

then lead to mechanical compression of the subacromial structures (Flatow et al., 1994).

In addition, scapular upward rotation during humeral elevation is essential to prevent

impingement of structures under the acromion (Flatow et al., 1994). The supraspinatus

tendon, subacromial bursa, long head of the biceps brachii tendon, and the capsule of the

shoulder joint are the tissues that are found in the subacromial space (Michener et al.,

2003).

Stability of the GH joint is produced by both static (passive) and dynamic

(active) mechanisms. Static stability is obtained through GH ligaments, joint capsule,

glenoid concavity and labrum (Rockwood et al., 2004). Alternatively, dynamic

stabilization of the GH joint is accomplished by the forces created through the

coordinated contraction of the rotator cuff muscles. This results in a better congruency

between the articular surface of the humeral head and the concave surface of the glenoid fossa (Armfield et al., 2003). During shoulder motion the dynamic stabilizers are the dominant mechanisms that provide stability for the GH joint (Armfield et al., 2003).

There are numerous techniques used to monitor humeral head translation. The most common techniques utilized include roentgenogram (X-ray), and magnetic resonance imaging (MRI) (Yamaguchi et al., 2000, Poppen and Walker, 1976, Paletta et al., 1997, Deutsch et al., 1996, Graichen et al., 2005, Graichen et al., 2000, Werner et al., 2006). Fluoroscopy, which is an imaging technique based on x-ray technology, is also commonly utilized to allow real time digital collection of images. Bezer et al (2005), used plain radiographs to measure superior excursion of the humeral head to help them determine the location and size of the cuff tear preoperatively. In more recent studies, Teyhen and colleagues (2008) measured GH migration during dynamic arm elevation using fluoroscopy and investigated the effect of rotator cuff fatigue. Additionally, Bey et al (2008) utilized bi-planar x-ray to measure 3D GH joint kinematics dynamically in patients who had undergone rotator cuff repair.

An increase in scapular upward rotation may serve to assist with humeral elevation (McCully et al., 2006). A more upwardly rotated scapula had been observed in patients suffering from rotator cuff tears (Mell et al., 2005, Paletta et al., 1997, Yamaguchi et al., 2000). In addition, a weak or dysfunctional rotator cuff musculature demonstrated more upward rotation during humeral elevation in the scapular plane during mid-ranges of motion (Ebaugh et al., 2006, McCully et al., 2006).

Current studies that collected images of the shoulder complex were either taken statically or during dynamic shoulder elevation. Numerous authors have speculated that dynamic shoulder motion occurs frequently in everyday activity, although, we are not aware of any published studies comparing the translation of the humeral head and upward rotation of the scapular between static and dynamic trials. The purpose of the present study was to examine the effect of shoulder movements (i.e. static & dynamic) on humeral head translations and scapular upward rotation in healthy individuals. In addition, we want to examine the effects of increased muscle activation by adding wrist weights during arm elevation. We hypothesize that there will be an increase in measured humeral head translation and scapular upward rotation during dynamic trials.

METHODS

Subjects

Fourteen healthy subjects, six males and eight females (age 25 ± 6, weight 67.9 ± 12.9 kg, height 170.5 ± 8.1 cm) participated in the study. Subject exclusion criteria for the study was as follows: 1) less than $135°$ of active humeral elevation in the scapular plane; 2) prior shoulder surgery; 3) shoulder injury in the past six months; 4) presence of shoulder pain preventing the correct execution of tests; 5) history of cervical or shoulder pain or pathology; and 6) women who were currently pregnant. The study was approved by the University of Oregon, Office for Protection of Human Subjects. Each subject signed a consent form.

Protocol

All testing was completed in a single session and performed on the dominant upper extremity. Subjects performed a standardized warm-up procedure including Codman's pendulums and stretches for the shoulder muscles. Codman's pendulum exercises were performed with subjects bent over with the non-dominant hand on a table. Subjects performed one set of 15 repetitions of arm circles, both clockwise and counterclockwise, followed by one set of 15 repetitions of a back and forth movement in the sagittal plane. Stretches consisted of holding a static external and then internal rotation position, both with the shoulder abducted to approximately 90°, for two sets of 15 seconds each. Following the warm-up procedure, subjects were fitted with a lead apron to protect them from further radiation. The testing protocol was thoroughly explained to the subject. Prior to data collection, practice trials were performed by the subjects. A calibration marker with a known length was positioned by the scapular spine in order to scale the digital images.

Subjects performed two different conditions of shoulder elevation in the scapular plane. The first condition involves dynamic movement during shoulder elevation and the second condition involves holding arm in different angles of shoulder elevation (0°, 30°, 60°, 90°, and 120°). For each of condition, subjects performed two trials. Each trial was separated by a 15 second rest and there was a 5 minute rest between conditions. All trials started with the arm at the side which is defined as 0° of humeral elevation. Additionally, the trials for each condition were randomized between subjects to account for fatigue effect due to the wrist weight.

During dynamic condition, two trials were performed. One trial consisted of the subjects elevating their dominant arm in the scapular plane up to 120° of shoulder elevation without any wrist weight on their dominant arm for three repetitions. On the second, the subject had a wrist weight equal to an external shoulder torque of 50% of the baseline torque while elevating their dominant arm. The amount of resistance used in each condition was calculated separately for each subject, and was based on his/her body mass and the lengths of the humerus, forearm, and hand segments, as calculated from bony landmarks. Each subject's body mass and upper extremity segment lengths were used to calculate the torque about the unloaded shoulder at 90° of elevation using anthropometric data and this was taken as the baseline shoulder torque (Dempster, 1955). Subjects elevated their arm within 4 seconds and lowered their arm also in 4 seconds time with the guidance of the investigator.

For the second condition (static), the investigator positioned the subject's dominant arm in different elevation angles using a digital inclinometer. The subject was instructed to hold the arm in different shoulder elevation angles (arm at the side,, 30°, 60°, 90°, and 120°) with and without any wrist weight. In each of the trials, fluoroscopic images were taken.
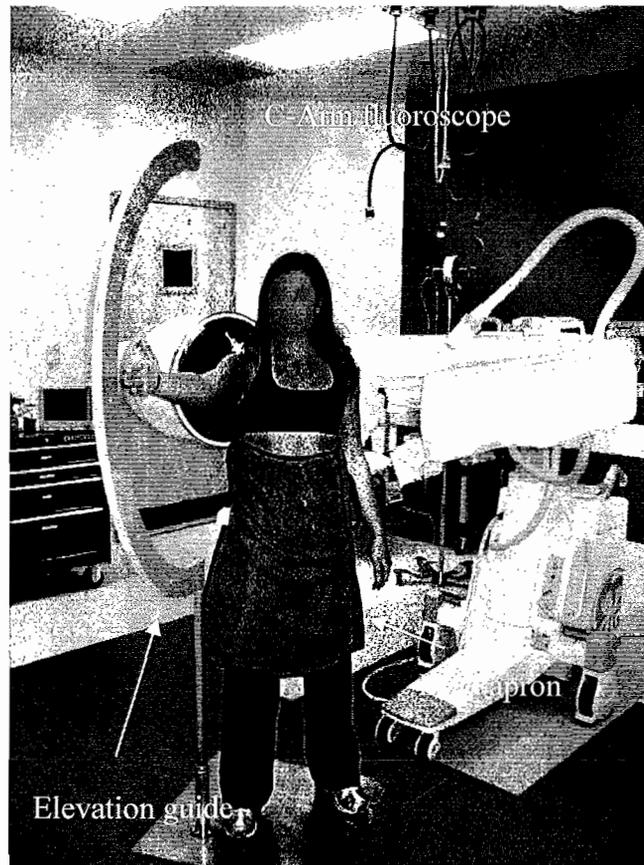
Figure 3.1. Subject set-up with the customized elevation guide.

During practice trials using live fluoroscopy, the investigator positioned the

subject so that the anterior side of the scapula was perpendicular to the field of view of

the fluoroscope in order to minimize projection errors. Using a customized shoulder

elevation guide, each subject was asked to elevate their arm as close as possible to this

semi-circular guide (Figure 3.1). The foot position was marked on the platform to

maintain consistency within conditions. During the dynamic trials, continuous imaging

was utilized to capture shoulder elevation. In the static trials, images were taken during

the predetermined shoulder elevation angles.

Kinematic measurement

Data were collected using a GE (OEC) 9800 Fluoroscopy unit. Sampling rate was set at 8 Hz. The fluoroscopy was set at a normal standard mode (62-73 kvp and 0.62-2.0 mA) and the average subject radiation exposure was 380.2 mR. Humeral head translation was measured using a 2-D registration technique developed by Crisco et al (1995). In addition, points were digitized on the glenoid face, the humeral head, and the humeral shaft using Space edge detection software (Lewis Center for Neuroimaging, University of Oregon, Eugene, http://lcni.uoregon.edu/%7Emark/Space_program.html, Figure 3.2). In order to compare the static and dynamic trials, humeral elevation angles for both conditions were closely matched by calculating the humeral angle of each static position with respect to gravity (Table 3.1). The measured superior humeral head translation and scapular upward rotation was calculated by comparing the static and dynamic trials in each humeral elevation angle with respect to the corresponding elevation angle during the static trial for both the weighted and non-weighted condition (i.e. 30° humeral elevation static to 30° humeral elevation dynamic). This method of measuring humeral head translation was previously validated by the investigator with a measured error of less than 0.5 mm (San Juan, 2009).

Calibration marker
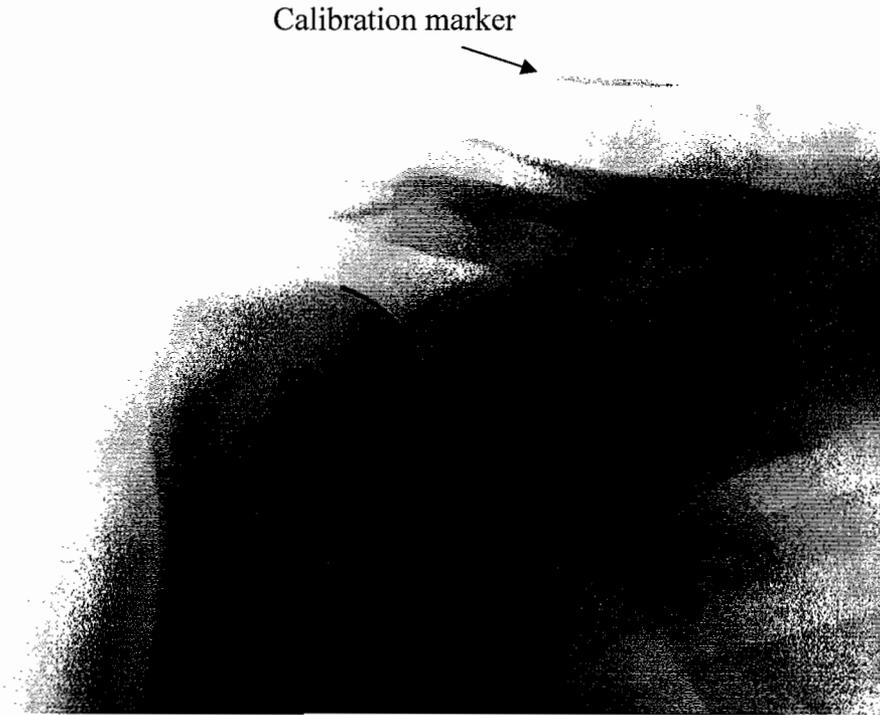
Figure 3.2. Actual digital x-ray image with a representation of digitized points using the Space edge detection software. The center circle on the humeral head represents the calculated geometric center based on the digitized arc on the humeral head.

Table 3.1. Calculated humeral elevation angle of static and dynamic trials during the non-weighted condition.

| Condition	Humeral Elevation (°)				
	Arms at Side	30	60	90	120
Static	7.6 ± 4.7	31.8 ± 6.6	60.0 ± 7.3	91.4 ± 7.0	121.8 ± 8.3
Dynamic	9.1 ± 6.4	30.5 ± 5.3	60.2 ± 3.7	90.0 ± 1.9	117.6 ± 3.7

Data analysis

In order to compare between conditions, the dynamic trial at each humeral elevation angle was compared to the matching static trial at that elevation angle. A one-sample *t*-test compared to zero was performed in order to test statistical significance between static and dynamic conditions. The two conditions were static and dynamic for both humeral elevation and scapular upward rotation trials. Moreover, each condition was further subdivided into weighted and non-weighted trials. The overall alpha level for all tests was adjusted using Bonferroni correction and was set at 0.01.

RESULTS

For the non-weighted condition, the mean humeral elevation angle for the arm at the side was $7.6 \pm 4.7°$. There was no statistically significant difference observed for the measured humeral head translation between static and dynamic trials during the non-weighted conditions for all humeral elevation angles (Figure 3.3). However, scapular upward rotation was significantly larger for the dynamic condition at 120° of humeral elevation (Figure 3.4).

For the weighted trials, only 10 subjects were included in the analysis due to poor quality of the digital x-ray images. At 0° of humeral elevation, there was no significant increase in superior translation for the dynamic condition, when compared to the static condition (Figure 3.5). Figure 3.6 illustrates that there was as statistically significant difference at 120° of humeral elevation. The scapula had less upward rotation during the dynamic trial. The humeral elevation angle for the weighted condition during the arm at the side was $8.5 \pm 5.8°$.
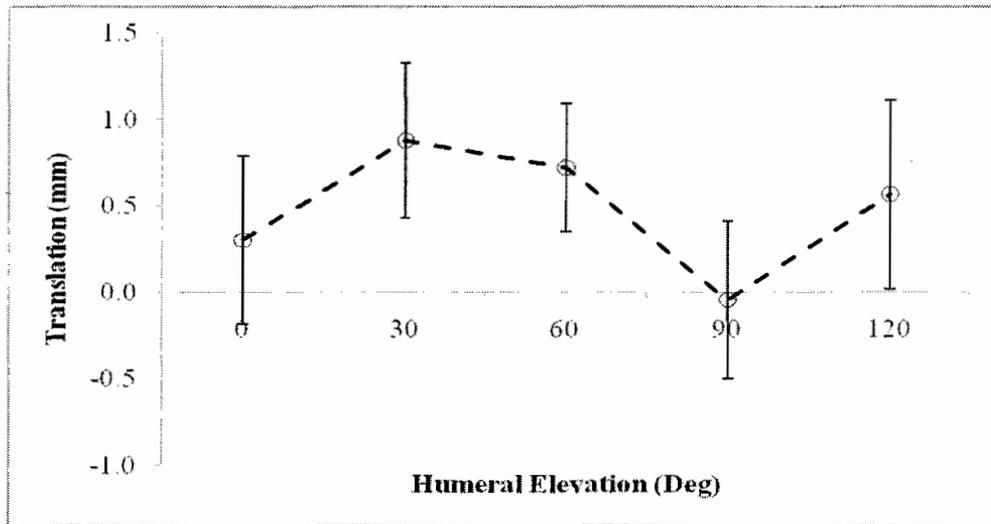
Fig. 3.3. The difference between static and dynamic conditions in measured humeral head translation during the non-weighted trial. A positive number represents the humeral head is located superiorly compared to static condition.
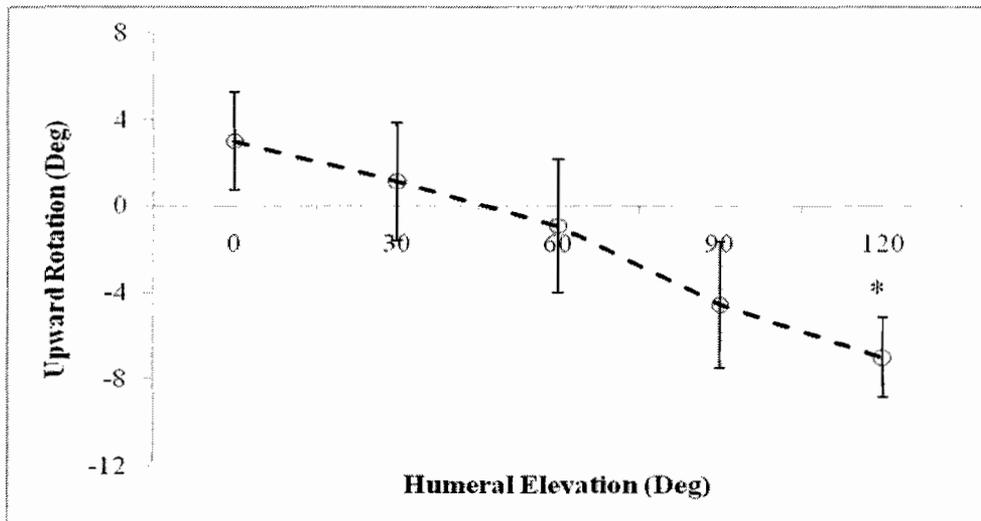
*p < 0.01

Fig. 3.4. The difference between static and dynamic conditions in scapular upward rotation during the non-weighted trial. Positive numbers depicts more upward rotation during the dynamic condition compared to the static.
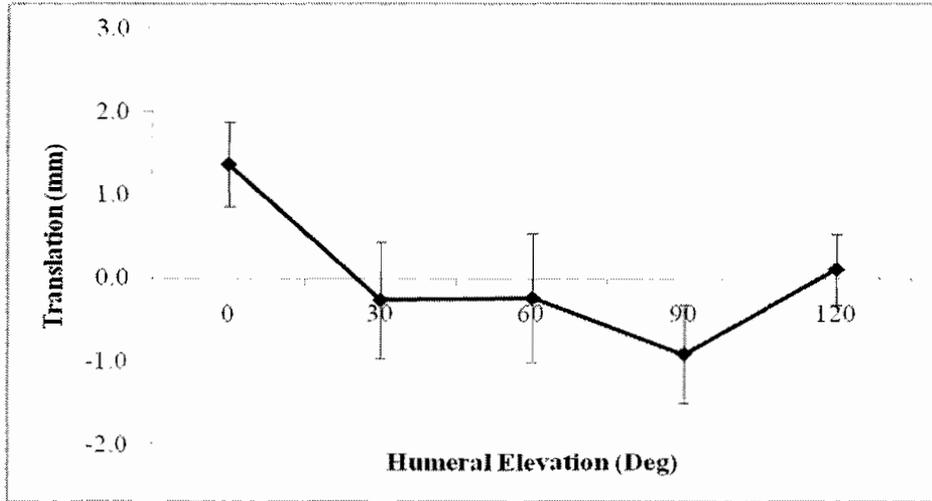
Fig 3.5. The difference between static and dynamic conditions in measured humeral head translation during the weighted trial. A positive number represents the humeral head is located superiorly compared to static condition. Measured humeral head translation during the weighted trial.
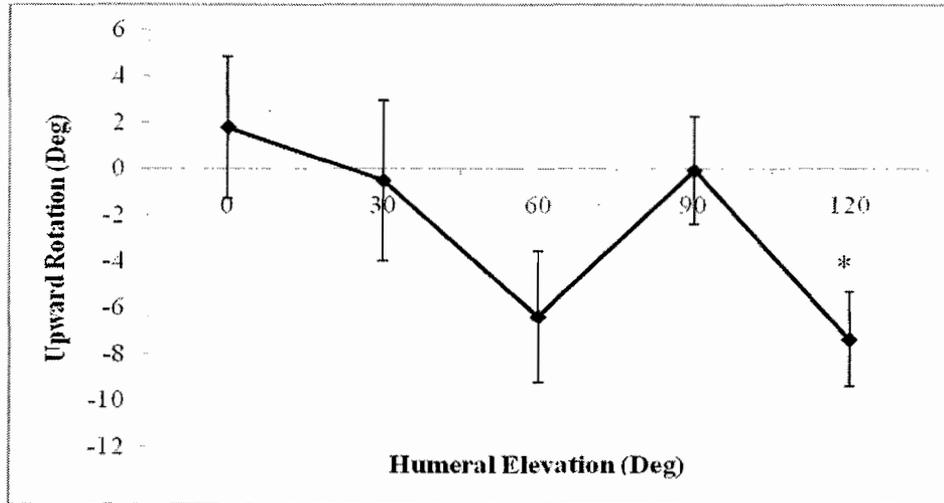
*p < 0.01

Fig. 3.6. The difference between static and dynamic conditions scapular upward rotation during the weighted trial. Positive numbers depicts more upward rotation during the dynamic condition compared to the static.Scapular upward rotation during the non-weighted trial.

DISCUSSION

The evaluation of GH joint kinematics is important to better understand the true mechanism of shoulder pathologies (i.e. subacromial impingement syndrome). The aim of the present study was to examine the effect of shoulder movement in measured humeral head translation and scapular upward rotation. In addition, wrist weight was added to increase muscle activation during arm elevation. We failed to support the hypothesis that dynamic shoulder elevation would result in increased superior humeral head translation at mid range of motion, specifically at $30° - 60°$ of humeral elevation, for both weighted and non-weighted condition. The result of the current study showed that there was no statistical significant difference in humeral head translation during the weighted and non-weighted condition.

When measuring humeral head translation, past studies have used the neutral humeral head position during the control condition as the reference point when compared to pathological or experimental condition (Werner et al., 2006, Deutsch et al., 1996). For the current study, the author chose to compare the differences between static and dynamic trials in each corresponding humeral elevation angle with respect to the static trials (i.e. $30°$ humeral elevation dynamic to $30°$ humeral elevation static). The investigator was more interested in the differences between trials than within conditions.

During the non-weighted trial, the humeral head was superiorly located at mid range of motion in the dynamic elevation trial with respect to the static trial. On the other hand, in the weighted condition, the humeral head was inferiorly located with respect to the static trial after the initial position or arm at the side. The difference seen between the

location patterns of the humeral head between weighted and non-weighted conditions might be attributed to the increased activation of muscles responsible for depressing the humeral head into the glenoid cavity. In order to compensate for the increased load brought about by the added external weight, the rotator cuff muscles increase their muscle activation. It is well documented that the rotator cuff musculature is responsible for maintaining the humeral head centered into the glenoid cavity during the entire shoulder elevation motion. It has also been shown that teres minor, latissimus dorsi and long head of the biceps might play a role in assisting the rotator cuff in depressing the humeral head into the glenoid fossa (Halder et al., 2001, Steenbrink et al., 2009, Warner and McMahon, 1995).

For the present study, only scapular upward rotation was measured due to the 2-D nature of the fluoroscopy unit. Taking images in a true anterior-posterior view of the shoulder enabled measurement of upward rotation. This study illustrated that at a 120° of humeral elevation, the dynamic trials were statistically significant from the static trials on both weighted and non-weighted condition. The position of the scapula was less upwardly rotated. Both conditions showed a trend of less upward rotation after 30° of humeral elevation.

The present study acknowledges the fact that GH kinematics is a 3-D motion. Care was taken in order to minimize any projection error brought about by out of plane motion. Additionally, smaller sample size, especially in the weighted condition could have resulted in the lack of difference between trials. Future studies would look at

differences in humeral head translation and scapular upward rotation before and after paralysis of supraspinatus and infraspinatus muscle.

CONCLUSIONS

In conclusion, the results of the present study showed that there was no difference between static and dynamic motions in measured humeral head translation at mid-ranges of motion. It can be argued that studying static positional behavior is just as valid as studying dynamic motion. However, dynamic motions are more representative of shoulder movement performed during normal activity especially unconstrained motion. We recommend adding more subjects to test the hypothesis that dynamic trials compared to static trials will result in increased superior humeral head translation and more scapular upward rotation. Future studies will utilized dynamic motion and examine the humeral head translation after paralysis of rotator cuff musculature.

BRIDGE

The result of the second study showed that there was no difference in measured humeral head translation and scapular upward rotation between static and dynamic trials during shoulder elevation. However, dynamic motions are more representative of shoulder motion in everyday living. As a result, dynamic motions will be utilized in the third study. The purpose of the third study was to examine the effects of suprascapular nerve block on measured humeral head translation, scapular upward rotation, and muscle activation patterns of GH muscles and latissimus dorsi. Chapter IV describes the changes in GH and scapular kinematics after paralysis of supraspinatus and infraspinatus in 20 healthy subjects.

CHAPTER IV

HUMERAL HEAD TRANSLATION AFTER A SUPRASCAPULAR NERVE BLOCK

INTRODUCTION

Shoulder impingement and rotator cuff tears are among the most common chronic shoulder injuries in the general population and in athletes involved in overhead throwing sports (Soslowsky et al., 1997, Wong et al., 2003, Williams and Kelley, 2000, Ludewig and Cook, 2002, Hulstyn and Fadale, 1997, Flatow et al., 1994, Almekinders, 2001). Although there are clearly underlying biological factors involved, many clinicians feel that abnormal mechanical forces may lead to a progression from impingement syndrome, or tendonitis, to rotator cuff tears. Since patient data are rarely available before the development of cuff tears, it is not known whether increased superior translation of the humeral head is causal or compensatory in nature.

A weak or dysfunctional rotator cuff musculature may result in changes to both GH and scapular kinematics (Michener et al., 2003). These changes include increased superior humeral head translation (Chen et al., 1999, Steenbrink et al., 2009, Terrier et al., 2007, Teyhen et al., 2008) and greater scapular upward rotation (Ebaugh et al., 2006, Tsai et al., 2003, Ludewig and Cook, 2000). Over time, if these alterations are left untreated they may lead to more debilitating shoulder pathology, such as rotator cuff tears.

Scapular upward rotation is the predominant motion of the scapula (Michener et al., 2003). It allows the acromion to elevate during GH elevation and appears to facilitate prevention of impingement under the acromion (Flatow et al., 1994) Studies have shown that altered scapular upward rotation has been associated with individuals suffering from shoulder impingement (Ludewig and Cook, 2000, McClure et al., 2006). In addition, differences in upward rotation have been observed with *in-vivo* models that attempted to mimic shoulder muscle dysfunction (Ebaugh et al., 2005a, McCully et al., 2006).

Changes in humeral head translation have been observed in patients with rotator cuff tears and shoulder impingement (Bezer et al., 2005, Deutsch et al., 1996, Paletta et al., 1997, Poppen and Walker, 1976, Yamaguchi et al., 2000). When compared to asymptomatic controls, patients with rotator cuff tears demonstrated greater humeral head translation during shoulder elevation, especially during the mid-ranges of motion (Deutsch et al., 1996, Yamaguchi et al., 2000). The geometric center of the humeral head was more superiorly located with respect to the center of the glenoid fossa.

Suprascapular nerve blocks are commonly performed clinically for pain relief of the shoulder due to conditions such as adhesive capsulitis and nerve entrapment (Tan et al., 2002, Shanahan et al., 2003, Karatas and Meray, 2002). However, several investigators have taken advantage of its innervation to perform nerve block studies for biomechanical evaluations of strength (Kuhlman et al., 1992, Howell et al., 1986, Colachis and Strohm, 1971) and kinematics (Howell and Kraft, 1991). Additionally, cases of suprascapular neuropathy had been reported in volleyball players resulting in weakness of the supraspinatus and infraspinatus muscle (Sandow and Ilic, 1998, Dramis

and Pimpalnerkar, 2005). Due to the compressive functions of both the supraspinatus and infraspinatus muscles, interventions that result in dysfunction of these muscles are candidate models for rotator cuff pathology. Since the suprascapular nerve innervates both the supraspinatus and infraspinatus, a suprascapular nerve block was utilized to achieve dysfunction of these muscles.

There were two goals of the current study. The first was to examine the effects of a suprascapular nerve block on superior translation of the humeral head and scapular upward rotation during dynamic shoulder abduction and the second was to assess muscle activation patterns of GH muscles and latissimus dorsi during these motions. I hypothesize that a suprascapular nerve block will result in a compensatory increase in superior translation of the humeral head and greater scapular upward rotation. Additionally, I hypothesize a compensatory increase of the deltoid musculature and latissimus dorsi muscle activation after the block.

MATERIALS AND METHODS

Twenty healthy subjects volunteered for the study, 10 males and 10 females (age 25 ± 5 y/o, height 171.4 ± 6.7 cm, weight 66.9 ± 10.1). A sample size calculation based on data from Sharkey and Marder (1995), revealed that 17 subjects can detect a minimum power of 0.8. Subject exclusion criteria for the study were as follows: 1) less than 135 degrees of active humeral elevation in the scapular plane; 2) prior shoulder surgery; 3) shoulder injury in the past six months; 4) presence of shoulder pain preventing the correct execution of tests; 5) any allergies to lidocaine; 6) history of cervical or shoulder pain or pathology; 7) women who were currently pregnant; and 8) BMI more than 30 kg/m^2

(threshold for obesity as defined by the CDC). Approval for the study was obtained from the University of Oregon, Office for Protection of Human Subjects. Each subject signed a consent form.

All testing was completed in a single session and performed on the dominant upper extremity. Subjects performed a standardized warm-up procedure including Codman's pendulums and stretches for the shoulder muscles. Codman's pendulum exercises were performed with subjects bent over with the non-dominant hand on a table. Subjects performed one set of 15 repetitions of arm circles, both clockwise and counterclockwise, followed by one set of 15 repetitions of a back and forth movement in the sagittal plane. Stretches consisted of holding a static external and then internal rotation position, both with the shoulder abducted to approximately 90°, for two sets of 15 seconds each. Following the warm-up procedure, subjects were fitted with a lead apron to protect them from radiation. The testing protocol was thoroughly explained to each subject. Prior to data collection, practice trials were performed by the subjects. A calibration marker with a known length was positioned by the scapular spine in order to scale the digital images (Figure 4.1).

Subjects were asked to stand while performing normal shoulder elevation in the scapular plane prior to and following a suprascapular nerve block. Scapular plane orientation was defined as approximately 30-35 degrees anterior to the coronal plane. Prior to each collection, the investigator positioned the arm in the correct scapular plane, with the help of real time fluoroscopic image and returned the arm to the subject's side. Shoulder elevation trials were collected using fluoroscopy with subjects standing at a

marked position, eyes facing forward, elbow in full extension, and slight forearm

pronation. Using a customized shoulder elevation guide, each subject was asked to

elevate their arm as close as possible to this semi-circular guide (Figure 4.2). The foot

position was marked on the platform to maintain consistency within trials.
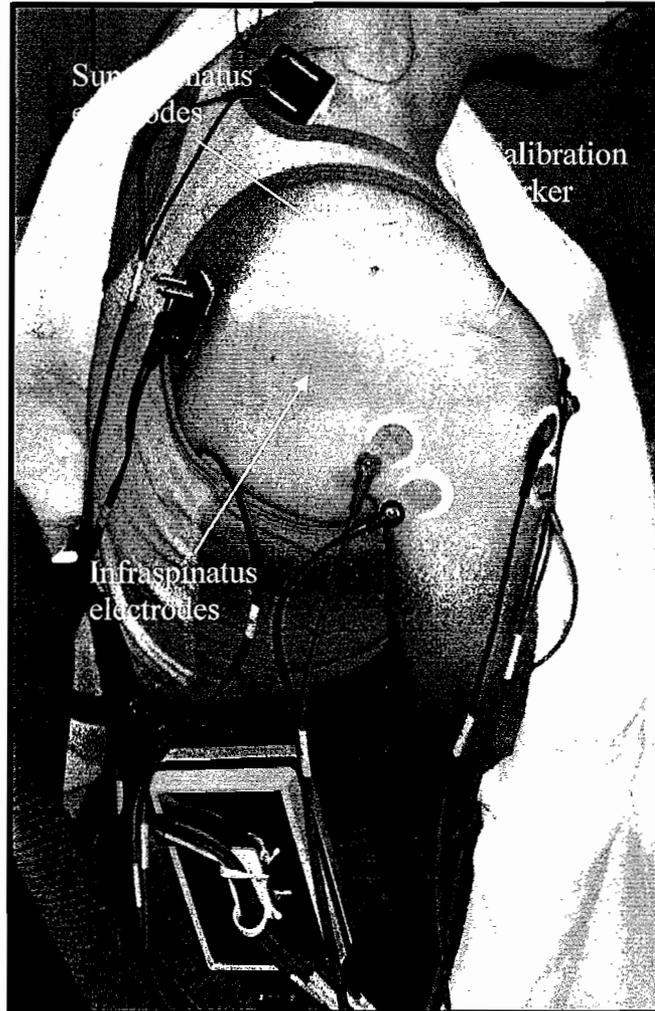
Figure 4.1. Surface and Fine-wire EMG set-up.

The range of motion was subject dependant, but all trials began with the arm at

the subject's side. Two shoulder elevation trials were collected prior to a suprascapular

nerve block, and the best digital image quality between the two trials was used for

analysis. After the nerve block, two shoulder elevation trials were collected. To control the velocity of motion, audible counts of four seconds (eight seconds total) were used during both shoulder elevation and depression in the scapular plane. Each trial consisted of two shoulder elevations and one shoulder depression in the scapular plane. Immediately following each shoulder motion trial, force measurements were collected. Each trial had a total time of 7 minutes; from the start of a trial to the succeeding trial. The actual elevation trial plus force measurement lasted for about 3 minutes.

A GE (OEC) 9800 fluoroscopy unit was utilized for collecting two-dimensional *in-vivo* kinematics of the GH joint. The sampling rate was set at 8 Hz, which is the highest rate of for this system. The fluoroscopy was set at a normal standard mode (59-72 kvp and 0.52-1.5 mA) and the average subject radiation exposure was 659 mR. A standardized protocol was utilized when taking fluoroscopic images in order to regulate each data collection across subject and condition. The protocol was able to control focal point, magnification, and abduction velocity of the arm. During data collection, the subjects were asked to stand in between the c-arm. Through the help of real time fluoroscopy, the investigator adjusted the subject's position so that the scapula was perpendicularly aligned to the field of view of the fluoroscope to avoid distortion of the glenoid cavity. In addition, the distance between the shoulder and the fluoroscopy machine remained constant for a given subject to minimize magnification errors.
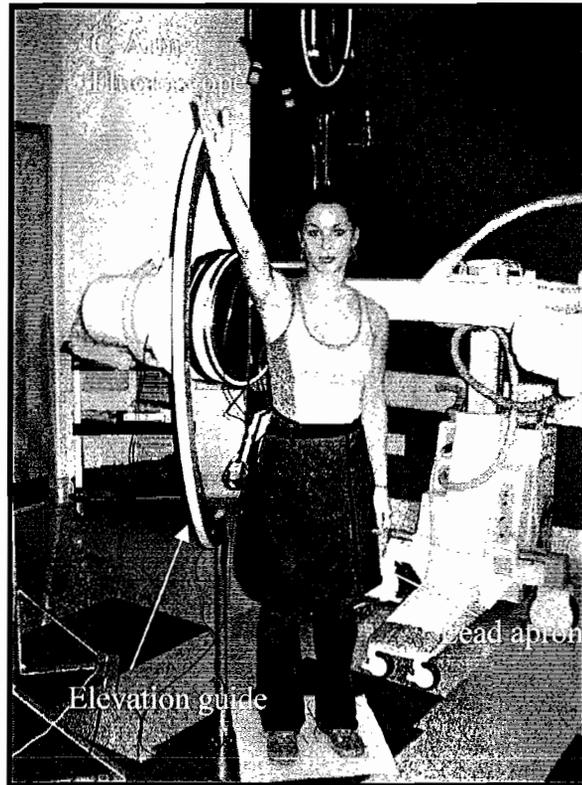
Figure 4.2. Subjects set- up during the elevation trial

Humeral head translation was measured using a 2-D registration technique

developed by Crisco et al.(1995) In addition, figure 4.3 depicts the points that were

digitized on the glenoid face, the humeral head, and the humeral shaft using Space

edge detection software (Lewis Center for Neuroimaging, University of Oregon,

Eugene, http://lcni.uoregon.edu/%7Emark/Space_program.html). The measured

humeral head translation and scapular upward rotation were calculated by comparing

the pre and post nerve block trial in each humeral elevation angle with respect to the

corresponding elevation angle during the pre-nerve block trial (i.e. 30° humeral

elevation pre-nerve block to 30° humeral elevation post-nerve block). This method of

measuring humeral head translation was previously validated by the investigator with

a measured error of less than 0.5 mm (San Juan, 2009).
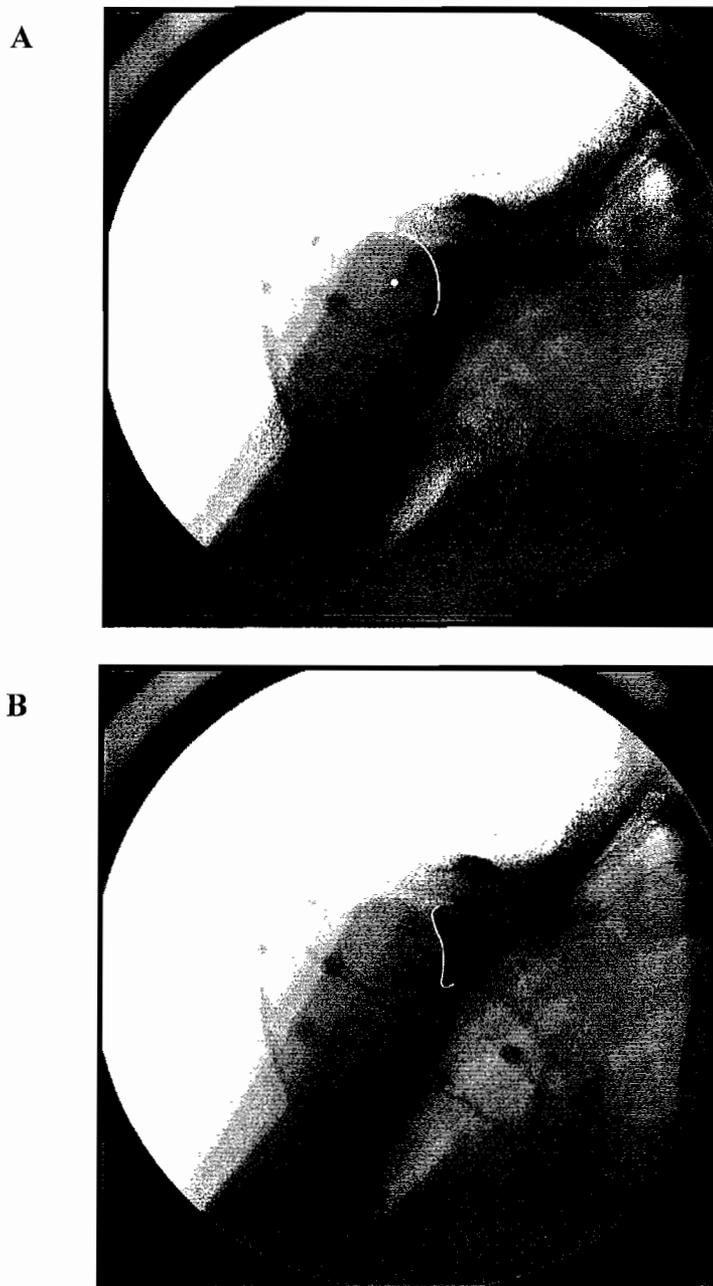
Figure 4.3. Actual x-ray images with digitization of an arc at the humeral head and an illustration of the geometric center of the humeral head **(A)** and digitized glenoid used for contour registration **(B).**

Electromyography (EMG) data were collected to verify minimal muscle activation post suprascapular nerve block. In addition, muscle activation patterns pre and post nerve block were analyzed. Kinematic measurements were synchronized with the EMG activity using an external trigger. The Myopac Jr. (Run Technologies, Mission Viejo, CA) was used to collect raw surface and fine-wire EMG data. This unit provided signal amplification, band pass filtering (10-1000Hz), and a common mode rejection ratio of 110 dB. Output from the Myopac was linked to an analog to digital board in a laptop computer and data were collected at a frequency of 1200 Hz. Disposable Blue Sensor surface electrodes (Ambu Inc, Linthicum, MD) were placed over the anterior deltoid, middle deltoid, posterior deltoid and latissimus dorsi muscles along their primary muscle fiber directions. Sterilized fine-wire electrodes (Chalgren Enterprise, Inc, Gilroy, CA) were inserted intramuscularly in the supraspinatus and infraspinatus muscles. Electrode placement was as follows – supraspinatus: into supraspinous fossa just above middle of spine of scapula; infraspinatus: into infraspinous fossa two fingerbreadths below medial portion of spine of scapula; anterior deltoid: mid-way along a line from the lateral third of the clavicle to the deltoid tuberosity; middle deltoid: lateral aspect of the arm approximately 3 cm below the acromion; posterior deltoid: approximately 2 cm below the lateral border of the spine of the scapula and angled on an oblique angle toward the arm; latissimus dorsi: approximately 4 cm below the inferior tip of the scapula, half the distance between the spine and the lateral edge of the torso (Figure 3) (Cram et al., 1998, Perotto and Delagi, 2005).

To allow for normalization of EMG measures, EMG data were collected during a standard Maximum Voluntary Contraction (MVC) for each muscle. These data acted as a normalizing reference and were used to determine percent amplitude values for each muscle during arm elevation. For the supraspinatus, manual resistance was applied just proximal to the wrist joint as the subject attempts to initiate abduction of the humerus. For the infraspinatus, manual resistance was applied just proximal to the wrist joint as the subject attempts to externally rotate their shoulder. For the anterior deltoid muscle, manual resistance was applied proximal to the elbow as the subject attempts to elevate their arm. For the middle deltoid muscle, elbow should be flexed and manual resistance was applied proximal to the elbow as the subject attempts to abduct their arm. For the posterior deltoid muscles, shoulder was positioned in 80 degrees of abduction in slight extension with the humerus in slight medial rotation and manual resistance was applied against the posterolateral surface of the arm proximal to the elbow as the subject attempts to adduct and flex their shoulder. For the latissimus dorsi muscles, adduction of the arm, with extension, in the medially rotated position, and manual resistance was applied against the forearm proximal to the wrist joint in the direction of abduction and slight flexion of the arm (Kendall et al., 1993).

External rotation forces were measured with a Microfet 2 Manual Muscle Test (MMT) device (Hoggan Health, Ind, West Jordan, UT). The Microfet 2 MMT is a hand-held device used to objectively measure muscle strength. Subjects were seated in a chair during force measurement. Since force measurement was performed before and after the

nerve block, markers were placed on the area where the MMT was applied during data collection. This ensured consistency of the resistant moment arm. During force measurement, subjects were instructed to push as hard as they can against the MMT for 5 seconds while verbal encouragement was provided by the investigator. Using a custom windows application, the 4th second was averaged and used for analysis. The MMT was positioned and held by the investigator on the designated part of the forearm. The testing position was elbow flexed at 90°, thumb pointing up and shoulder external rotation with arm at the side. This position of the arm was chosen for both tests because it has been reported to best isolate the infraspinatus muscle (Kuechle et al., 2000, Kelly et al., 1996).

The suprascapular nerve block was performed by a board certified anesthesiologist (PK). He performs this block regularly in his clinical practice for adhesive capsulitis of the shoulder and to diagnose and treat impingement syndrome of the nerve in the canal. Subjects were asked to sit, with their head flexed forward, throughout the nerve blocking procedure. The area around the shoulder was sterilized with Betadine and the scapular spine was palpated bilaterally for comparison and accuracy. One inch above the junction of the middle and outer third of the scapular spine, the suprascapular nerve was targeted at the scapular notch through a skin wheel of 0.2 ml of 1% lidocaine. After aspiration does not result in blood, lidocaine 1.5% 1 ml with epinephrine was injected. A total of 100 mg of lidocaine was injected to the subject's nerve (Figure 4.4). A time stamp was recorded, and a countdown timer was initiated, the moment the needle was withdrawn. Five minutes following the initial injection an external rotation manual muscle test, 15 degrees of bilateral humeral

abduction, was performed to check for muscle weakness. External rotation force, supraspinatus and infraspinatus EMG activity reduction of 50% was the threshold needed in order to proceed to the post block trials (Figure 4.5). Ten minutes following initial injection, subjects were asked to stand, and the post block trials were collected. The first post nerve block trial (Post-NB1) was administered approximately ten minutes after the nerve block, while the second trial (Post-NB2) was performed approximately 60 minutes after the block.
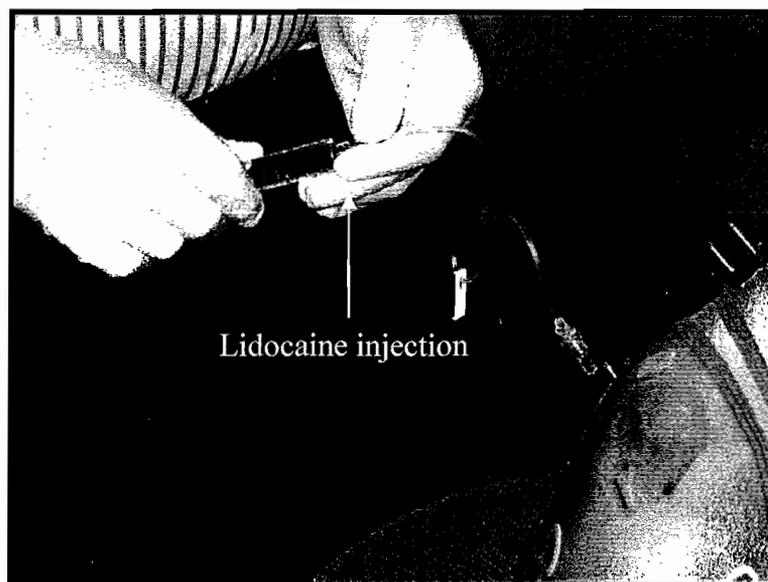
Figure 4.4. Subject set-up during the suprascapular nerve block procedure

Statistical analysis

A one sample *t*-test compared to zero was performed in order to test statistical significance between conditions. The two conditions were pre-nerve block (Pre-NB) and post-nerve block (Post-NB). Measured humeral head translation and scapular

upward rotation served as the dependent variables. The overall alpha level for all tests was adjusted with a Bonferroni correction and was set at 0.01. For the EMG activity, a one-way repeated measure analysis of variance was used to compare differences between humeral elevation angles prior to and after the nerve block and alpha level was set at 0.05. All data were plotted as mean values ± standard error of the mean.
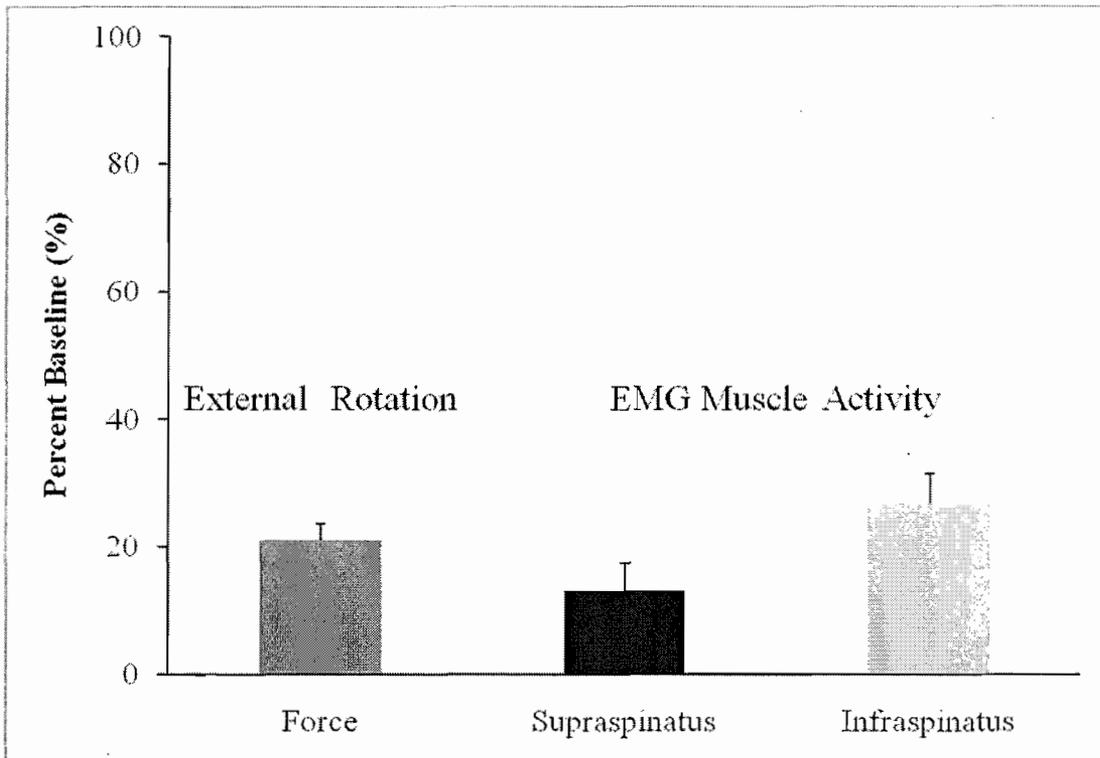
Figure 4.5. Comparison of baseline and post-nerve block criteria used for determining a successful suprascapular nerve block. Supraspinatus and infraspinatus muscle activity data was taken from Post-NB1 elevation trial at 90° of humeral elevation.

RESULTS

Force measurement

Figure 4.6 depicts the external rotation force produced by Post-NB1 and Post-NB2. After 60 minutes of the administration of the suprascapular nerve block, the external rotation force was still reduced by 50% across subject.
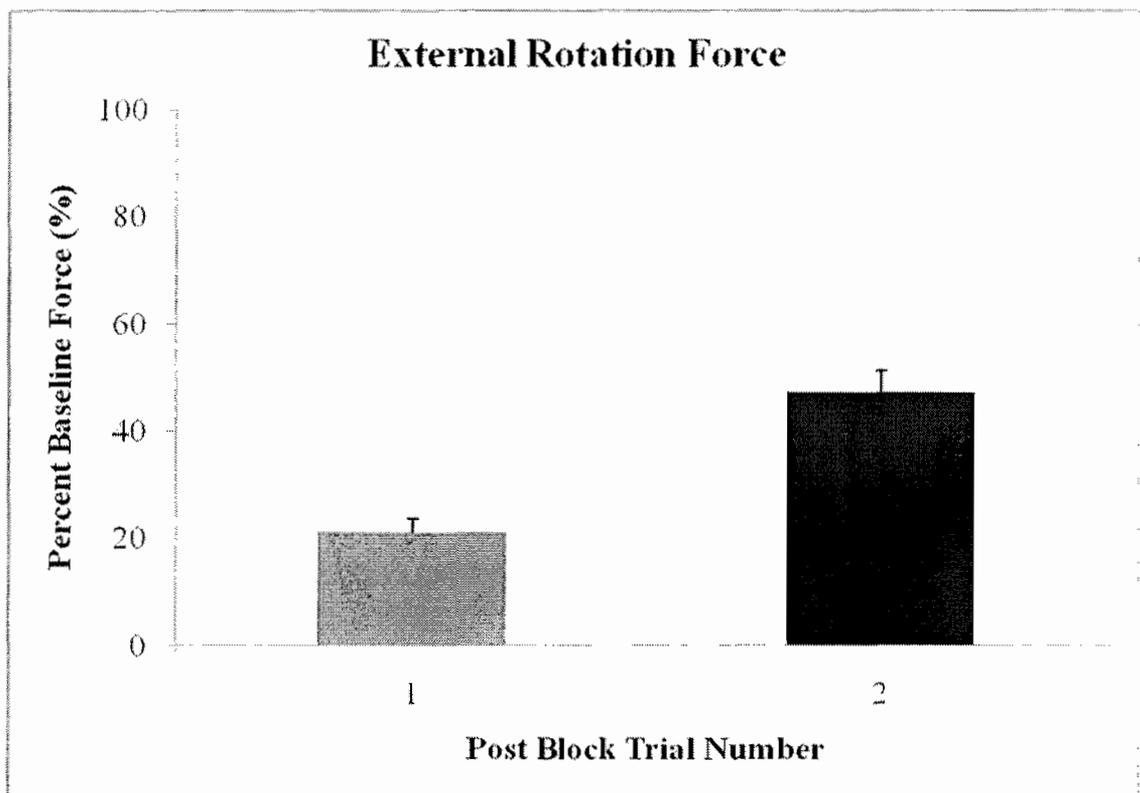
Figure 4.6. Post-nerve block trial external rotation torque. Post block trial 1 was performed after a successful nerve block. Post block trial 2 was after 60 minutes of the successful administration of the block.

Glenohumeral translation and scapular upward rotation

At 60° of humeral elevation, the measured humeral head was statistically significant for both Post-NB1 and Post-NB2 (Figure 4.7A & B). This illustrates that the humeral head was superiorly located compared to the Pre-NB conditions. For scapular upward rotation, Post-NB1 was statistically significant at humeral elevation angles of 30°, 60°, and 90° (Figure 4.7C). In contrast, Post-NB2 did not show any significant differences across all humeral elevation angles (Figure 4.7D). Both Post-NB conditions had the same pattern of greater upward rotation after 30° of humeral elevation and begin to lessen after 90°.

EMG muscle activation

Only 19 subjects were included in the analysis of EMG activity due to synchronization problems with one of the subjects. The supraspinatus, infraspinatus, and middle deltoid demonstrate statistically significant differences from 30° - 120° of humeral elevation angles (Figure 4.8A, B and D). Supraspinatus and infraspinatus had decreased muscle activation after the nerve block. The anterior deltoid, middle deltoid and posterior deltoid showed statistically significant differences at higher humeral elevation angles. In addition, the deltoid muscle group had increased muscle activation during higher humeral elevation (Figure 4.8C, D and E). The posterior deltoid, during Post-NB2, was the only one that showed statistically significant differences when the arm is at the side (Figure 4.8E). The latissimus dorsi did not show any significant differences across all humeral elevation angles (Figure 4.8F).
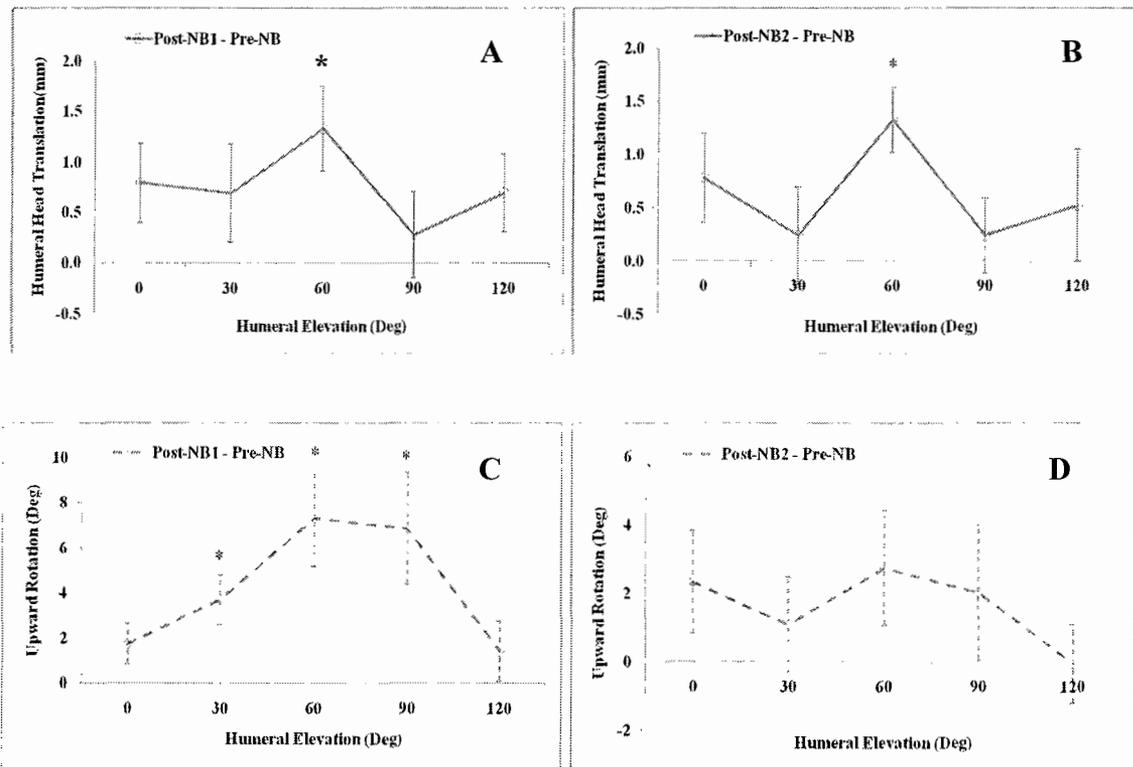
* p < 0.01

Figure 4.7. Difference in measured humeral head translation. Positive numbers represent superior location of the humeral head after the nerve block (**A & B**). **C & D** represents the scapular upward rotation. A positive number represents greater scapular upward rotation.
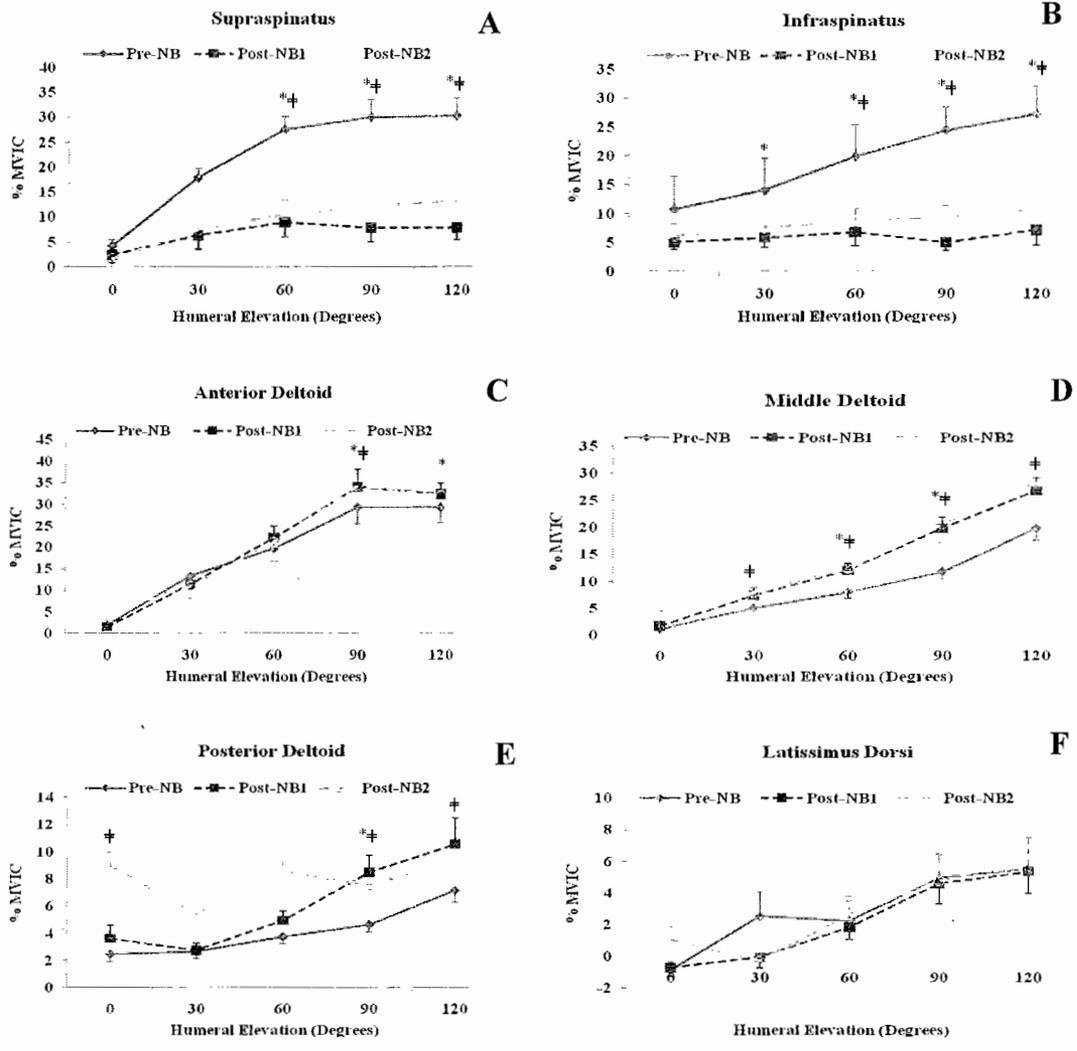
* p < 0.05 (Post-NB1 – Pre-NB)
‡ p < 0.05 (Post-NB2 – Pre-NB)

Figure 4.8. EMG muscle activation of different shoulder muscles.

DISCUSSION

The purpose of the study was to assess the effect of suprascapular nerve block on humeral head translation, scapular upward rotation and shoulder muscle activation patterns. The current study supported the stated hypothesis that the nerve block will results in a compensatory increase in superior translation of the humeral head and greater scapular upward rotation.

For the current study, the authors choose to compare the pre-nerve block to the post-nerve block conditions in each corresponding humeral elevation angle with respect to the pre-nerve block (i.e. 60° humeral elevation Pre-NB to 60° humeral elevation Post-NB). This was because the emphasis of the study was to look at differences in measured humeral head translation and scapular upward rotation between conditions at specific humeral elevation angle. The majority of the studies that measured humeral head translation used the humeral head neutral position of the control condition as the reference point (Deutsch et al., 1996, Paletta et al., 1997, Poppen and Walker, 1976, Werner et al., 2006).

The observed superior translations at 60° of humeral elevation in the current study are similar to the findings in patients with impingement and rotator cuff tears (Bezer et al., 2005, Deutsch et al., 1996, Paletta et al., 1997, Poppen and Walker, 1976, Yamaguchi et al., 2000). This provided evidence that there is a compensatory increase in humeral head translation during the mid-range of motion after paralysis of supraspinatus and infraspinatus. In a similar study performed by Werner et al (2006) they did not find any significant differences in measured humeral head translation after suprascapular nerve block. There are two possible reasons for

the differences seen in measured humeral head translation. First, the reference point utilized by the current study was different. The current study used the corresponding humeral elevation angle of the Pre-NB condition to compare translation of the humeral head while the latter study used the humeral head location in the neutral position as the reference. Second, the subjects were seated during arm elevation trials compared to the current study were the subjects were standing. Lastly, they tested 10 subjects while the current study had collected and analyzed 20 subjects.

The present study had similar results seen in a related research design that was previously completed in our laboratory examining the scapular kinematics after suprascapular nerve block that found a more upwardly rotated scapula at mid-ranges of motion after the block (McCully et al., 2006). Additionally, this result is in accordance with other studies that examined scapular kinematics in rotator cuff patients compared to healthy individuals (Mell et al., 2005, Paletta et al., 1997, Yamaguchi et al., 2000). It is interesting to see increases in scapular upward rotation after paralysis of the supraspinatus and infraspinatus since contraction of these muscles is not responsible for any scapular motion. This result may be due to the fact that some of the subject's reported experiencing difficulty elevating their arm after the suprascapular nerve block. Therefore, the subjects were trying to compensate for the loss of function of the supraspinatus in arm elevation. During arm elevation, the subjects may possibly hike their shoulder and by this induce greater upward rotation of the scapula.

In addition, an increase in muscle activation was observed in all the deltoid muscles after 90° of humeral elevation. The middle deltoid showed increase muscle

activation starting at 30° of elevation. This result is in accordance with Thompson et al (1996) that showed a significant increase in the middle deltoid force required to initiate abduction force after paralysis of supraspinatus in cadaver. This might be due to the fact that it is compensating for the loss of abductor effect of the supraspinatus during the early stages of elevation. One of the main actions of the supraspinatus is to aid the deltoid in elevating the GH joint (Rockwood et al., 2004). Moreover, McCully et al (2007) in their study showed increases in the deltoid muscle group after suprascapular nerve block.

The main goal of the study was to mimic rotator cuff dysfunction and not rotator cuff tears. The authors used suprascapular nerve block to paralyze the supraspinatus and infraspinatus. The result of the current study showed a more superiorly located humeral head after nerve block at 60° of humeral elevation with a mean value of 1.3 mm. This value is comparable to studies that measured humeral head translation and found significant differences. Chen et al (1999) using a muscle fatigue model observed increased superior humeral head translation of 2.5 mm after the deltoid and rotator cuff were fatigued. Deutsch et al (1996) reported superior translation of the humeral head equivalent to 1.2 mm with rotator cuff patients during humeral elevation. In a more recent study, Bey et al (2008) reported observing superior translation ranging from approximately 2.6 mm during shoulder elevation in subjects that had surgically repaired supraspinatus tendon tear.

The current study was design to address the limitation of the 2-D imaging technique used to measure kinematics. Using a 2-D imaging technique to measure GH and scapular kinematics that is a 3-D motion presents inherent projection error due to out

of plane motions. In order to avoid out of plane motion, the investigator made sure that the face of the scapula was directly perpendicular to the field of view of the fluoroscope. In addition, foot location was marked for each subject in order to attain consistent position between trials.

The result of the present study may have implications in designing rehabilitation and strengthening protocol for individuals with shoulder impingement, and individuals with weak or dysfunctional rotator cuff musculature. Exercises focusing on strengthening and increasing endurance of the rotator cuff musculature may help prevent weak and dysfunctional rotator cuff muscles. This could help avoid symptoms of shoulder impingement like pain during shoulder elevation due to increased superior translation of the humeral head. Increased muscular strength and endurance would be beneficial for workers and athletes that perform numerous overhead activities which predispose them to experience shoulder impingement overtime (Hulstyn and Fadale, 1997, Ludewig and Borstad, 2003, Svendsen et al., 2004).

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Subacromial impingement syndrome is characterized by a mechanical compression of the soft tissues in the subacromial space with symptoms that typically include shoulder pain, stiffness, tenderness, and weakness. Authors have speculated that SAIS leads to tear of the rotator cuff tendons. However, it is unknown for certain what the true mechanisms of SAIS are that lead to rotator cuff tear's or if SAIS even leads to rotator cuff tears. Data are rarely available for patients before they develop cuff tears; it is not known whether abnormal decentralization of the humeral head is causal or compensatory in nature. The purpose of this dissertation was to validate a technique in measuring humeral head translation in 2-D images that can be use by both researchers and clinicians to examine the difference in measured humeral head translation and scapular upward rotation after paralysis of the supraspinatus and infraspinatus muscles.

The first study showed that the 2-D contour registration technique had reasonably low error after 60° of humeral elevation compared to the manual digitization method that was commonly used in the literature. In addition, the contour registration allowed measurement of scapular upward rotation. One of the advantages of using the contour registration technique was its ability to objectively align two contours and generate a

transformation matrix between the two images. This avoided any subjective digitization between images that can introduce potential user error during the process.

The second study demonstrated that there were no differences in measured humeral head translation and scapular upward rotation between static and dynamic trials for both weighted and non-weighted conditions. However, the non-weighted condition depicted a more superiorly located geometric center of the humeral head in the mid-ranges of motion. With regards to scapular upward rotation, both conditions illustrated a less upwardly rotated scapula during the mid-ranges of motion. These findings suggest that measuring GH and scapular kinematics was not affected by the type of shoulder motion implemented during data collection. However, dynamic trials are more representative of motions performed in everyday living.

The third study examined the difference in measured humeral head translation and scapular upward rotation prior to and after a suprascapular nerve block in healthy individuals. The study showed a more superiorly located humeral head center and a more upwardly located scapula at mid-range of shoulder elevation after the nerve block. In addition, there was an increase in middle deltoid activity after the block. These findings suggest that paralysis of the supraspinatus and infraspinatus resulted in a compensatory increase in humeral head superior translation, scapular upward rotation and middle deltoid activity. These may indicate that a weak or dysfunctional rotator cuff can decrease the subacromial space during shoulder elevation due to increase in humeral head translation. In addition, increase in middle deltoid activity may contribute to the more

superiorly located humeral head. This is due to the fact that at the beginning of abduction the deltoid's force vector points superiorly that tends to pull the humeral head superiorly.

It is hard to follow the history of patients who suffered from rotator cuff tear or shoulder impingement. It involves performing a prospective study that could take years to develop. The results of this dissertation may contribute to better understanding the mechanism of shoulder impingement and rotator cuff tear. Through the use of the suprascapular nerve block model, the present study was able to compare humeral head translation on the same individual before and after paralysis of the supraspinatus and infraspinatus muscle. The suprascapular nerve block model gave us an insight of what can happen if the supraspinatus and infraspinatus were dysfunctional. It causes an increase in superior humeral head translation. Eventually overtime, this can cause shoulder impingement and rotator cuff tear if left untreated. In addition, it has some clinical implications in terms of patient rehabilitation and strengthening. The present results suggest that strength imbalances of the deltoid musculature and rotator cuff muscles can aid in increasing humeral head superior translation in the mid-ranges of motion during shoulder elevation. These results support the idea of conservative treatment of shoulder impingement performed in physical therapy and sports medicine facilities. Strengthening the supraspinatus and infraspinatus can counter the effects of the deltoid musculature in its cranial pull on the humeral head during the initial stages of abduction. This could potentially prevent narrowing of the subacromial space.

STRENGTH OF THE STUDY

This investigation has several strengths. First, I was able to validate a technique to measure humeral head translation and scapular upward rotation using 2-D imaging. I am not aware of any published studies that validated this technique. To our knowledge, this was the first study that validated a 2-D measurement technique in measuring humeral head translation to a gold standard.

Second, the current study examined the differences in measured humeral head translation between conditions in its corresponding humeral elevation angle prior to the block. The common practice was to use the control condition as the reference point of the measured humeral head translation. This technique gave us a better understanding of what was occurring at that specific elevation angle after the block.

Third, to our knowledge, this is the first study that examined the differences in measured humeral head translation between static and dynamic elevation trials. However, we did not find any significant differences between them. Numerous authors have speculated that dynamic shoulder motion occurs frequently during normal activity.

Fourth, studies that examined humeral head translation compared healthy subjects with individuals with shoulder impingement or rotator cuff tear patients. The authors assumed that the patient's GH kinematics will behave the same way as the healthy control group before they developed the pathology. The current study used the same individual as their own control to better remove the effects of subject variability on the measured kinematics.

Finally, using suprascapular nerve block to mimic a rotator cuff dysfunction enabled us to isolate paralysis of the supraspinatus and infraspinatus. Other studies used muscle fatigue models to mimic dysfunction of the rotator cuff musculature. However, this technique cannot isolate specific muscles.

LIMITATIONS OF THE STUDY

The first concern is the use of 2-D imaging in measuring kinematics of a 3-D shoulder motion. This could result in projection errors due to out of plane motions. The first study enabled us to better understand which extreme motions can influence an increase in measurement error. In addition, we were able to pick a more suitable technique in measuring humeral head translation that would result in lesser errors. In order to address this concern, the investigator made sure through the help of live fluoroscopy to position each subject so that the field of view of the fluoroscope is directly perpendicular to the anterior face of the scapula. Moreover, a customized elevation guide was utilized in order to maintain a consistent plane of elevation, and this also allowed foot position to be marked so that subject positioning will be the same for all the trials.

Second, in every EMG study, muscle cross talk is always a concern. This especially occurs in surface EMG. Due to muscles overlapping, it is possible to acquire activity of neighboring muscles. In able to address this concern, the investigator performed the manual muscle test in the same manner in all the subjects and marked the skin for proper electrode placement. The investigator was trained in the use of fine-wire electrodes by a physician who performs the procedure frequently in his practice. In

addition, the investigator had sufficient practice in inserting the fine-wire electrode, so proper placement was ensured.

Third, due to the height limit of the fluoroscopy machine, we had to exclude subjects that are taller than 180.3 cm (5' 11").

Fourth, the sampling rate for the kinematic data was limited to 8 Hz. This is the maximum sampling rate that the fluoroscopy unit allowed for data collection.

Fifth, the number of shoulder elevations per trial performed during the nerve block study was limited. Due to concern of increased radiation exposure, the elevation was reduced to two. This limited the number of trials to choose from in terms of the quality of the image to be analyzed.

RECOMMENDATIONS FOR FUTURE RESEARCH

The current study showed that dysfunction of the supraspinatus and infraspinatus through suprascapular nerve block resulted in a more superiorly located humeral head. It will be interesting to see whether increasing the strength of the supraspinatus and infraspinatus could decrease superior translation of the humeral head in patients experiencing pain due to impingement because of increased superior humeral head translation. Fluoroscopy could be used to measure humeral head location during shoulder elevation of shoulder impingement patients before the start of physical therapy treatment and then measure it again at the end of the treatment visits. This will give us an objective way of telling whether increasing the strength of the supraspinatus and infraspinatus helped alleviate pain during elevation due to a decrease superior humeral head translation.

The result of the present study did not show any significant differences in measured humeral head translation between the static and dynamic trials. This may be due to the small sample size. This study should be continued and more subjects should be tested. It is important to know whether results of studies performed with dynamic shoulder motion is comparable to those performed statically.

APPENDIX A

CONSENT FORM STUDY 2

University of Oregon
Consent to Take Part in a Research Study

Project: Measuring Humeral Head Translation Using Fluoroscopy

You are invited to participate in a research study conducted by Andrew Karduna, PhD, from the department of Human Physiology at the University of Oregon (UO). The purpose of this study is to compare the differences in shoulder movements when healthy subjects hold their arms in space compared to when subjects move their arms naturally. We will be using x-rays to evaluation the motion. You were selected as a possible participant in this study because you do not have a shoulder problem.

If you decide to participate, you understand that the following things will be done to you. You will be asked to fill out a brief form to provide basic information such as age, height and weight and which arm is your dominant arm. You will then be asked to move your shoulder while we make measurements using fluoroscopy (a form of x-ray).

There is no direct benefit to you by participating in this study. However, you understand that information gained in this study may help researchers to better understand shoulder pathologies. You will be paid $40 for your participation in this study. This is to help defray the costs incurred for participation. If you cannot complete the study, you will still be paid $10 per half hour (up to $40) for your time

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept confidential by coding the data with subject numbers, rather than names. Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the University of Oregon. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you take part in this research, you will have one medical imaging study which uses radiation. The test you will have is a shoulder fluoroscopy. While standard x-ray is like taking a snapshot from a camera with a single, flash of exposure, Fluoroscopy is like real-time movie footage with continuous exposure. This radiation exposure is not necessary

for your medical care and is for research purposes only. While no radiation dose has been determined to be entirely safe, the amount to which you will be exposed in this study is not known to cause health problems. In addition, lead apron will be provided to all the subjects to minimize further exposure to radiation. To give you an idea about how much radiation you will get, we will make a comparison with an every-day situation. Everyone receives a small amount of unavoidable radiation each year. Some of this radiation comes from space and some from naturally-occurring radioactive forms of water and minerals. This research gives your body the equivalent of about 1 extra year's worth of this natural radiation. The radiation dose we have discussed is what you will receive from this study only and does not include any exposure you may have received or will receive from other tests.

This study may be harmful to an unborn child. There is not enough medical information to know what the risks might be to an unborn child in a woman who takes part in this study. Women who can still become pregnant must have a negative pregnancy test no more than 24 hours prior to the study. This will require you to collect a sample of urine and have it tested by one of the investigators. If the pregnancy test is positive (meaning that you are pregnant), you will not be able to take part in the study. In the case that you have a positive pregnancy test, we will ask you to see your physician or a provider in the University of Oregon Student Health Center (if you are a University of Oregon student). There is no cost for the pregnancy test.

If you are physically injured because of the project, you and your insurance company will have to pay your doctor bills. If you are a UO student or employee and are covered by a UO medical plan, that plan might have terms that apply to your injury. If you experience harm because of the project, you can ask the State of Oregon to pay you. If you have been harmed, there are two University representatives you need to contact. Here are their addresses and phone numbers:

General Counsel
Office of the President
University of Oregon
Eugene, OR 97403
(541) 346-3082

Office for Protection of Human Subjects
University of Oregon
Eugene, OR 97403
(541) 346-2510

A law called the Oregon Tort Claims Act limits the amount of money you can receive from the State of Oregon if you are harmed. The most you could receive would be $100,000, no matter how badly you are harmed. If other people are also harmed by the project, all of you together could only receive $500,000.

You will be offered a copy of this form to keep. If you have any questions after the experiment, please contact the principal investigator, Dr. Andrew Karduna (541) 346-0438, Department of Human Physiology, University of Oregon, Eugene OR, 97403. If you have questions regarding your rights as a research subject, please contact the Office for Protection of Human Subjects, University of Oregon, Eugene, OR 97403, (541) 346-2510.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights or remedies.

Print Name _____

Signature _____   Date _____

APPENDIX B

CONSENT FORM STUDY 3

University of Oregon
Consent to Take Part in a Research Study

Project: Humeral Translation under Suprascapular Nerve Block

You are invited to participate in a research study conducted by Andrew Karduna, PhD from the department of Human Physiology at the University of Oregon (UO). The purpose of this study is to measure the effects of temporary paralysis of a nerve on shoulder motion. This procedure will be performed by Dr Peter Kosek, a board certified anesthesiologist. This research will help us with our understanding of rotator cuff tears, which is a common orthopaedic shoulder problem in older individuals. You were selected as a possible participant in this study because you do not have a shoulder problem.

If you decide to participate, you understand that the following things will be done to you. You will be asked to fill out a brief form to provide basic information such as age, height and weight and which arm is your dominant arm. You will then be asked to move your shoulder while we make measurements. The investigator, Bernardo San Juan, MA, ATC will insert a pair of small wires into two of your shoulder muscles to monitor muscle activity. The small wires will be in the shoulder muscles for approximately 2 hours. This technique, called fine-wire electromyography (EMG), is a well established and tested method for assessing muscle activity and is used in clinical settings. In addition, 4 pairs of surface electrodes will be placed on your skin by the shoulder to monitor muscle activity. This procedure is also known as surface EMG. Then a physician will perform a suprascapular nerve block, which is a standard clinical procedure. The nerve block involves the insertion of a needle into the top of your shoulder and the injection of a small amount of numbing medicine. The medicine, called lidocaine, is the same local anesthetic that many dentists and physicians use – it is sometimes referred to as xylocaine (and is similar to novocaine). If you have ever had an allergic reaction to lidocaine/xylocaine or novacaine, you cannot participate in this study.

Once the physician has confirmed the success of the block, you will be asked several more times to repeat the motions you performed previously. It is estimated that the entire testing process will take approximately 2 hours. The effects of the nerve block will start to diminish is as little as half an hour and complete recovery typically occur within 2-3 hours.

There is no direct benefit to you by participating in this study. However, you understand that information gained in this study may help health care professionals better understand how to treat patients with rotator cuff tears. You will be paid $100 for your participation in this study. This is to help defray the costs incurred for participation such transportation as well as your time. If you cannot complete the study, you will still be paid $25 per half hour (up to $100) for your time.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept confidential by coding the data with subject numbers, rather than names. Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the University of Oregon. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

Electromyography (EMG) is widely used in research and clinical procedure to monitor muscle activity. Since fine-wire electrodes will be administered, a needle inserted into a muscle belly, there are risks involved with this procedure. You may experience muscle soreness from the test procedures. This could occur immediately after testing, or up to two days later. You might develop skin irritation or an infection from the electrodes (sterile techniques will be employed to help minimize the risk of an infection). Additionally, you might develop small bruises from the wire electrodes. Although highly unlikely, there is very slight risk that you might experience an electrical shock from the test equipment. This event is rare and has never been seen to happen in clinical practice. For the surface EMG, there is a very slight risk that your skin might show allergic reaction to the gel present on the surface electrodes.

Although a nerve block is a common clinical procedure, as with any procedure involving an injection, there are always risks that need to be considered and addressed. Any time a needle punctures the skin; there is a very slight risk of infection. To help prevent this, standard clinical procedures will be use to maintain sterility of the injection area. Pneumothorax (puncture of a lung) or allergic reactions to lidocaine are also potential risk. However, the physician overseeing this project has been performing, teaching and observing this procedure for 10 years and has never seen either one of these very rare occurrences. Finally, some people pass out from stress of seeing a needle. Therefore, a physician qualified to deal with this occurrence will only perform this procedure. If you have any question or concerns regarding the above-mentioned risks, please talk to the investigator now. Additionally, if you have any known allergies to local anesthetics like lidocaine, xylocaine or novocaine, or disinfectants like Betadine or Iodine, please tell the investigator now.

If you take part in this research, you will have one medical imaging study which uses radiation. The test you will have is a shoulder fluoroscopy. While standard x-ray is like

taking a snapshot from a camera with a single, flash of exposure, Fluoroscopy is like real-time movie footage with continuous exposure. This radiation exposure is not necessary for your medical care and is for research purposes only. While no radiation dose has been determined to be entirely safe, the amount to which you will be exposed in this study is not known to cause health problems. In addition, lead apron will be provided to all the subjects to minimize further exposure to radiation. To give you an idea about how much radiation you will get, we will make a comparison with an every-day situation. Everyone receives a small amount of unavoidable radiation each year. Some of this radiation comes from space and some from naturally-occurring radioactive forms of water and minerals. This research gives your body the equivalent of about 1 extra year's worth of this natural radiation. The radiation dose we have discussed is what you will receive from this study only and does not include any exposure you may have received or will receive from other tests.

This study may be harmful to an unborn child. There is not enough medical information to know what the risks might be to an unborn child in a woman who takes part in this study. Women who can still become pregnant must have a negative pregnancy test no more than 24 hours prior to the study. This will require you to collect a sample of urine and have it tested by one of the investigators. If the pregnancy test is positive (meaning that you are pregnant), you will not be able to take part in the study. In the case that you have a positive pregnancy test, we will ask you to see your physician or a provider in the University of Oregon Student Health Center (if you are a University of Oregon student). There is no cost for the pregnancy test.

If you are physically injured because of the project, you and your insurance company will have to pay your doctor bills. If you are a UO student or employee and are covered by a UO medical plan, that plan might have terms that apply to your injury. If you experience harm because of the project, you can ask the State of Oregon to pay you. If you have been harmed, there are two University representatives you need to contact. Here are their addresses and phone numbers:

General Counsel
Office of the President
University of Oregon
Eugene, OR 97403
(541) 346-3082

Office for Protection of Human Subjects
University of Oregon
Eugene, OR 97403
(541) 346-2510

A law called the Oregon Tort Claims Act limits the amount of money you can receive from the State of Oregon if you are harmed. The most you could receive would be $100,000, no matter how badly you are harmed. If other people are also harmed by the project, all of you together could only receive $500,000.

In order to do this research, you must also authorize us to access and use some of your personal health information as part of the Fluoroscopy procedures. An authorization form is attached for you to review and sign and is an addendum to this consent form.

You will be offered a copy of this form to keep. If you have any questions after the experiment, please contact the principal investigator, Dr. Andrew Karduna (541) 346-0438, Department of Human Physiology, University of Oregon, Eugene OR, 97403. If you have questions regarding your rights as a research subject, please contact the Office for Protection of Human Subjects, University of Oregon, Eugene, OR 97403, (541) 346-2510.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights or remedies.

Print Name_____

Signature _____ Date _____

APPENDIX C

SUBJECT INTAKE FORM

University of Oregon
Project: Humeral Translation under Suprascapular Nerve Block

Name _____   Subject Code _____

Date _____   Dominant Side _____

Body Weight _____   Height _____

Age _____   Gender _____

Ethnic Category   **Racial Categories**
Check One: Check One:
_____ Hispanic or Latino   _____ American Indian/Alaska Native
_____ Not Hispanic or Latino   _____ Black or African American
_____ Unknown or Not Reported   _____ Asian
                                         _____ Native Hawaiian or Other Pacific Islander
                                         _____ White
                                         _____ More Than One Race
                                         _____ Unknown or Not Reported

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