THE PREDICTIVE RELATIONSHIP BETWEEN SCAPULAR KINEMATICS AND ATHLETE'S SCORE ON THE SICK SCAPULA STATIC MEASUREMENTS SCALE

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ABSTRACT

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The predictive relationship between scapular kinematics and athlete's score on the SICK Scapula Static Measurements Scale

(Under the direction of Dr. Joseph B. Myers, Dr. Kevin Guskiewicz, Shana Harrington, and Johna Mihalik)

Objective: To determine the predictive relationship between three-dimensional scapular kinematic data and an athlete's score on the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale. **Design:** Quasi-experimental, one group design with counterbalancing of functional tasks. **Subjects:** Forty, NCAA Division I and recreational overhead athletes. **Measurements:** The SICK Scapula, Static Measurements Scale was used to assess scapular dysfunction. Scapular and humeral kinematic data were recorded to determine position and orientation. **Results:** Simple regression analyses revealed weak significant relationships between scapular upward rotation at zero degrees and at thirty degrees of humeral elevation in the sagittal plane; and scapular elevation at zero degrees of humeral elevation in the sagittal plane, and SICK scapula score. **Conclusion:** Based on our results which demonstrated weak relationships between scapular kinematic data analysis and score on the SICK Scapula Static Measurements Scale, the ability of this scale to detect scapular dysfunction is questionable.

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CHAPTER I

INTRODUCTION

Statement of the problem

Athletes are predisposed to developing scapulothoracic and glenohumeral pathologies due to the repetitive overhead movement patterns inherent to athletic activity. These repetitive overhead motions are believed to apply extreme stresses to both active and passive structures of the shoulder (Burkhart, Morgan et al. 2003). Athletes may develop alterations in scapular static positioning, scapular kinematics, or scapular force couple production which eventually may manifest as pain, scapular dyskinesis or shoulder pathology. Abnormal scapular kinematics in one or more planes and associated abnormal muscle function are believed to contribute to shoulder pain and pathology (Fu, Harner et al. 1991; Glousman, Jobe et al. 1998; Kibler, WB, 1991). Furthermore, alterations in scapular positioning and motion occur in 68% to 100% of all patients with shoulder injuries (Warner, Micheli et al. 1992).

Scapular dyskinesis is described as alterations of scapular position, at rest or with coupled arm motion, that create clinical dysfunction of the shoulder and that are commonly associated with injuries (Kibler and McMullen, 2003). Scapular dyskinesis is the likely result of several contributing factors. Excessive thoracic kyphosis and increased cervical lordosis are two factors that result in excessive scapular protraction and acromial depression, which predispose the athlete to symptoms of subacromial impingement (McClure, Michener et al.

2001). Fractures, joint instabilities and injury to the scapular muscles or nerves may lead to muscle inhibitions and alterations in muscle activation which manifest as abnormal scapular kinematic patterns. A lack of flexibility of the pectoralis minor or short head of the biceps brachii muscles, as well as, a tight posterior glenohumeral joint capsule could contribute to the abnormal patterns and positions associated with scapular dyskinesis (Burkhart, Morgan et al. 2003).

Scapular dysfunction in athletes could also be described as SICK scapula. SICK scapula is a relatively new term that describes a collection of signs and symptoms that is frequently observed in athletes. SICK is an acronym that is used to refer to the objective findings common to the scapular syndrome: *Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition, and dysKinesis of scapular movement* (Burkhart et al., 2003). Scapular malposition, the trademark of SICK scapula syndrome, describes the asymmetric position of the scapula in the involved shoulder and is recognized as one shoulder appearing lower than the other. In addition, the inferior medial border of the scapula appears prominent with SICK scapula. Coracoid pain and malposition are due to excessive scapular protraction and lack of posterior scapular tilt, as well as, tightness in the pectoralis minor or short head of the bicep brachii muscles. The final component, dyskinesis of scapular movement, describes alterations in scapular positioning and in scapular movement patterns during arm motion.

Kibler and McMullen have divided SICK scapula into three classes according to the location of the scapular prominence (Kibler and McMullen 2003). Type I describes an abnormal rotation around the transverse axis which presents as an inferior medial scapular border prominence. Type II describes an abnormal rotation around the vertical axis which presents as a prominence of the entire medial scapular border. Type III involves a superior translation of the entire scapula and the prominence of the superior medial scapular border (Kibler and McMullen, 2003). In the presence of any of these dyskinetic patterns, the scapula becomes less effective in contributing to asymptomatic, normal shoulder function.

Significance

The scapula serves multiple roles in the production of optimal glenohumeral and scapulothoracic motions. As the stable base for glenohumeral motion, the scapula provides dynamic stability for the glenohumeral joint, elevates the acromion during throwing motions and serves as a pivotal link in the proximal-to-distal sequencing of velocity, energy, and forces of shoulder function (Kibler and McMullen 2003). The presence of SICK scapula may cause adverse alterations in scapular kinematics and muscle function that possibly predispose the athlete to further injury to the glenohumeral joint. Therefore, the ability to successfully recognize and evaluate SICK scapula syndrome is critical to early implementation of treatment and rehabilitation interventions that would eventually correct scapular dyskinesis.

Currently, there is a lack of evidence-based research describing the three-dimensional scapular and clavicular positions and orientations; as well as, the scapular kinematic patterns present in overhead athletes. Previous researchers have sited the need for future studies of three-dimensional scapular kinematics: "Further three-dimensional kinematic analysis of the shoulder complex is necessary in combination with EMG data to enhance the understanding of shoulder muscle function" (Ludewig, Cook et al. 1996).

This study was one of few research projects to focus solely on the effects of SICK scapula syndrome on scapular positioning and kinematics. The researchers aimed to determine the predictive relationship between scapular kinematic data analysis and athlete's score on the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale. This project should add important information regarding the predictability of the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale in determining scapular dysfunction. The results from this research should encourage further understanding of the potential predisposing factors and existing dyskinetic scapular patterns associated with SICK scapula syndrome. If proven valid, this scale may be implemented by clinicians in order to more effectively recognize and evaluate athletes at risk or already displaying SICK scapula syndrome. Clinicians will be equipped to determine the most effective treatment and rehabilitation exercises aimed at correcting scapular malposition and dyskinesis; thereby reducing the risk of further injury to the glenohumeral joint.

Purpose

The purpose of this study was to determine the predictive relationship between scapular kinematic data analysis and overhead athlete score on the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale. This project should add important information regarding the ability of the SICK Scapula, Static Measurements Scale to detect scapular dysfunction in overhead athletes.

Research Design

This study will be quasi-experimental in nature, specifically a nonequivalent one-group design with a counterbalancing of tasks.

Research Questions

1. Is the degree of scapular anterior or posterior tilt during functional tasks a valid predictor of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale?

2. Is the degree of scapular internal and external rotation during functional tasks a valid predictor of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale?

3. Is the degree of scapular upward and downward rotation during functional tasks a valid predictor of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale?

4. Is the degree of scapular elevation and depression during functional tasks a valid predictor of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale?

5. Is the degree of scapular protraction and retraction during functional tasks a valid predictor of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale?

Research hypotheses

H_a: Increased scapular anterior tilt will be a valid predictor of a higher score on the SICK Scapula Static Measurements, 0 to 20 point rating scale.

H_a: Increased scapular internal rotation will be a valid predictor of a higher score on the SICK Scapula Static Measurements, 0 to 20 point rating scale.

H_a: Decreased scapular upward rotation will be a valid predictor of a higher score on the SICK Scapula Static Measurements, 0 to 20 point rating scale.

H_a: Decreased scapular elevation will be a valid predictor of a higher score on the SICK Scapula Static Measurements, 0 to 20 point rating scale.

H_a: Decreased scapular retraction will be a valid predictor of a higher score on the SICK Scapula Static Measurements, 0 to 20 point rating scale.

Independent variables

1. Functional tasks

   - Glenohumeral (GH) elevation in sagittal plane (flexion)

   - Glenohumeral (GH) elevation in scapular plane (scaption)

2. Humeral angles:

   - Humeral angles 0 º, 30 º, 60 º, 90 º, 120 º during the ascending phase of both functional tasks

Dependent variable

The dependent variable was the subjects' overall score on the SICK Scapula Static Measurements, 0 to 20 point Rating Scale. The amount of three-dimensional scapular movement, measured in degrees, which occurred during the functional tasks, was studied in order to determine if kinematics were predictive of subject score on the SICK Scapula Static Measurements, 0 to 20 point rating scale. Scapular orientation was measured in the sagittal plane as anterior or posterior tilt, in the scapular plane as upward or downward rotation, and in the transverse plane as internal or external rotation. Scapular position was measured in the scapular plane as elevation or depression and in the transverse plane as protraction or retraction.

Operational definitions

1. Overhead athletes: Male and female, NCAA Division I, recreational and club athletes, 18 to 25 years old who participated in a sport that requires their arm to be above shoulder height on a repetitive basis during throwing or striking activities (swimming, tennis, volleyball, baseball, softball). Athletes were active in their overhead sport for a minimum of 30 minutes, three times a week.

2. Functional tasks:

Glenohumeral elevation in sagittal plane (flexion) with hand in neutral position.

Glenohumeral elevation in the scapular plane (scaption) with hand in neutral position.

Definition of terms

1. SICK scapula was defined by the following signs and symptoms (Burkhart et al., 2003).

- Qualitative –
  - inferior medial border prominence
  - lowered scapula on involved side
  - coracoid process pain
  - rapid downward rotation (kick out sign) with active shoulder abduction and forward flexion
- Quantitative –
  - asymmetrical scapular position on the involved side greater than 1.5 cm for all landmarks based on a measure of distance between the inferomedial angle of the scapula and the nearest spinous process for each of the following positions:
    - arms relaxed at sides
    - hands on hips with 10 degrees of shoulder extension
    - 90 degrees of shoulder abduction and shoulder internal rotation

2. The SICK Scapula, Static Measurements, 0 to 20 point Rating Scale (Burkhart, Morgan et al. 2003) is a measurement scale that awards points for subjective complaints, objective assessments, and anatomical landmark measurements which indicate the presence and severity of scapular malposition. A score of zero represented an asymptomatic, bilaterally symmetrical scapula; whereas a score of 20 represented the worst asymmetrical, symptomatic scapula (Figure 1).

Inclusion criteria

Subjects included male and female, NCAA Division I, recreational and club athletes, 18 to 25 years old who participated in a sport that requires their arm to be above shoulder height on a repetitive basis during throwing or striking activities (swimming, tennis, volleyball, baseball, softball). Athletes were active in their overhead sport for a minimum of 30 minutes, three times a week.

Exclusion criteria

Subjects included male and female athletes with no previous medical history of the following conditions:

1. shoulder or neck surgery
2. cervical spine pathology
3. adhesive capsulitis
4. rotator cuff tears
5. acute acromioclavicular joint pathology
6. scoliosis
7. unstable episodes of the glenohumeral joint, such as subluxations or dislocations within the past 6 months.

Assumptions

1. Gender did not influence the results of this study.
2. Subjects' self-reported information was both honest and unbiased.
3. Subjects performed to the best of their ability on all functional tasks.

4. All athletes perform relatively the same functional glenohumeral and scapulothoracic movement patterns, regardless of their specific sport.

Limitations

1. Variations in sport specific training intensity, duration and frequency between athletes.
2. No subject randomization
3. No blinding of researchers
4. Individual variability: differences between dominant and non-dominant shoulders.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The purpose of this literature review is to discuss the pathological effects of scapular malposition and dyskinesis on scapulothoracic and glenohumeral motion in the athlete. This review will provide a comprehensive overview of the normal anatomy, functions and kinematics of the scapula. Because the scapula and the glenohumeral joint work together to produce motion of the upper extremity, it is important to briefly review shoulder anatomy, function and kinematics as they have a direct effect on scapular position and motion. Alterations in normal scapular position and kinematics predispose the athlete to a myriad of shoulder and scapulothoracic pathologies. SICK scapula, an overuse muscular fatigue syndrome characterized by excessive scapular protraction and anterior tilt, has been identified as one of many causes of shoulder pain in overhead athletes (Burkhart, Morgan et al. 2003). The signs, symptoms and direct effects of SICK scapula syndrome on overhead motion will be discussed in detail. This literature review will explain the methods for recognizing and assessing SICK scapula syndrome, as they are crucial components of the evaluation process. The review will conclude with a synopsis of current research surrounding scapular dyskinesis and SICK scapula; as well as, a detailed rationale for this research study.

Anatomy overview

The scapula

The scapula is a thin, flat bone that lies on the posterolateral thoracic wall, covering the second and seventh ribs, approximately. This triangular-shaped bone is attached to the axial skeleton by the strut of the clavicle and stabilized onto the chest wall by the muscle attachments to the spinous processes of the ribs (Kibler, WB, 1998). The scapula's thin, wide design allows for smooth gliding along the thoracic wall and provides a large surface area for the attachment of periscapular muscles. The convex posterior scapular surface is divided by the scapular spine into a supraspinous fossa and an infraspinous fossa. The concave costal scapular surface forms the large subscapular fossa. These fossae serve as bony attachment sites for several scapular muscles. The glenoid cavity of the scapula, directed anterolaterally and superiorly, serves as a socket to the humeral head as the scapula articulates with the humerus to form the glenohumeral joint. The acromion and coracoid processes project from the body of the scapula and serve as attachment sites for several ligaments and muscles. The coracoacromial ligament connects these two processes to form the coracoacromial arch, which serves as a protective barrier to superior translation of the humeral head (Carmichael and Hart 1985).

Scapular musculature

Scapulothoracic musculature stabilizes the scapula as a sturdy base throughout glenohumeral motion; as well as, dynamically positions the scapula for efficient glenohumeral motion (Paine and Voight 1993). The scapulothoracic musculature can be subdivided into three groups of muscles: superficial posterior, deep posterior and intrinsic scapulohumeral muscles. The superficial posterior group includes the upper, middle and lower trapezius, the serratus anterior and the latissimus dorsi. The deep posterior group consists of the levator scapulae, rhomboid major and rhomboid minor. Lastly, the intrinsic scapulohumeral muscles consist of the deltoid, supraspinatus, infraspinatus, teres minor, teres major and subscapularis. Although there are 14 muscles that surround and attach to the scapula, the upper and lower portions of the trapezius and the serratus anterior muscles are believed to be the most important for producing upward rotation and retraction of the scapula (Inman, Saunders et al. 1996). Furthermore, the upper and lower trapezius and serratus anterior muscles were found to facilitate scapular external rotation and posterior tilt (Ludewig, Cook et al. 1996), thereby elevating the acromion. Oftentimes, inhibition of the serratus anterior and the lower trapezius is a result of a non-specific response to shoulder pain, rather than a specific response to a glenohumeral pathology (Kibler 1998). Serratus anterior and lower trapezius inhibition is manifested in a lack of acromial elevation and consequent secondary subacromial impingement, which is evident in the early stages of rotator cuff tendinits and glenohumeral instability (Kibler 1998).

Injuries that result in the inhibition or disorganization of the activation patterns of scapular stabilizing muscles adversely alter the normal role of the scapula during coupled scapulohumeral motion; therefore enhancing functional deficits (Kibler and McMullen 2003). Scapular malposition and dyskinesis can lead to alterations in the relationship between length and tension of each muscle, thus adversely affecting muscle force generation (Myers, Laudner et al. 2005).

The shoulder complex

The shoulder is the most complex joint in the body and is comprised of three bones and four articulations (Inman, Saunders et al. 1996). The sternoclavicular (SC) joint is a synovial, biaxial, saddle articulation of the sternum and the sternal end of the clavicle. This joint serves as the only articulation between the upper limb and the axial skeleton. The acromioclavicular (AC) joint is a synovial, uniaxial, plane articulation between the acromion of the scapula and the acromial end of the clavicle. The scapulothoracic articulation, which is not considered a true joint, describes the movement of the scapula along the thoracic wall. Abnormal positioning or motion at the SC or AC joints or the scapulothoracic articulation will undoubtedly alter the function of the arm at the "true shoulder joint", the glenohumeral articulation.

The glenohumeral (GH) joint is a synovial, multi-axial, ball-and-socket articulation of the head of the humerus and the glenoid fossa of the scapula. The glenohumeral joint possesses the most available range of motion of all joints in the human body. Unfortunately, the increase in joint mobility compromises the stability of the joint. Due to the incongruent surfaces between the humeral head and the gleniod fossa, the glenohumeral joint is often illustrated as a "golf ball on a tee." In fact, only 25 to 30% of the humeral head makes contact with the glenoid fossa at any given time (Terry and Chopp 2000). Therefore, the stability of the glenohumeral joint is maintained by static structures, such as the glenohumeral ligaments, the glenoid labrum, and intra-articular pressure, as well as, dynamic structures, namely the glenohumeral and scapulothoracic musculature.

Glenohumeral joint stability

The ligaments of the glenohumeral joint capsule, the glenoid labrum and intra-articular pressure function to provide static joint stability to the glenohumeral joint. Furthermore, dynamic joint stability is provided by glenohumeral and periscapular musculature. Ligaments stabilizing the glenohumeral joint include the coracohumeral ligament and the superior, middle, and inferior glenohumeral ligaments. The glenohumeral and coracohumeral ligaments externally reinforce the anterior aspect of the joint capsule; therefore restricting anterior translation of the humeral head. The coracohumeral ligament and the superior glenohumeral ligament strengthen the capsule superiorly, thus restricting inferior humeral head migration. Both the coracohumeral and the middle glenohumeral ligaments limit external rotation of the humerus, especially between 60 and 90 degrees of humeral elevation (Culham and Peat 1993). The anterior and posterior bands of the inferior glenohumeral ligament provide inferior and anterior joint stability, serving as a hammock to the humeral head during abduction and external rotation (Burkhart, Morgan et al. 2003). Despite the ligamentous reinforcements, the glenohumeral joint capsule remains lax and fits loosely around the humeral head, allowing for 2-3 mm of humeral head distraction from the gleniod fossa (Culham and Peat 1993). The gleniod labrum is a fibrocartilaginous, ring-like structure that serves to enhance and deepen the articulating surface between the humeral head and the glenoid fossa; therefore increasing static joint stability. Intra-articular pressure of the glenohumeral joint provides minimal static stability of the humeral head within the glenoid fossa. Glenohumeral and scapular musculature serve to dynamically stabilize the humeral head within the glenoid fossa. The supraspinatus, infraspintaus, teres minor and subscapularis muscles, collectively known as the rotator cuff complex, act dynamically and synchronically to abduct, depress and rotate the humeral head about the glenoid cavity (Inman, Saunders et al. 1996). The rotator cuff depresses and rotates the humeral head on the glenoid during overhead motion to maximize the articulating surface area; thereby enhancing dynamic joint stability.

Functions of the scapula

The scapula plays an integral role in maintaining ideal glenohumeral articulation to ensure optimal function of the shoulder joint. The scapula must move in coordination with the moving humerus so that the axis of rotation of the glenohumeral joint is constrained within a physiological pattern throughout the full range of shoulder motion (Kibler and McMullen 2003). During overhead activity, the scapula functions to achieve appropriate motions and positions in order to facilitate efficient physiology and biomechanics for optimum shoulder function. (Kibler 1998). The primary role of the scapula is to serve as a stable base of support for the glenohumeral joint, while still facilitating motion along the thoracic wall. This is accomplished by the scapula's ability to move in three dimensions about the trunk while still maintaining glenoid-humeral alignment and proper angulation of the humerus with the trunk (Kibler 1998; Burkhart, Morgan et al. 2003; Kibler and McMullen 2003; Myers, Laudner et al. 2005). Proper alignment of the glenoid allows for optimum function of the bony constraints to glenohumeral motion and allows the most efficient position of the intrinsic muscles of the rotator cuff to allow compression to the glenoid fossa, thereby enhancing the muscular constraint systems around the shoulder. (Kibler 1998, Pink 1996). A second function of the scapula is retraction and protraction along the thoracic wall to facilitate the overhead cocking position. Efficient achievement of the cocking position allows for re-tensioning of the anterior muscular structures and efficient change of muscle phase of contraction from eccentric to concentric on the anterior muscles and concentric to eccentric function on the posterior muscles (Kibler 1998; Fleisig, Andrews et al. 1995). Achieving an optimal cocking position facilitates the explosive acceleration phase of overhead motion. During acceleration, the scapula must protract laterally and then anteriorly around the thoracic wall in order to maintain a normal position with the humerus and also to dissipate some of the deceleration forces that occur as the arm moves forward during the follow-through phase (Kibler 1998; Fleisig, Andrews et al. 1995). A third role of the scapula during overhead activity is elevation of the acromion. The scapula must upwardly rotate in the cocking and acceleration phases to clear the acromion from the moving rotator cuff to decrease impingement and coracoacromial arch compression (Kibler 1998). Coordinated elevation and upward rotation of the scapula with the humerus is important for maintaining sufficient subacromial space as the humerus is elevated to approximately 90 degrees during the throwing motion, thus avoiding rotator cuff impingement in this position (Myers, Laudner et al. 2005; Kibler, 1998). Another role of the scapula is to serve as a base of attachment for several muscles that are critical to optimal upper extremity motion. Kibler et al. (Kibler 1998) has identified three groups of muscles that attach to the scapula, each group performing specific shoulder functions. The first group, which consists of the trapezius, rhomboid, levator scapulae and the serratus anterior muscles, functions to stabilize and rotate the scapula. These muscles attach to the medial, superior and inferior borders of the scapula and control the motion and position of the scapula; thereby enabling the scapula to accomplish its many roles. The second group of muscles, which attach along the lateral aspect of the scapula, includes the deltoid, biceps brachii, and triceps brachii muscles. These extrinsic muscles of the shoulder perform gross motor activities of the glenohumeral joint. Lastly, the third group, consisting of the subscapularis, supraspinatus, infraspinatus and teres minor muscles, form the intrinsic muscles of the rotator cuff. The rotator cuff muscles, which attach along the entire surface of the scapula, work concentrically and eccentrically to compress the humeral head into the glenoid fossa, especially when the arm is between 70º and 100º of humeral abduction. Finally, the scapula's role as a stable and controlled platform is a critical component of the kinetic chain transfer of the large forces and high energy produced by the legs, back and trunk to the arm and hand for delivery (Kibler 1998). The various interrelated functions of the scapula work in concert to maintain the glenohumeral axis of rotation in a path for optimal shoulder joint kinematics, as well as, to provide a sturdy base for muscular attachment.

Scapular positioning

The normal static position of the scapula is thought to be 30-45 degrees anterior to the frontal plane (Poppen and Walker 1976). This position is commonly known as "the scapular plane." Proper three dimensional positioning of the scapula relative to the humerus and the trunk is crucial for optimum muscle function since the scapula serves as the common point of attachment of the rotator cuff musculature, the scapular stabilizers and the primary movers of the humerus (Myers, Laudner et al. 2005). Pathologies of the shoulder or scapula are closely associated with scapular malposition and dyskinesis. Ludewig and Cook (2000) observed decreased scapular upward rotation and decreased posterior tilt during humeral elevation in patients with subacromial impingement. Moreover, patients suffering from subacromial impingement demonstrated less scapular elevation, in addition to decreased posterior tilting

(Lukasiewicz, McClure et al. 1999). In fact, alterations in scapular position occur in 32% of patients with glenohumeral instability and in 57% of patients suffering from subacromial impingement (Warner, Micheli et al. 1992). Burkhart et al and Kibler (Burkhart, Morgan et al. 2003; Kibler and McMullen 2003) determined that altered three-dimensional scapular kinematics are closely associated with subacromial impingement, labral abnormality and rotator cuff pathologies.

Scapular kinematics

Three-dimensional scapular motion is described according to the scapula's relative orientation on the thoracic wall (Karduna, McClure et al. 2001). Scapular rotations about three axes are used to describe the orientation of the scapula relative to the thorax. Ludewig et al. describes scapular rotation about an axis perpendicular to the plane of the scapula as upward or downward rotation, rotation about an axis parallel to the scapular spine as anterior or posterior tilting, and rotation around a vertical axis as internal or external rotation (Ludewig, Cook et al. 1996). Rotations of the clavicle are used to describe the position of the scapula on the thorax and include protraction and retraction and elevation and depression (Karduna, McClure et al. 2001). The ability of the scapula to move in three dimensions about the trunk while maintaining glenohumeral alignment and proper angulation of the humerus with the trunk enables the scapula to be a stable base of support between the humerus and the trunk, while still allowing for the high degree of movement needed for the upper extremity (Myers, Laudner et al. 2005). McClure and Michener (McClure, Michener et al. 2001) observed the normal scapular kinematic pattern during arm elevation to be progressive scapular upward rotation, external rotation and posterior tilt, with the clavicle simultaneously retracting and elevating.

Any observable alterations in the position of the scapula and the patterns of scapular motion in relation to the thorax are characteristic of a dyskinetic scapula (Kibler and McMullen 2003). Abnormal scapular kinematics and associated muscle function presumably contribute to shoulder pain and pathology (Ludewig, Cook et al. 1996). In fact, alterations in scapular motion have been observed in 64% of patients with glenohumeral instability and in 100% of patients suffering from subacromial impingement (Warner, Micheli et al. 1992). As the dyskinetic scapula deviates into increased anterior tilting, increased internal rotation, and decreased upward rotation, the subacromial space is reduced; thereby compressing the subacromial structures (Borstad and Ludewig 2002).

Scapulohumeral rhythm

Scapulohumeral rhythm describes the movement of the scapula relative to the movement of the humerus throughout the full range of glenohumeral abduction. Inman et al. (Inman, Saunders et al. 1996) observed that during the first 30 to 60 degrees of humeral abduction and flexion, the scapula stabilizes itself against the thoracic wall. Furthermore, Kibler (Kibler 1998) suggested that the scapula moves laterally during the first 30 to 50 degrees of glenohumeral abduction. This is known as the setting phase. As abduction increases, the scapula upwardly rotates one degree for every two degrees of humeral abduction; therefore creating a 2:1 humerus to scapula movement ratio (Inman, Saunders et al. 1996). As humeral abduction increases, the scapula rotates about a fixed axis through an arc of approximately 65 degrees as the shoulder reaches full elevation. From 90 degrees to full abduction, the scapula abducts and upwardly rotates one degree for each one degree of humeral elevation, a 1:1 movement ratio. For the scapula to abduct and upwardly rotate throughout the entire 180 degrees of humeral abduction, the clavicle must elevate approximately 40 degrees and rotate in a posterosuperior direction at least 10 degrees (Andrews and K. 1994)

Pathophysiology of the SICK scapula syndrome

Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition and scapular dyKinesis are characteristic findings of SICK scapula (Burkhart et al., 2003).

Asymmetric scapular malposition, which typically presents as the involved shoulder being lower than the other, is actually a rotational malposition of the scapula in excessive protraction and anterior tilt (Burkhart, Morgan et al. 2003). In this position, the coracoid is tilted anteroinferiorly and laterally, placing the pectoralis minor and short head of the biceps muscles in an adaptively tight position. Tightness in the pectoralis minor and short head of the biceps muscles may enhance anterior tilt and forward pull on the scapula, resulting in increased scapular protraction (Kibler and McMullen 2003).

The prominence of the scapular inferior medial border is primarily due to abnormal rotation around a transverse axis (Kibler and McMullen 2003). The prominent inferior medial border may be a result of weakness of the serratus anterior muscle. Because the serratus anterior functions to stabilize the scapula along the thoracic wall, inhibition of this muscle causes the scapula to move laterally and posteriorly away from the thorax, giving the appearance of a "winged scapula." The winging scapula is particularly evident during controlled, eccentric lowering of the arm from an overhead position (Borstad and Ludewig 2002).

Coracoid pain associated with SICK scapula presents as tenderness on the medial tip of the coracoid at the point of insertion of the pectoralis minor tendon. Coracoid tenderness is a result of scapular malpositioning in excessive protraction and anterior tilt, which produces tight pectoralis minor and short head of the biceps muscles. This tightness lowers the leading edge of the acromion; thereby enhancing scapular malposition and decreasing the available range of motion of the arm (Burkhart, Morgan et al. 2003). Athletes with coracoid pain resulting from SICK scapula usually lack full active humeral flexion with the affected arm and have accentuated coracoid pain as the clinician attempts maximum passive forward flexion (Burkhart, Morgan et al. 2003).

Scapular dyskinesis describes alterations of scapular position, at rest or with coupled arm motion, that create clinical dysfunction of the shoulder and that are commonly associated with injury (Kibler and McMullen, 2003). Scapular dyskinesis is described as a non-specific response to shoulder dysfunction since no specific pattern of dyskinesis is associated with a specific shoulder diagnosis.

Since scapular dyskinesis could not be classified according to shoulder diagnosis, Burkhart, Morgan, and Kibler (Burkhart, Morgan et al. 2003) categorized the altered scapular kinematic patterns into three classifications of SICK scapula: Type I, Type II and Type III. Type I is characterized by an inferior medial scapular border prominence resulting from an abnormal rotation around the transverse axis of the scapula. Type II is classified as a medial scapular border prominence resulting from an abnormal rotation around the scapula's vertical axis. Lastly, type III involves a superior translation of the entire scapula yielding the prominence of the superior medial border of the scapula. Type I and Type II SICK scapula are most commonly associated with glenohumeral labral pathology, while Type III is related to impingement and rotator cuff lesions (Burkhart, Morgan et al. 2003).

Subjective Findings of SICK scapula syndrome

The most commonly presented complaint associated with SICK scapula syndrome is anterior shoulder pain at the medial aspect of the coracoid process. This pain may be due to the static malposition of the coracoid and the resulting scapular dyskinesis (Burkhart, Morgan et al. 2003). Athletes who present with SICK scapula may also report posterior superior scapular pain or superior scapular pain that radiates into the ipsilateral paraspinous cervical region, especially along the levator scapulae muscle. Scapular malpositioning in excessive scapular protraction and anterior tilt place traction on the levator scapulae; hence creating pain and muscle spasm (Burkhart, Morgan et al. 2003). Athletes suffering from SICK scapula may also complain of proximal lateral arm (subacromial pain); however the cause of this pain is not found to be true mechanical subacromial impingement. Rather, the true origin of this subacromial pain is rooted in a malpositioned dyskinetic acromion resulting from scapular protraction during all phases of the throwing cycle (Burkhart, Morgan et al. 2003). Lastly, the athlete with SICK scapula may possibly experience radicular, thoracic outlet symptoms into the arm, forearm and hand. These symptoms are the result of an anteroinferiorly positioned lateral clavicle that decreases the space of the subclavian chest wall; thus impinging the brachial plexus (Burkhart, Morgan et al. 2003).

Current research suggests that coracoid pain is the most frequently reported symptom of SICK scapula. Morgan (Burkhart, Morgan et al. 2003) diagnosed and treated 96 overhead athletes with SICK scapula syndrome and found that 80% presented with coracoid pain, while 70% presented with both coracoid pain and posterosuperior scapular pain. Only 20% of the athletes reported proximal lateral arm (subacromial) pain, 5% presented with AC joint pain and another 5% reported thoracic outlet radicular symptoms into the arm, forearm and hand.

Methods for assessing scapular orientation and position

The scapula can be assessed qualitatively and quantitatively in both static and dynamic positions. Static qualitative assessment involves visual inspection by the clinician. The statically observable lowered scapular position is suggestive of underlying muscle activation alterations that produce altered kinematics of the scapula upon dynamic use. (Burkhart, Morgan et al. 2003). The static quantitative assessment involves collecting landmark measurements and movement ratios using tests such as the lateral scapular slide test. Qualitative dynamic assessment requires visual inspection by the clinician. If the clinician suspects scapular dyskinesis, a scapular retraction test should be conducted to determine if scapular repositioning reduces the athlete's pain. The scapular retraction test reduces the effects of impingement by repositioning the scapula in retraction which decreases glenoid anterior tilt and reduces mechanical impingement and pain (Burkhart, Morgan et al. 2003). Quantitative dynamic assessment is performed using an electromagnetic tracking system to collect precise three-dimensional scapular kinematic data.

The researchers in this study implemented two methods in order to collect data on the subjects' scapular position and orientation. The SICK Scapula, Static Measurements point scale (Burkhart & Morgan et al. 2003) was utilized to collect both qualitative, subjective and quantitative, objective information (Figure 1). Also, the researchers collected quantitative data using an electromagnetic tracking device to capture three-dimensional scapular kinematic data as subjects performed two functional tasks.

SICK Scapula, Static Measurements point scale

The SICK Scapula, Static Measurements, 0 to 20 point scale (Burkhart, Morgan et al. 2003) is a measurement scale that awards points for subjective complaints, objective findings and the presence and severity of scapular malposition (Figure 1). The subjective assessment involves awarding one point for complaint of pain over each of the following areas: pain over the coracoid process, acromioclavicular joint, periscapular region, proximal lateral arm or radicular pain. The objective assessment involves awarding one point for complaint of tenderness or pain from palpation of the coracoid process, the acromioclavicular joint and the superior medial angle of the scapula. Objective evaluative testing consists of the scapular assistance test and clinical tests for subacromial impingement and thoracic outlet paresthesia. Positive results from these tests would warrant addition of points. Quantitative static measurements of scapular malpositioning are taken in three modes. The first, infera, is the difference in vertical height between the superomedial scapular angle of the SICK scapula and the superomedial angle of the contralateral scapula. The second, scapular lateral displacement, is measured as the distance (in cm) between the superomedial scapular angle from the midline. The third measurement, scapular abduction, involves using a standard goniometer to measure the angular degrees from the medial scapular margin to plumb midline. Scapular measurements between the involved and uninvolved scapulae are compared. Scale points are awarded as the discrepancy between the involved and uninvolved scapular measurements reaches and or exceeds one centimeter or five degrees. The scores of the subjective, objective and scapular measurement sections are summed to achieve a total score. A score of zero represents an asymptomatic, symmetrical scapula; whereas a score of 20 represents the worst asymmetrical, symptomatic scapula (Burkhart, Morgan et al. 2003).

The SICK Scapula Static Measurements Scale was devised as a clinical tool to statically assess the severity of the syndrome at the time of presentation and to objectively monitor clinical improvement during the treatment phase (Burkhart, Morgan et al. 2003). Although this grading system for the severity of scapular malposition is based on several measurements, Burkhart et al. recognized that the use of superficial landmarks may make the measurements less reliable and less reproducible than desired (Burkhart, Morgan et al. 2003). However, the SICK Scapula Static Measurements Rating Scale can be incorporated to provide clinicians with a qualitative sense of the severity of the SICK scapula syndrome and with a method of measuring an athlete's progress during a rehabilitation program.

Currently, no research has been conducted to assess the reliability and precision of the SICK Scapula Static Measurements Rating Scale. Prior to the study, reliability and precision of the SICK scapula static measurements point scale were established from a small pilot study by the principle investigators using intra-class correlation coefficient (ICC) and standard error of measurement (SEM). The inter-session reliability and precision were calculated to yield an ICC of 0.682 and SEM of 1.44 points, respectively. The inter-tester reliability and precision were calculated to yield an ICC of 0.684 and SEM of 1.18 points, respectively.

Electromagnetic tracking

The Motion Star (Ascension Technology Corp, Burlington, VT) electromagnetic tracking device integrated with MotionMonitor (Innovative Sports Training, Inc, Chicago, Ill) motion-capture software was utilized to collect three-dimensional kinematic data of the scapula and humerus. Miniature electromagnetic receivers were secured with double sided adhesive tape, athletic tape and elastic pre-wrap over the spinous process of the seventh cervical vertebrae, over the flat, broad portion of the right and left acromion processes and over the posterior aspect of both humeri at the area of least muscle mass. A fourth receiver was attached to a stylus to be used for digitization of landmarks (Myers, Laudner et al. 2005; Thigpen, Padua et al. 2006).

The electromagnetic receiver position and orientation data of the thoracic, scapular and humeral receivers were transformed into a local coordinate system for each of the respective segments. The local coordinate system for each segment was defined according to the recommendations established by the International Shoulder Group of the International Society of Biomechanics (Wu 2005). Two points first defined the segment's longitudinal axis with a third point defining the plane. A second axis was determined perpendicular to the plane, and the third axis was defined as perpendicular to both of the first two axes. When standing in a neutral stance, the orthogonal coordinate system for each segment will be vertical (y-axis), horizontal to the right (x-axis), and posterior (z-axis). Matrix transformations for each of the segments were used to move from the global to local coordinate systems, producing a 4 x 4 position and orientation matrix.

Euler-angle decompositions were used to describe humeral and scapular orientation with respect to the thorax. Scapular orientation was defined using three axes with the acromial angle serving as the origin: the z-axis described the vector from thoracic spine to acromial angle; the x-axis described the vector perpendicular to the plane set by the thoracic spine, acromial angle and inferior angle of scapula; and the y-axis is defined as the vector perpendicular to the x and z axes. Orientation of the scapula was described as rotation about the y-axis of scapula (internal/external rotation), rotation about the x-axis of the scapula (upward/downward rotation), and rotation about the z-axis of scapula (anterior/posterior tilt). Each of these rotations was chosen based on the recommendations of the International Shoulder Group (Wu 2005).

Position of the scapula was described in terms of elevation/depression and protraction/retraction. Scapulothoracic movement does not involve any bone-bone contact and the scapula does not attach directly to the thorax. The only attachment of these two segments is via the clavicle, a rigid body with a fixed length. As such, the position of the scapula can be described by two degrees of freedom as if in spherical space, by both elevation/depression and protraction/retraction (Karduna, McClure et al. 2001; McClure, Michener et al. 2001). The position of the angulus acromialis (AA) and incisura jugularis (IJ) points with respect to the global coordinate system (tracked by the scapular and thoracic receivers, respectively) were used to calculate a vector from the IJ point to the AA point. The angle of this vector relative to the transverse plane that bisects the IJ point represented scapular elevation/depression of the scapula. For scapular protraction/retraction, this vector was projected onto the transverse plane bisecting IJ and was calculated as the angle between this projection and the frontal plane that bisects IJ.

Current research

SICK Scapula, Static Measurements point scale

Burkhart et al. (Burkhart, Morgan et al. 2003) reported unpublished data from a study conducted by P. Donely and J. Cooper that assessed a group of 19 asymptomatic professional baseball players who met the qualifying criteria for SICK scapula. These healthy athletes were studied to determine if scapular malpositioning is a normal adaptive phenomenon in the overhead athlete. The athletes in this study exhibited no evidence of a SICK scapula or even scapular asymmetry as measured with a 20 point SICK Scapula, Static Measurements scale. Donely and Cooper discovered that the healthy overhead athlete exhibited no component of the SICK scapula syndrome; therefore confirming that SICK scapula syndrome is abnormal and predisposes the shoulder to pathologic symptomatology (Burkhart, Morgan et al. 2003).

Electromagnetic tracking device

McClure et al. (McClure, Michener et al. 2001) studied scapular motion patterns during dynamic shoulder movement using a direct technique involving the insertion of two bone pins into the spine of the scapula. One three-dimensional motion receiver was fixed to the bone pins, one to the third thoracic spinous process with tape, and one to the humerus with a specially designed cuff. Scapular kinematic data was collected as the subjects performed three tasks: elevation of the humerus in the scapular plane, elevation of the humerus in the sagittal plane, and humeral external rotation. The researchers observed that during humeral elevation in the scapular plane, the scapula upwardly rotated, tilted posteriorly around a medial-lateral axis, and externally rotated around a vertical axis; while the clavicle elevated and retracted. Interestingly, researchers found that the scapular kinematics during humeral elevation in the sagittal plane did not differ substantially from the kinematics during scapular plane elevation. Results from the humeral external rotation task showed the majority of motion to occur at the end-range of external rotation as the scapula upwardly rotated, tilted posteriorly and externally rotated, while the clavicle retracted. In addition, the researchers found the mean ratio of glenohumeral to scapuolothoracic motion to be 1.7:1. McClure et al. (McClure, Michener et al. 2001) implemented an invasive method of scapular tracking utilizing bone pins and an electromagnetic tracking system to observe three-dimensional scapular kinematic patterns during dynamic humeral motions. Based on the results from this study, these researchers concluded that normal scapular motion consists of substantial rotation around three axes, not simply upward rotation.

Karduna et al. (Karduna, McClure et al. 2001) assessed the accuracy of measuring three-dimensional dynamic scapular kinematics utilizing two non-invasive methods with an electromagnetic tracking device. Whereas McClure et al. studied scapular kinematics utilizing invasive bone pins into the scapular spine, Karduna and associates compared the accuracy of two non-invasive measurement techniques: one method involved securing a receiver directly to the acromion, while the other method involved mounting a receiver to an adjustable plastic jig that fit over the scapular spine and acromion. These two separate methods were implemented to collect scapular kinematic data as subjects performed four active humeral motions: elevation of the humerus in the scapular plane, elevation of the humerus in the sagittal plane, horizontal adduction and internal to external rotation. The concurrent validity of both methods was assessed separately by comparison with data collected simultaneously from an invasive approach in which bone pins were drilled directly in to the scapula. Based on the results from this study, Karduna concluded that both methods may offer reasonably accurate representations of scapular motion that could be helpful in detecting motion abnormalities associated with shoulder pathologies, as well as, in assessing alterations in kinematics following treatment interventions (Karduna, McClure et al. 2001).

Myers et al. (Myers 2006) studied the reliability and precision of in vivo scapular kinematic measurements using an electromagnetic tracking devices. Three electromagnetic receivers were secured to various anatomical landmarks for kinematic analysis of the scapula and the humerus during humeral elevation and depression in the sagittal, scapular and frontal planes. Reliability of all scapular kinematic variables during humeral movements was established with the use of ICCs, which provide a numeric indication of the repeatability between trials. The intrasession reliability for most of the scapular kinematic variables in this study exceeded .90, thus indicating a level of high reliability when comparing data between trials within testing sessions. Therefore, the results of this study suggest that in vivo scapular kinematics can be assessed with an electromagnetic tracking device with reasonable reliability. In addition, Myers et al. calculated the intrasession precision level, which is recorded as the standard error of measurement or SEM, for each scapular kinematic variable during each humeral movement. The SEM represents the expected unit-based standard deviation for a particular measurement. In most cases, the intrasession SEM was calculated to be below two degrees of error; therefore indicating good precision. All reliability coefficients were greater than .93, with less than 0.5 degrees of error. Myers et al. (Myers 2006) suggest that in vivo scapular kinematics can be measured with high reliability and precision with intrasession research designs using an electromagnetic tracking devices.

The researchers in this study of the SICK Scapula Static Measurements Rating Scale in overhead athletes based the methodological procedures and protocols upon the results of the current scapular kinematic research conducted by McClure, Karduna, Myers and other researchers. For this study, the researchers implemented a non-invasive approach utilizing a three-dimensional electromagnetic tracking system to observe scapular kinematic patterns during dynamic humeral movements.

Rationale for the study

A malpositioned and dyskinetic scapula produces alterations in both static positioning and dynamic movements of the glenohumeral and acromioclavicular joints; as well as, altered function of the muscles that insert on the scapula. Because of these complex interrelationships, the presence of SICK scapula syndrome may result in a spectrum of clinical complaints originating from any or all of these anatomical locations. (Burkhart, Morgan et al. 2003). Therefore, the researchers in this study collected qualitative and quantitative, subjective and objective data utilizing the SICK Scapula, Static Measurements Point Scale and the Motion Monitor electromagnetic tracking device in order to examine any predictive relationships between scapular kinematics and contributing factors of SICK scapula syndrome. The results from this research should aid clinicians in effectively recognizing and evaluating athletes with SICK scapula; as well as, providing clinicians with a better understanding of the effects of SICK scapula syndrome on the shoulder complex. Furthermore, results from this study may help clinicians in determining the most effective rehabilitation exercises to correct scapular malposition and dyskinesis; thereby, reducing the risk for further injury to the glenohumeral joint.

CHAPTER III

METHODS

Participants

One group of forty overhead athletes (12 female swimmers, 8 male swimmers, 9 female volleyball players, 10 female softball players) participated in this study (Table 1). Subjects were recruited from a population of male and female NCAA Division I and recreational club athletes, ages 18 to 25 years old, who participated in overhead athletic activity for a minimum duration of 30 minutes, 3 times a week. Overhead athletic activity was defined as a sport that requires the arm to be above shoulder height on a repetitive basis during throwing or striking activities (swimming, tennis, volleyball, baseball, softball).

Exclusion criteria

Subjects were excluded from this study if they had medical history of shoulder or neck surgery, cervical spine pathology, adhesive capsulitis of the shoulder, rotator cuff lesions, scoliosis, acute acromioclavicular joint injury, or glenohumeral joint subluxations or dislocations within the past six months.

Instrumentation

Screening for SICK scapula

The researchers used the SICK Scapula, Static Measurements, 0-20 point Rating Scale to screen overhead athletes for the presence of SICK scapula (Burkhart, Morgan et al. 2003). Prior to the study, reliability and precision of the SICK scapula static measurements point scale were established from a small pilot study by the principal investigators. The inter-session reliability and precision were calculated and yielded an ICC of 0.682 and SEM of 1.44 points, respectively. The inter-tester reliability and precision were calculated and yielded an ICC of 0.684 and SEM of 1.18 points, respectively.

Scapular kinematics

The Motion Star (Ascension Technology Corp, Burlington, VT) electromagnetic tracking device integrated with Motion Monitor (Innovative Sports Training, Inc, Chicago, Ill) motion-capture software was utilized to collect three-dimensional scapular kinematics. The Motion Star system has been shown to be accurate within 1.8mm for linear displacements and 0.5º for angular displacements (Thigpen, Padua et al. 2006). The Motion Star tracking system consisted of a transmitter and six miniature receivers. The transmitter emitted a low-frequency electromagnetic field, which was detected by the receivers. Each receiver was able to calculate receiver position relative to three planes and to orientate motion around 3 axes, thus allowing six degrees of freedom to be measured. The relative orientation and position of the receivers within the electromagnetic field were relayed to the computer and were processed and displayed using the Motion Monitor motion-capture software. All scapular and glenohumeral kinematics were sampled at a rate of 100 Hz. Three-dimensional scapular kinematic data was recorded in degrees of scapular anterior/posterior tilt, upward/downward rotation and internal/external rotation. Scapular position was recorded as degrees of elevation/depression and protraction/retraction.

Procedures

Subjects reported to the university-based laboratory for one session lasting approximately 90 minutes. Prior to participation, all subjects completed an informed consent form approved by the University Biomedical Review Board.

Female subjects wore a sports bra and males were shirt-less during testing to allow access to the scapula. Prior to the testing session, subjects were screened for both inclusion and exclusion criteria. The subjects who met the criteria proceeded to the testing procedures. All procedures were performed on the subjects' testing arm, determined by either the subjects' self-reported painful arm, or if no pain was reported, by dominant arm. Subjects were screened by both principal investigators who were blinded to each other's screening process and to the resulting SICK score until both screenings were completed. The subject's overall SICK score was taken as the mean of the two scores obtained from the blinded screenings.

Protocol

In preparation for the collection of three-dimensional scapular kinematics, electromagnetic receivers were secured on the subject's body segments with double-sided adhesive tape, athletic tape and elastic pre-wrap over the following landmarks: the spinous process of the seventh cervical vertebrae, the flat, broad portion of the acromion process of the scapula (bilaterally), and the posterior aspect of humerus just distal to triceps brachii muscle belly (bilaterally) (Table 2). A fourth receiver was secured to a stylus that was used for digitization of landmarks (Myers, Laudner et al. 2005; Thigpen, Padua et al. 2006).

After securing the receivers, subjects stood with their arms hanging naturally beside their body while the investigator digitized the bony landmarks on the thorax, humerus and scapula to allow transformation of the receiver data from the global coordinate system to anatomically based local coordinate systems. The sensor placement and the landmarks used to define the local coordinate system were in accordance to the recommendation of International Society of Biomechanics Shoulder Group (Table 3).

Once preparation was completed, the subject performed two tasks: glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane. The researcher implemented counterbalancing of tasks by assigning task order prior to subject testing. Both motions occurred through a range of motion of approximately 0º of humeral elevation to approximately 180 º of humeral elevation in their respective planes of motion. Subjects elevated both arms to the terminal end point in the available range of motion while maintaining a neutral hand position throughout the entire range of motion.

The plane of humeral elevation and the speed of the movement during the two tasks were standardized across subjects with the use of PVC pipes and metronome. Tasks were performed bilaterally, from a standing position, feet at a comfortable width and eyes fixed forward. A pole made of PVC pipe was placed 30º anterior to the frontal plane of the thorax to serve as a guide for subjects performing glenohumeral elevation in the scapular plane (scaption). The pole was placed in the humeral sagittal plane and used as a guide during glenohumeral elevation in the sagittal plane. Subjects were asked to complete their full range of motion bilaterally at a controlled movement velocity by moving in time with a digital metronome set at 1 Hz.

Subjects were allowed three practice trials of each functional task to be tested: glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane (30º anterior to the frontal plane of thorax). Each functional task consisted of ten continuous repetitions, with each repetition lasting approximately four seconds (two-second ascending phase, two-second descending phase). After the completion of the first task, subjects were allowed a two-minute rest before starting the next task.

Data Reduction

Raw kinematic data were low pass filtered with a fourth-order zero-phase shift at a 6.6 Hz cut off frequency (Ludewig and Cook 2000; Borstad and Ludewig 2002; Myers, Laudner et al. 2005; Thigpen, Padua et al. 2006). Scapular position and orientation were analyzed at 0 º, 30 º, 60 º, 90 º and 120 º of the ascending phase of glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane.

The position and orientation data of the thoracic, scapular and humeral receivers were transformed into a local coordinate system for each of the respective segments. Definitions of the local coordinate systems are presented in Table 3. The coordinate systems used were in accordance with recommendations established by the International Shoulder Group of the International Society of Biomechanics (Wu 2005). Two points first defined the segment's longitudinal axis with a third point defining the plane. A second axis was determined perpendicular to the plane, and the third axis was defined as perpendicular to both of the first two axes. When standing in a neutral stance, the orthogonal coordinate system for each segment was vertical (y-axis), horizontal to the right (x-axis), and horizontal to the posterior (z-axis). Matrix transformations for each of the segments were used to move from the global to local coordinate systems, producing a 4 x 4 position and orientation matrix.

Euler-angle decompositions were used to describe scapular orientations with respect to the thorax. Scapular orientation was defined using three axes with the acromial angle serving as the origin: the z-axis described the vector from thoracic spine to acromial angle; the x-axis described the vector perpendicular to the plane set by the thoracic spine, acromial angle and inferior angle of scapula; and the y-axis is defined as the vector perpendicular to the x and z axes. Orientation of the scapula was described as rotation about the y-axis of scapula (internal/external rotation), rotation about the x-axis of the scapula (upward/downward rotation), and rotation about the z-axis of scapula (anterior/posterior tilt). Each of these rotations was chosen based on the recommendations of the International Shoulder Group (Wu 2005).

Scapulothoracic movement does not involve any bone-bone contact and the scapula does not attach directly to the thorax. The only attachment of these two segments is via the clavicle, a rigid body with a fixed length. As such, the position of the scapula was described by two degrees of freedom: elevation/depression and protraction/retraction (Karduna, McClure et al. 2001; McClure, Michener et al. 2001). The position of the angulus acromialis (AA) and incisura jugularis (IJ) points with respect to the global coordinate system (tracked by the scapular and thoracic receivers, respectively) were used to calculate a vector from the IJ point to the AA point. The angle of this vector relative to the transverse plane that bisects the IJ point represented scapular elevation/depression of the scapula. For scapular protraction/retraction, this vector was projected onto the transverse plane bisecting IJ and was calculated as the angle between this projection and the frontal plane that bisects IJ.

Statistical analysis

Simple linear regression analyses were performed implementing scapular kinematic variables as the predictor of score on SICK Scapula, Static Measurements Rating Scale. The analyses were run separately for each scapular kinematic variable at each humeral angle for both tasks. A total of fifty linear regression analyses were performed. An alpha level of .05 was set prior to the study. Due to performing multiple comparisons within the five orthogonal humeral angles of the tasks' ascending phase, an adjusted alpha level of 0.01 was implemented in order to control for inflation of the type I errors. SPSS version 13.0 was the statistical software program utilized to perform analyses.

CHAPTER IV

RESULTS

Forty, NCAA division I and/or recreational overhead athletes (10 softball players, 21 swimmers, and 9 volleyball players; 33 right arm dominant, 7 left arm dominant) participated in this study. Due to errors in data analysis, one subject was dropped from this study. Of the remaining 39 participants, 22 reported current shoulder pain. The descriptive statistics for participant demographics and their SICK Scapula Score are presented in Table 1.

Statistical Results

Descriptive statistics for each scapular variable at the ascending angles of the humeral flexion and scaption tasks are presented in Table 4 and Table 5, respectively.

A simple linear regression indicated that scapular upward rotation at zero degrees of humeral elevation in the sagittal plane significantly predicts the overall SICK score ($F(1,37) = 9.812$, $p = .003$, $r^2 = .210$). The mathematical prediction equation for this regression would be: Overall SICK score = .230 (Upward/Downward Rotation at 0 degrees humeral elevation) + 4.167. Figure 1 represents this weak, significant predictive relationship.

A simple linear regression indicated that scapular upward rotation at 30 degrees of humeral elevation in the sagittal plane significantly predicts the overall SICK score ($F(1,37) = 8.107$, $p = .007$, $r^2 = .180$). The mathematical prediction equation for this regression would be: Overall SICK score = .198 (Upward/Downward Rotation at 30 degrees humeral elevation) + 3.015. The graphic representation for this weak linear relationship appears in Figure 2.

A simple linear regression indicated that scapular elevation at zero degrees of humeral elevation in the sagittal plane significantly predicts the SICK score ($F(1,35) = 8.040$, $p = .008$, $r^2 = .187$). The mathematical prediction equation for this regression would be: Overall SICK score = .247 (Elevation/Depression at 0 degrees humeral elevation) + 1.820. Figure 3 depicts this weak linear relationship.

The remaining 22 scapular kinematic variables for sagittal plane elevation; as well as, all 25 scapular kinematic variables for scapular plane elevation were found to not be significant predictors of SICK Scapula score.

CHAPTER V

DISCUSSION

The purpose of this study was to determine the predictive relationship between scapular kinematic data analysis and overhead athlete score on the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale. Had this scale been proven to be a predictor of scapular dysfunction, results from three-dimensional scapular and humeral kinematic data would have illustrated the findings compromising the subject's SICK scapula score.

The most important finding of our study was that the SICK Scapula, Static Measurements, 0 to 20 point rating scale did not prove to be a strong predictor of scapular dysfunction in overhead athletes. During humeral elevation in the sagittal plane, scapular upward rotation at zero degrees, scapular upward rotation at thirty degrees, and scapular elevation at zero degrees were found to be statistically significant predictors of an increased SICK scapula score. We found no significant relationships between scapular kinematics and SICK scapula score during humeral elevation in the scapular plane. These findings were considered significant based upon obtaining a p-value of .01 or less; however, the strength of the significant relationship between scapular kinematic data and subject SICK score, represented by the r^2 value, proved to be extremely weak for all scapular variables.

Despite our hypotheses that increased scapular anterior tilt, increased scapular internal rotation and excessive protraction coupled with decreased scapular upward rotation and elevation would predict an increased SICK scapula score, no statistical significance was found for the relationship between scapular internal/external rotation, scapular anterior/posterior tilt, and scapular retraction/protraction on the subject's SICK scapula score. This lack of statistically significant relationships between the kinematic data of the SICK scapula trademark positions (increased anterior tilt, internal rotation and protraction) and subject score on the SICK Scapula Static Measurements scale questions the scale's predictive value and ability to detect scapular dysfunction. Moreover, the significant results found with scapular upward rotation and scapular elevation during the humeral flexion task were very weak predictive relationships.

We expected to see relationships between the scapular kinematic variables and the subjects' SICK scapula score based on the current literature describing the altered scapular kinematic patterns that are associated with repetitive overhead motions which cause shoulder pain and altered muscle force couple production. Current research shows that scapular kinematics may be altered by weak or dysfunctional scapular musculature (Ludewig and Cook 2000), fatigue of the infraspinatus and teres minor (Tsai 1998), and changes in thoracic and cervical spine posture (Ludewig, Cook et al. 1996; Kebaetse, McClure et al. 1999). The researchers recognized that the participants in this study may display one or several of the previously mentioned contributors to scapular dyskinesis due to muscular and postural changes induced by repetitive overhead motions.

Furthermore, recent research in patients with subacromial impingement syndrome has demonstrated decreased scapular posterior tilt, decreased scapular upward rotation and decreased scapular external rotation during glenohumeral elevation (Lukasiewicz, McClure et al. 1999; Ludewig and Cook 2000; Endo, Ikata et al. 2001). Based on this literature, we hypothesized that the participants in the current study would display decreased scapular upward rotation, decreased scapular external rotation and decreased scapular posterior tilt, similar to the patients with subacromial impingement, due to the participants' report of shoulder pain, the participants' observed posture of excessive scapular protraction and anterior tilt, and the frequency of overhead motion during the participants' sport training.

Our results regarding scapular kinematics in overhead athletes are in contrast to some findings of current research on subacromial impingement. Ludewig et al. (Ludewig and Cook 2000) demonstrated that subjects who reported symptoms of subacromial impingement displayed decreased scapular upward rotation, increased scapular anterior tipping, and increased scapular internal rotation during humeral elevation in the scapular plane. Similarly, Endo et al. (Endo, Ikata et al. 2001) reported decreased scapular posterior tilt and decreased scapular upward rotation in subjects with subacromial impingement. In contrast, we demonstrated that increases in scapular upward rotation and elevation at zero degrees and with scapular upward rotation at thirty degrees of humeral elevation in the sagittal plane were significant predictors of an increased SICK scapula score. Interestingly, we found no significant relationships for scapular anterior/posterior tilt or scapular internal/external rotation on SICK scapula score. However, our results demonstrating a weak predictive relationship between increased scapular elevation at zero degrees of humeral elevation and increased SICK scapula score are in agreement with findings of Lukasiewicz et al. (Lukasiewicz, McClure et al. 1999) which displayed increased scapular elevation in subjects reporting symptoms of subacromial impingement.

Our results are supported by the findings of McClure et al. (McClure, Michener et al. 2006) who displayed greater scapular upward rotation and clavicular elevation during mid-range humeral flexion in subjects with subacromial impingement. Interestingly, McClure et al. (McClure, Michener et al. 2006) found no differences between groups in forward shoulder posture; which is believed to capture potential tightness of the pectoralis minor muscle and to manifest as excessive scapular protraction and coracoid pain. Similarly, we also found no significant results regarding the degree of scapular protraction in predicting the presence of SICK scapula syndrome in overhead athletes.

Although the previously mentioned studies specifically address subacromial impingement and not SICK scapula syndrome, the results may be relevant to SICK scapula syndrome because scapular malposition and dysfunction are major contributors to subacromial impingement (Hebert, Moffet et al. 2002). Similarities in pathological signs and symptoms confirm that scapular malposition and dyskinesis are inherent to both SICK scapula syndrome and subacromial impingement. Therefore, the scapular kinematics observed in the subacromial impingement studies were considered to be relevant and applicable to the participants in our study of SICK scapular syndrome.

We demonstrated that increases in scapular upward rotation at zero degrees and at thirty degrees of humeral elevation in the sagittal plane were found to be weak predictors of an increased SICK scapula score. Although, these findings are in contrast to the results of the previously mentioned studies of patients with subacromial impingement, the increased scapular upward rotation of participants in the current study may be explained by the findings of Myers et al (Myers, Laudner et al. 2005). In a study of scapular position and orientation in throwing athletes, Myers et al. demonstrated that normal, healthy throwing athletes may develop an adaptive increase in scapular upward rotation to assist in subacromial clearance throughout the throwing movement pattern; thereby preventing subacromial impingement. In addition, Myers et al. acknowledged that scapular malpositioning may exist in the absence of and as a prevention to shoulder pain and dysfunction. These preventative adaptations could explain why there were participants in our study who did not report shoulder pain but who displayed increases in scapular upward rotation and elevation. Furthermore, current research displays that coordinated elevation and upward rotation of the scapula with the humerus is important for maintaining sufficient subacromial space as the humerus is elevated to approximately 90° during the throwing motion, thus avoiding impingement of the rotator cuff in this position (Dillman, Fleisig et al. 1993; Kibler 1998; Myers, Laudner et al. 2005).

Based on the literature describing these adaptations in overhead athletes, it is not surprising that we observed that increases in scapular upward rotation and elevation at zero degrees of humeral elevation in the sagittal plane and scapular upward rotation at thirty of humeral elevation in the sagittal plane were associated with slight increases in SICK scapula score. Although, these relationships were significant, they were extremely weak, as represented by the r squared values in Table 4. Perhaps the findings from this study further confirm the idea that overhead athletes may develop adaptations in scapular positioning without suffering from shoulder pain.

The discrepancy between the existence of shoulder pain, scapular malposition and shoulder or scapular dysfunction creates significant challenges in clinical assessment. Although the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale was designed to aid clinicians in the evaluation of scapular dysfunction, we recognized several potential flaws of the scale which may have resulted in skewed scoring.

Shoulder pain may exist without the presence of scapular malpositioning and/or dyskinesis; therefore, subjects could display no signs of scapular malposition, but may report "yes" responses to the subjective and objective portions of the scale. These subjects may earn up to 11 points; thereby being classified as having SICK scapula syndrome without actually presenting signs of scapular malposition or dyskinesis. This score would be a misrepresentation of SICK scapula in that the subject does not display the trademark characteristics of **S**capular malposition, **I**nferior medial border prominence, **C**oracoid pain and malposition, and dys**K**inesis of scapular movement.

As previously noted by the significant findings of Myers et al, overhead athletes may display asymptomatic scapular malpositioning presented as an adaptive increase in scapular upward rotation (Myers, Laudner et al. 2005). In this case, overhead athletes screened with the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale may earn high scores in the scapular malposition section, yet have no subjective or objective complaints of pain. This subject's SICK score would be a misrepresentation of pathology in that scapular malpositioning alone does not indicate a symptomatic shoulder.

In our study, over half of the subjects reported having a painful shoulder, yet only four were clinically diagnosed post-screening as having SICK scapula syndrome. This disconnection highlights the ambiguity of the relationship between shoulder pain and actual scapular malposition or dyskinesis. Furthermore, these results may potentially indicate that the SICK Scapula Static Measurements Scale is a weak predictor and detector of scapular dysfunction.

Considering that participants in this study were Division I overhead athletes (with the exception of two subjects who were recreational level) who participated in their sport at high intensities, for several hours a week; and that 22 of the 40 participants reported shoulder pain, we hypothesized that this sample of overhead athletes would produce moderate to high SICK scapula scores. However, upon examination of the distribution of SICK scapula scores, it is clear to see that the majority of overhead athletes scored below 10 and the highest SICK scapula score recorded was 11. Based on these SICK scapula scores, none of the participants would be identified as having moderate to severe scapular pain or dysfunction. However, upon our observation of static and dynamic bilateral scapular asymmetry; as well as, standing cervical and thoracic posture, we would argue that nearly half of the participants displayed signs of scapular malposition and dysfunction. Therefore, we question the effectiveness of the items included in the SICK Scapula Static Measurements Scale in detecting the most prevalent signs and symptoms of scapular dysfunction. Perhaps, the subjective, objective and scapular malposition components that comprise the SICK Scapula Static Measurements Scale should be reassessed in their ability to detect scapular pain, malposition and dysfunction.

After screening nearly 100 subjects throughout the course of both pilot work and this research study, we recognized one potential obstacle of the SICK Scapula Static Measurements Scale to be the difficulty in scoring due to the scale's framework of point distribution and of screening components. Point distribution among the scale's sections is heavily weighted upon the subjective and objective portions of the scale; therefore, eleven of the scale's maximal twenty points are dependent upon the subject's report of shoulder or scapular pain. If the subject does not clearly identify the characteristics of pain, has a high pain tolerance or does not give an honest report of pain, the SICK score could be extremely misleading despite the results from the scapular malposition section. Also, in the case that subjective and objective reports of pain produce very low scores, only gross scapular malpositioning (i.e. > 15 degrees of scapular abduction) would result in a clinical diagnosis of SICK scapula syndrome. This degree of severe scapular malposition is very uncommon in both the overhead athlete and the common patient (Warner, Micheli et al. 1992; Lukasiewicz AC 1999; Ludewig PM 2000; Hebert, Moffet et al. 2002; Kibler and McMullen 2003; McClure, Bialker et al. 2004; McClure, Michener et al. 2006).

Imbalances in point distribution affect the scoring of the scapular malposition section as well. The scapular malposition scoring system, based on threshold values, creates a wide margin of error because scores can not be rounded up; despite being within one degree of the next scoring category. For example, if the researcher measures nine degrees of scapular abduction, the participant earns only one point (not rounding up to ten for two points) for the scapular abduction measurement because abduction has not met or exceeded ten degrees. Based on this threshold scoring system, mild scapular malposition would not likely yield more than a total score of three for the measurement section. This phenomenon reduces the clinical effectiveness of the SICK Scapula Measurement Scale because severe scapular malposition would have to exist in order to obtain significant scores. This severe degree of scapular malposition is uncommon in overhead athletes and in symptomatic patients.

Another potential flaw of the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale(Burkhart, Morgan et al. 2003) is that the scale contains items that screen for a wide variety of shoulder pathologies; instead specifically detecting scapular dysfunction, For example, the subjective portion includes assessing AC joint pain; proximal lateral arm pain, a symptom of subacromial impingement; and radicular pain, a symptom of thoracic outlet paresthesia. The objective portion re-assesses the AC joint pain, in addition to, testing for impingement and thoracic outlet syndrome. Because the scale includes assessment items to screen for such a wide range of shoulder pathologies, it sacrifices the ability to be highly specific and accurate in detecting the presence of the defining characteristics of SICK scapula. A subject may possess all of the classic characteristics of SICK scapula syndrome (i.e. **S**capular malposition, **I**nferior medial border prominence, **C**oracoid pain and malposition, and dys**K**inesis of scapular movement), but may not score any points for AC joint irritation, thoracic outlet paresthesias, or subacromial impingement syndrome. In this case, the subject would score relatively low for both the subjective and objective sections; therefore giving the illusion that the subject has no scapular dysfunction.

Potentially, the predictive value of the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale(Burkhart, Morgan et al. 2003) in detecting scapular pain and malposition must be challenged. Although this scale was designed to aid clinicians in detecting the potential, the presence, and/or the severity of SICK scapula syndrome, the scale's efficacy in specifically identifying scapular dysfunction may be hampered by the high dependency on subject self-reported pain, the inclusion of items that screen for other shoulder pathologies and the threshold scoring of scapular malposition.

We recognize a disconnection between the constructs of the SICK Scapula Static Measurements Scale and the actual presence of scapular malposition and dysfunction in overhead athletes. Although our statistical results showed that increased scapular upward rotation and elevation were predictive of an increased SICK scapula score, one must consider that increased scapular upward rotation and elevation could actually be healthy adaptations in overhead motion and that the increased SICK score could be attributed to factors, other than scapular position, that cause shoulder pain. We propose that the subject's SICK scapula score did not effectively indicate or describe scapular pain or malposition. Our significant findings indicating direct relationships between scapular upward rotation and elevation and an increased SICK scapula score are more than likely representative of a healthy adaptation in scapular position; instead of malpositioning that causes shoulder pain. We recognize that the presence of scapular malposition does not necessarily indicate scapular dysfunction. We are not convinced that our significant findings represent a true predictive relationship between increased scapular upward rotation and scapular elevation, and scapular pain and dysfunction in overhead athletes.

The discrepancy between the altered scapular kinematics we observed and the presence of scapular pain and dysfunction, which is supposedly indicated by the SICK scapula score, raises questions regarding the actual existence of SICK scapula syndrome. “SICK scapula” seems to be a catch-all, umbrella-term that has been misused to describe scapular malposition. We believe the characteristics of SICK scapula are neither closely related nor well-defined enough to be entirely exclusive in determining a specific pathology. The signs and symptoms included in the SICK Scapula Scale encompass several shoulder pathologies (subacromial impingement, AC joint pathology, thoracic outlet syndrome, and glenohumeral labral lesions); instead of delineating a separate condition. Because scapular dysfunction may be a component in many shoulder pathologies, it becomes difficult to establish a distinct syndrome based on the elements common to so many pathologies. A clinical diagnosis of SICK scapula syndrome reveals minimal information distinguishing the specific underlying anatomical and functional basis for shoulder pathology. Despite the argument for or against the presence of an actual SICK scapula syndrome, our research highlights the necessity for a more in-depth and specific scapular evaluation process.

Limitations

Perhaps the greatest limitation of this study was the narrow and low-end range of SICK scapula scores obtained when utilizing the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003). While subject recruitment made no distinction regarding a need for either symptomatic or asymptomatic shoulders, only four of forty subjects obtained scores from screening that qualified them to be clinically diagnosed with SICK scapula syndrome. Furthermore, no subject scored higher than an 11 out of a possible 20 points. Again, we attribute unexpected subject scoring to potential flaws with the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003).

The current study included athletes from several overhead sports: swimming, volleyball and softball. Unfortunately, two groups of overhead athletes not included in this study were baseball and tennis athletes. Despite extensive subject recruitment, the researcher was not able to obtain baseball or tennis athletes for testing due to the athletes' in-season sport. Therefore, we recognize the absence of baseball and tennis athletes in this study of overhead athletes as a limitation. These athletes are predisposed to shoulder and scapular pathologies; however caution must be used in extrapolating our findings to baseball or tennis athletes. Future studies should investigate the relationship between scapular kinematics and subject score on the SICK scapula scale present in baseball pitchers and field-players; as well as, tennis athletes.

A significant limitation in our study involves determining the variance between a subject's dominant and non-dominant shoulder. Due to instrumentation difficulties, we were limited to testing only the subject's dominant or painful shoulder. Therefore, we were not able to compare scapular kinematics bilaterally within each subject. A bilateral comparison would provide information regarding differences in scapular kinematics between a subject's healthy and pathological shoulder.

Future Research

Future research should seek to further identify scapular dysfunction in symptomatic overhead athletes. Based on our findings, we believe that it is necessary to conduct a much larger-scale research study including overhead athletes with ill-maintenance shoulders from a wide-variety of sports. Ideally, these athletes would better exemplify the SICK scapula syndrome in its most exaggerated form; thereby producing significant statistical and clinical findings.

In addition, future research should focus on collecting data to determine the most specific and valid objective assessments and measurements of scapular pain, malposition and dyskinesis. Once validity, reliability and specificity are determined, these items could be compiled and structured into a more effective, accurate and specific screening tool for clinicians. The designers should take precautions to ward against placing excessive emphasis on subjective reports of pain, to include items specifically sensitive to SICK scapula syndrome and to decrease the wide threshold scoring margin with scapular measurements.

We acknowledge the findings listed in Table 6 when offering sound recommendations regarding the development of a new and theoretically improved screening instrument. By dissecting SICK scapula syndrome score for each of the forty subjects screened, we were able to tease out exactly where the bulk of point allotment occurred, specifically among those with self-reported shoulder pain. Based on score breakdown, we conclude that ten characteristics of SICK scapula syndrome best exemplify the condition's signs and symptoms, thus serving as the most accurate predictors regarding its presence and severity. We recommend the following subjective questions for the presence of pain: coracoid process, periscapular, proximal lateral arm, and radicular symptoms. We recommend the following objective palpations and/or special tests for the presence of pain: coracoid process, superior medial scapular angle, and Hawkins-Kennedy Impingement Test. We recommend the following measurements for the determination of scapular malpositioning: infera 0 to 1 cm, lateral protraction 0 to 1 cm, and abduction 0 to 5 degrees.

We also recommend the implementation of a more detailed objective screening process; one which includes a postural assessment, observation and measurement of dynamic scapular positioning, soft-tissue mobility assessment, and scapular muscle strength assessment. Postural assessments should seek to identify and grade the presence of cervical lordosis, thoracic kyphosis, lumbar lordosis, pelvic rotations, and abnormal hip rotations that may affect scapular kinematics as energy is transferred through the kinetic chain from the lower extremity and core to the thorax and upper extremity (Sauers 2006). Clinicians may perform a quick and effective postural assessment utilizing a plumb-line while observing the patient from a side-view.

Scapular position should be observed at rest and during loaded and unloaded humeral elevation. While in resting position, clinicians should observe the scapulae for signs of winging (i.e. excessive scapular internal rotation, scapular anterior tilt, and scapular elevation). Dynamic scapular motion should be assessed in both loaded and unloaded conditions. Johnson et al.(Johnson 2004; Sauers 2006) developed a protocol to detect abnormal scapular motion via the repetitive challenging of the scapulae under loaded conditions. The authors data indicated that three tests were able to detect abnormal scapular motion: 1) observation of bilateral scapular motion during five to ten repetitions of unloaded humeral elevation in the scapular plane (scaption) to establish a baseline of scapular movement, 2) observation of bilateral scapular motion during five to ten repetitions of loaded (0.5-5 kg) scaption, and 3) observation of unilateral scapular motion during resisted isometric external rotation with the arm at the side in neutral rotation (i.e. scapular flip sign) (Johnson 2004; Sauers 2006).

The scapular lateral slide test is a semi-dynamic, quantitative assessment of scapular position. This test has been shown to be reliable in assessing the bilateral position of the scapulae in relation to a fixed point on the spine as varying loads are placed on the supporting scapular musculature (Kibler 1998; Kibler and McMullen 2003). The test involves a series of three measurement positions.

Evaluation of the mobility of the posterior glenohumeral joint capsule, the posterior shoulder musculature, and the anterior coracoid musculature provides critical information regarding the pathomechanical assessment of scapular dysfunction. Posterior glenohumeral joint capsule contracture has been shown to produce excessive superior and anterior humeral head translation, thereby compromising the size of the subacromial space and altering glenohumeral and scapular kinematics.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) Posterior shoulder tightness is an additional commonly described flexibility characteristic of scapular dysfunction. (Fleisig, Barrentine et al. 1996; Ludewig and Cook 2000; Ludewig PM 2000; Pink and Tibone 2000; Hebert, Moffet et al. 2002; Burkhart, Morgan et al. 2003; Kibler and McMullen 2003; Su, Johnson et al. 2004; Myers, Laudner et al. 2005; McClure, Michener et al. 2006; Thigpen CA In Press) Myers et al. quantify posterior shoulder tightness utilizing supine and side-lying horizontal adduction assessments.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) One final flexibility measurement to consider during scapular evaluation is pectoralis minor mobility. Due to its proximal attachment on the coracoid process of the scapula, inflexibility of the pectoralis minor muscle may manifest as excessive scapular anterior tilt and internal rotation, thus resulting in coracoid process pain and scapular dysfunction.

Manual muscle testing of the scapular stabilizing muscles is critical in determining the presence of or potential for scapular dysfunction. Strength of the middle and lower trapezius, rhomboids major and minor, and the serratus anterior muscles should be assessed through manual muscle testing techniques. Additional scapular muscle strength and endurance tests include the isometric scapular retraction pinch and wall push up tests. Typically, patients are able to hold an isometric pinch of the scapulae in retraction for 15 to 20 seconds without the onset of burning pain or muscle weakness. An inability to hold this position due to pain or weakness provocation is a positive sign indicating scapular muscle dysfunction.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) The ability of the serratus anterior muscle to stabilize the scapula on the thorax is easily evaluated with the wall push-up test. The patient performs 5-10 wall push-ups while the clinicians observes for abnormalities in scapular position and motion, specifically scapular winging.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000)

Conclusion

This study is the first to assess the predictive relationship between scapular kinematics and overhead athlete's score on the SICK Scapula, Static Measurements, 0 to 20

Point Rating Scale (Burkhart, Morgan et al. 2003). Three-dimensional scapular kinematic data of overhead athletes performing humeral elevation in the sagittal plane revealed very weak significant prediction of SICK scapula score. Scapular upward rotation at zero degrees of humeral elevation in the sagittal plane, scapular upward rotation at thirty degrees of humeral elevation in the sagittal plane, and scapular elevation at zero degrees of humeral elevation in the sagittal plane were found to be weak significant predictors of SICK scapula score in overhead athletes. No significant predictive relationships were found between scapular kinematics during humeral elevation in the scapular plane and SICK scapula.

APPENDIX A: TABLES

Table 1. Study Participant Demographics

	Male Participants (n = 8)		Female Participants (n = 31)	
	Mean	**±SD**	**Mean**	**±SD**
Age (years)	19.14	1.07	19.97	1.08
Height (cm)	181.43	2.48	173.79	8.42
Mass (kg)	73.87	3.59	69.00	7.90
SICK Score[a]	5.29	2.23	4.32	3.44
Subjective[b]	2.14	1.25	1.66	1.64
Objective[c]	1.43	0.79	1.45	1.62
Malpositioning[d]	1.71	0.64	1.23	0.84

[a] SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale(Burkhart, Morgan et al. 2003)
[b] Self-reported pain of the coracoid process, AC joint, periscapular soft tissue, proximal lateral arm, and/or elbow (possible 5 points)
[c] Self-reported tenderness to palpation of the coracoid process, AC joint, superior medial angle; (+) provocative impingement test (Hawkins-Kennedy Impingement Sign), (+) scapular assistance test, and/or (+) thoracic outlet syndrome test (Allen Test) (possible 6 points)
[d] Scapular malposition based on 1) infera (i.e. the visual appearance of a dropped scapula due to scapular tilting or protraction), 2) lateral displacement, and 3) abduction (possible 9 points)

Table 2. Description of Bony Landmarks

Bony Landmarks	Description of Palpation Point
Thorax	
8th Thoracic Spinous Process (T8)	Most dorsal point
Processus xiphoideus (PX)	Most caudal point of sternum
7th Cervical Spinous Process (C7)	Most dorsal point
Incisura jugularis (IJ)	Most cranial point of the sternum (suprasternal notch)
Scapula	
Angulus acromialis (AA)	Most lateral-dorsal point of scapula
Trigonum spinae (TS)	Midpoint of triangular surface on the medial border of the scapula in line with the scapular spine
Angulus inferior (AI)	Most caudal point of scapula
Humerus	
Medial epicondyle (ME)	Most medial point on the medial epicondyle
Lateral epicondyle (LE)	Most lateral point on the lateral epicondyle
Glenohumeral joint center (GH) ∗	

∗ The glenohumeral joint center was not palpated but rather estimated with a least squares algorithm for the point on the humerus which moves the least during several short arc humeral movements.(Harryman, Sidles et al. 1990; Stokdijk, Nagels et al. 2000)

Table 3. Definitions of Local Coordinate Systems

Local Coordinate System	Axis	Definition
Thorax	y_t	Vector from the midpoint of PX and T8 to the midpoint between IJ and C7, pointing upward
	z_t	Vector perpendicular to the plane formed by IJ, C7, and the midpoint between PX and T8, pointing to the right.
	x_t	Vector perpendicular to z_t and y_t
	Origin	IJ
Scapula	z_s	Vector from TS to AA, pointing to AA.
	x_s	Vector perpendicular to the plane formed by TS, AA, and AI, pointing forward.
	y_s	Vector perpendicular to x_s and z_s.
	Origin	AA
Humerus	y_h	Vector connecting GH and the midpoint of EL and EM, pointing to GH
	x_h	Vector perpendicular to the plane formed by EL, EM, and GH, pointing forward.
	z_h	Vector perpendicular to y_h and x_h
	Origin	GH

Thorax: **C7**:spinous process of 7th cervical vertebrae; **T8**:spinous process of 8th thoracic vertebrae; **IJ**: deepest point of Incisura Jugularis (suprasternal notch); **PX**: Processus Xiphoideus (xiphoid process), most caudal point on the sternum
Scapula: **TS**: trigonum spinae scapulae (root of the spine), the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine; **AI:** Angulus Inferior (inferior angle), most caudal point of the scapula; **AA:** Angulus Acromialias (acromial angle), most laterodorsal point of the scapula
Humerus: GH: Glenohumeral rotation center; **EL:** most caudal point on lateral epicondyle; **EM:** most caudal point on medial epicondyle

Table 4: Scapular Kinematics Data during Humeral Elevation in Sagittal Plane (Flexion)

	Mean	± SD	r^2	p
Scapular upward/downward rotation				
0^o humeral elevation	1.34	6.53	.210	.003*
30^o humeral elevation	7.40	7.09	.180	.007*
60^o humeral elevation	22.0	7.66	.088	.067
90^o humeral elevation	34.65	10.92	.058	.139
120^o humeral elevation	45.72	14.34	.048	.181
Scapular external /internal rotation				
0^o humeral elevation	25.44	11.38	.004	.713
30^o humeral elevation	31.64	11.60	.004	.718
60^o humeral elevation	40.26	12.43	.002	.797
90^o humeral elevation	42.21	14.63	.001	.882
120^o humeral elevation	37.82	20.02	.004	.702
Scapular posterior/anterior tilt				
0^o humeral elevation	13.33	5.11	.027	.314
30^o humeral elevation	10.74	6.01	.049	.177
60^o humeral elevation	10.64	6.89	.070	.104
90^o humeral elevation	9.05	11.22	.044	.202
120^o humeral elevation	2.13	18.92	.007	.600
Scapular protraction/retraction				
0^o humeral elevation	19.62	12.13	.001	.887
30^o humeral elevation	19.26	12.98	.002	.819
60^o humeral elevation	20.69	14.30	.046	.203
90^o humeral elevation	26.30	15.44	.056	.160
120^o humeral elevation	35.07	15.73	.083	.084
Scapular elevation				
0^o humeral elevation	11.48	5.60	.187	.008*
30^o humeral elevation	12.41	5.48	.118	.037
60^o humeral elevation	18.76	5.43	.016	.452
90^o humeral elevation	24.63	5.72	.000	.912
120^o humeral elevation	27.93	5.80	.001	.840

* Statistically significant predictor of SICK Scapula Score ($p \leq .01$).

Table 5: Scapular Kinematics Data during Humeral Elevation in Scapular Plane (Scaption)

	Mean	± SD	r^2	p
Scapular upward/downward rotation				
0^o humeral elevation	3.633	9.03	.069	.107
30^o humeral elevation	8.26	8.74	.040	.223
60^o humeral elevation	21.47	8.13	.072	.099
90^o humeral elevation	35.61	11.33	.055	.150
120^o humeral elevation	46.75	15.31	.092	.061
Scapular external /internal rotation				
0^o humeral elevation	25.74	15.06	.032	.273
30^o humeral elevation	27.29	18.95	.041	.217
60^o humeral elevation	28.54	16.88	.070	.151
90^o humeral elevation	32.17	25.51	.044	.258
120^o humeral elevation	36.38	25.39	.035	.311
Scapular posterior/anterior tilt				
0^o humeral elevation	12.53	5.57	.008	.583
30^o humeral elevation	10.70	5.27	.013	.482
60^o humeral elevation	8.60	5.95	.014	.470
90^o humeral elevation	6.52	8.83	.005	.670
120^o humeral elevation	4.30	15.54	.001	.870
Scapular protraction/retraction				
0^o humeral elevation	22.42	13.24	.015	.465
30^o humeral elevation	23.20	12.33	.004	.717
60^o humeral elevation	26.68	12.99	.008	.592
90^o humeral elevation	31.50	13.57	.018	.418
120^o humeral elevation	37.99	14.21	.027	.325
Scapular elevation				
0^o humeral elevation	11.40	6.18	.150	.018
30^o humeral elevation	12.91	5.86	.097	.061
60^o humeral elevation	19.08	5.67	.044	.214
90^o humeral elevation	25.54	5.70	.028	.324
120^o humeral elevation	30.60	5.84	.036	.259

Table 6. Breakdown of SICK Scapula Score

Subject #	SICK Score Total	Subjective Pain Reported	Subjective: Coracoid	Subjective: AC Joint	Subjective: Periscapular	Subjective: Prox Lat Arm	Subjective: Radicular	Objective: Coracoid	Objective: AC Joint	Objective: SM Scap Ang	Objective: Impingement Test	Objective: Scap Assist Test	Objective: TOS Parathesias	Scapular Malposition: Infera 1 cm	Scapular Malposition: Infera 2 cm	Scapular Malposition: Infera 3 cm	Scapular Malposition: Lat Prot 1 cm	Scapular Malposition: Lat Prot 2 cm	Scapular Malposition: Lat Prot 3 cm	Scapular Malposition: Ab 5 degrees	Scapular Malposition: Ab 10 degrees	Scapular Malposition: Ab 15 degrees
1	1	Y			xx																	
2	0	N																				
3	0.5	N												x								
4	1.5	N												x			x			x		
5	2	N									x						xx			x		
6	2	N												x			x				x	
7	10.5	Y		xx	xx	xx	x	xx	x	x	xx	xx	x	x			xx			xx		
8	5.5	Y	xx		xx			xx		xx	xx	xx										
9	2	Y					x				xx			x								
10	2	N							x								xx			x		
11	1	N						xx														
12	6	Y			xx	xx		xx		xx				x			x			x		
13	6.5	Y		x	xx	xx		x		x	xx						xx			xx		
14	7	Y	xx			xx	xx	xx			xx		x	x						xx		
15	5	Y	x		x	x			xx	x				x			x			xx		
16	0.5	N															x					
17	10.5	Y	xx	xx	xx	x	xx	xx	xx	xx	xx		x				xx			x		
18	2.5	N		xx						xx				x								
19	5	Y	xx				xx	xx			xx									xx		
20	7	Y	xx	x	xx	x		x		xx				x			xx			xx		
21	6.5	Y					xx	x	x	x	xx			xx			xx				x	
22	11	Y	xx	xx	xx	xx	xx	xx	xx	xx	xx		x	x			xx					
23	2	N	x											x								
24	5	Y	xx		x	x	xx				x			xx			x					
25	7	Y	x		xx	xx	xx	xx		x								x		xx		
26	7	Y	x		xx		xx	x	x	xx				xx			x			xx		
27	1	N												x			x					
28	8.5	Y	x	xx	xx	xx	x	xx	xx	xx	xx									x		
29	0	N																				
30	7.5	Y	xx	x	xx	x		xx	xx		x			xx			x			x		
31	10	Y	xx	xx	xx	xx	xx	xx	xx	xx	xx		x				x			x		
32	3.5	N	xx														x	x		xx		
33	2.5	N			xx									xx						xx		
34	5.5	Y	xx		xx			xx			xx						xx			x		
35	2.5	N	x					x			xx						x					
36	5.5	Y	xx		x	x	x			x	xx			x						xx		
37	6.5	Y	x		xx		xx	x		xx	x			x			x					
38	0	N																				
39	3.5	N	xx							x				x			x			xx		
40	1	N												xx								
Total	4.4		20	9	19	14	14	19	10	17	18	2	5	22	0	0	23	2	0	21	2	0

x = identified by one investigator
xx = identified by two investigators
Prox lat arm = proximal lateral arm
SM scap ang = superior medial scapular angle
Scap assist test = scapular assistance test
Lat prot = lateral protraction
abduction

APPENDIX B: FIGURES

Figure 1. The SICK Scapula, Static Measurements point scale (Burkhart et al., 2003)

ORTHOPAEDIC SURGERY
MORGAN KALMAN
CLINIC
ARTHROSCOPIC SPECIALISTS

DATE ______________ SPORT ______________
NAME ______________ POSITION ______________
AGE ______________ PRESENTING SX^{S} ______________

SUBJECTIVE	PAIN			YES	NO	SCORE
	Coracoid			1	0	
	AC Joint			1	0	
	Periscapular			1	0	
	Prox. Lat. Arm			1	0	
	Radicular			1	0	
OBJECTIVE						
	Coracoid			1	0	
	AC Joint			1	0	
	Sup. Med. Scap. Angle			1	0	
	Impingement Test			1	0	
	Scapular Asst. Test			1	0	
	Tos Paresthesias			1	0	
SCAP. MALPOSITION	**0cm**	**1cm**	**2cm**	**3cm**	**SCORE**	
Infera	0	1	2	3		
Lateral Protraction	0	1	1	3		
Abduction	0°	5°	10°	15°		
	0	1	2	3		
		TOTAL SCORE				

Figure 2. Predictive Relationship of Scapular Upward/Downward Rotation at Zero Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score

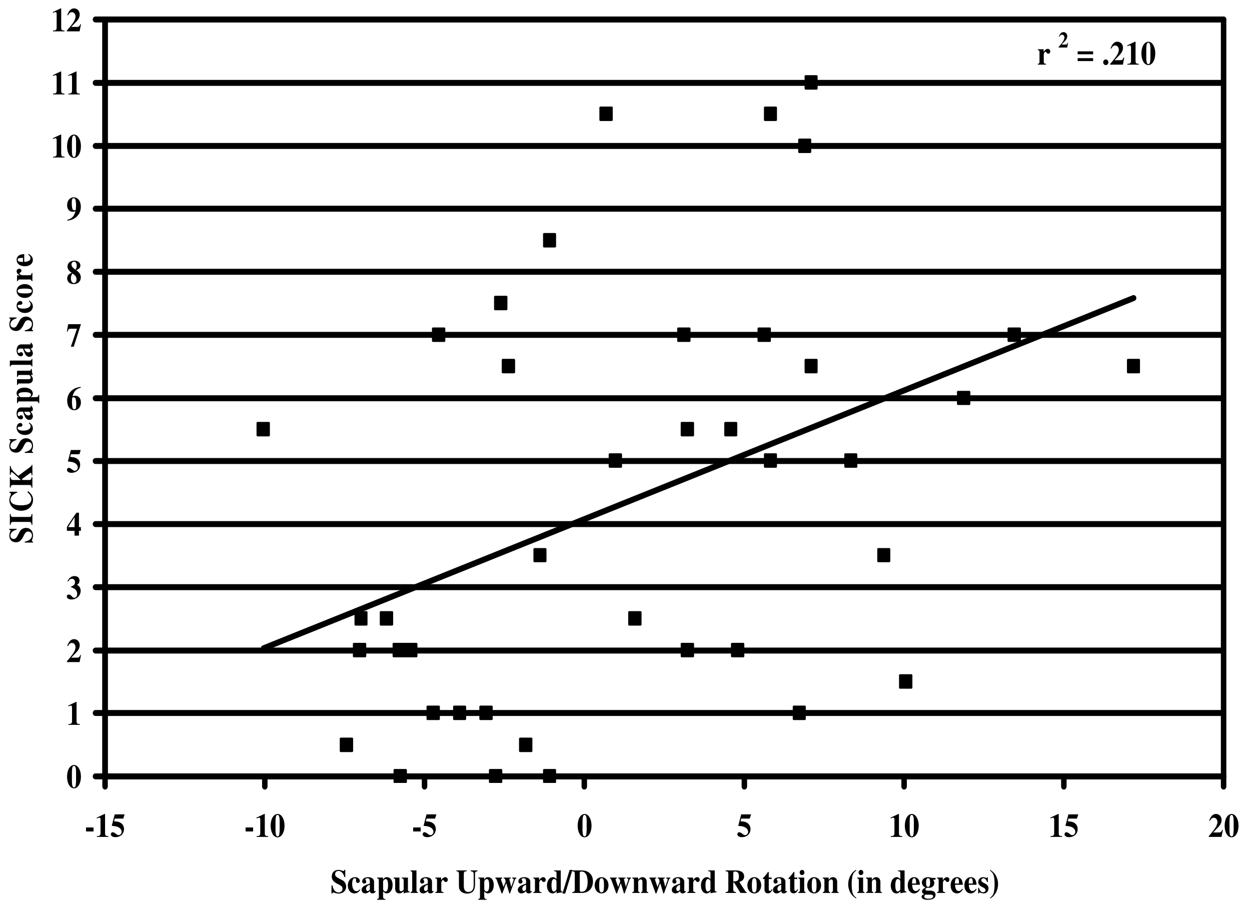


Figure 3. Predictive Relationship of Scapular Upward/Downward Rotation at Thirty Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score

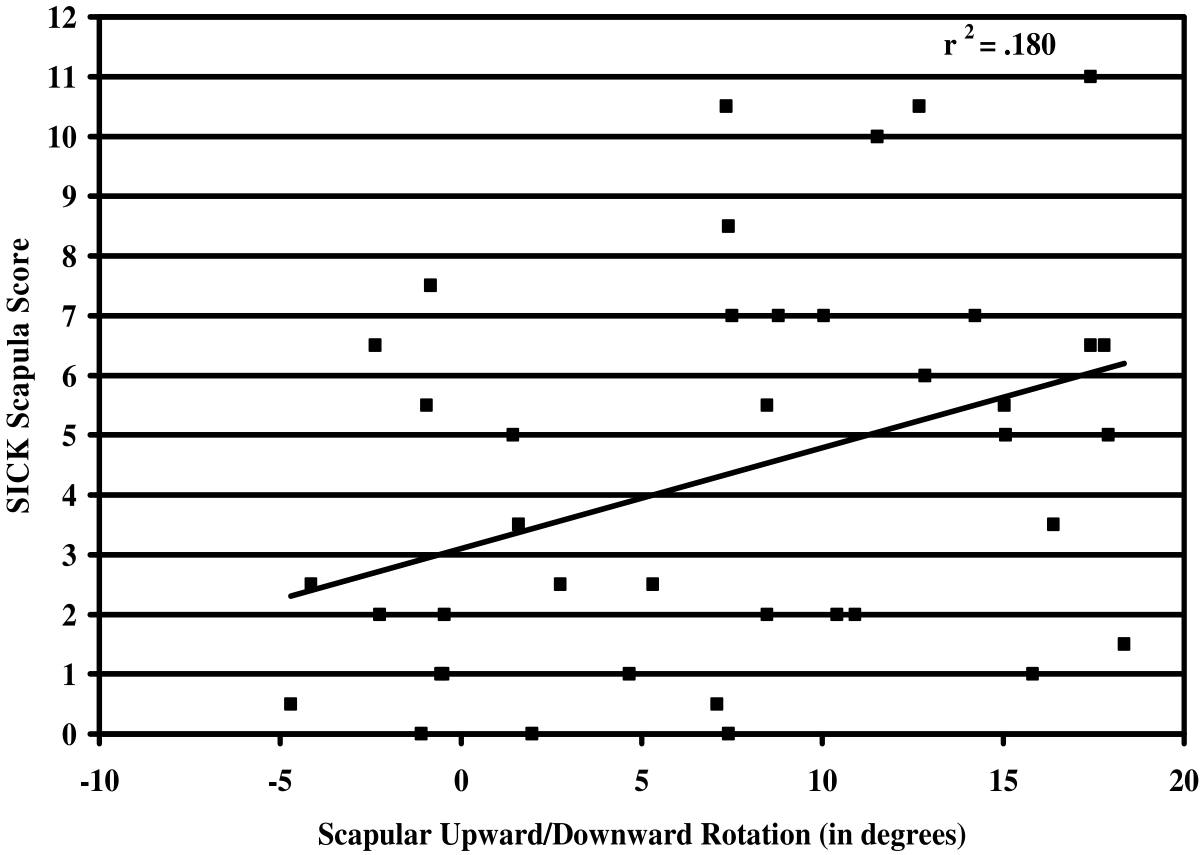
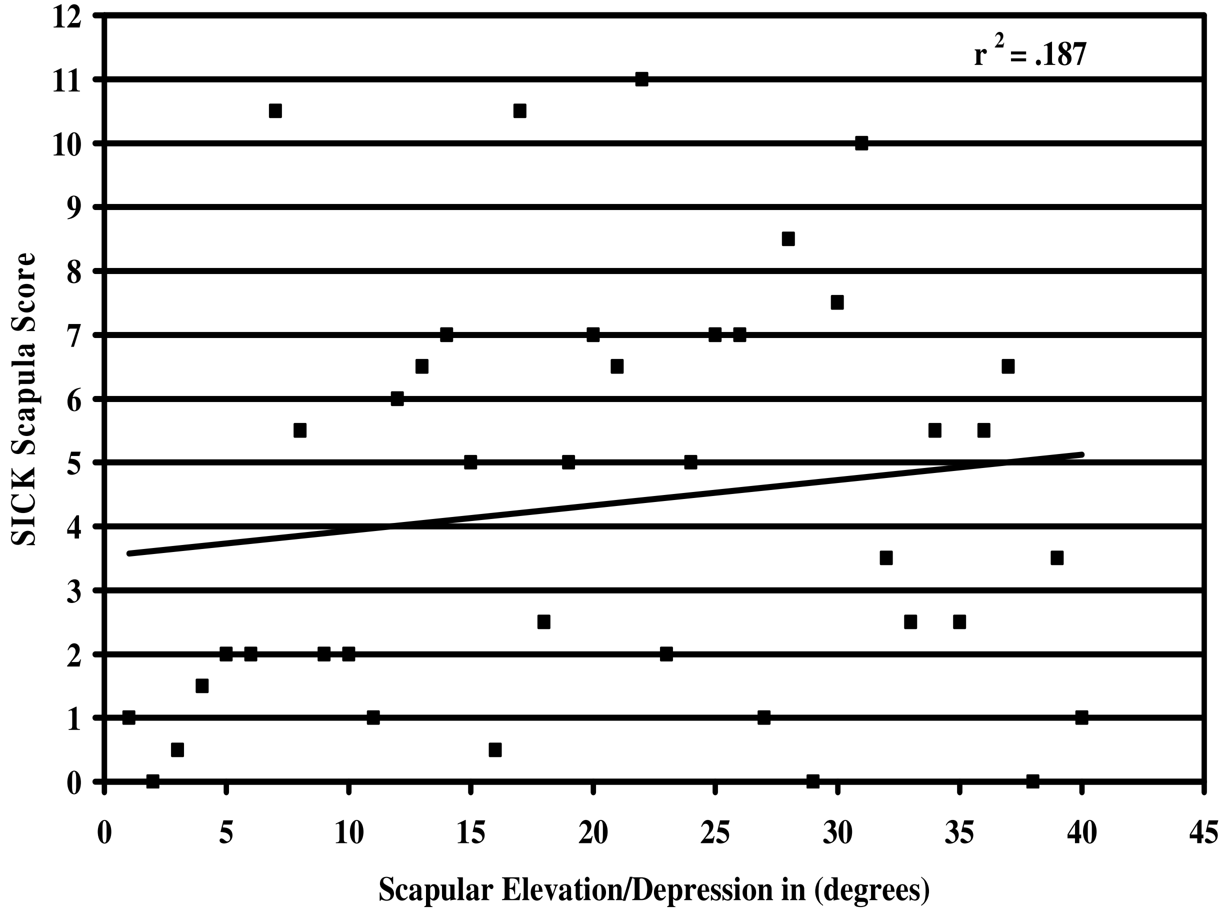


Figure 4. Predictive Relationship of Scapular Elevation/Depression at Zero Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score



APPENDIX C: MANUSCRIPT

ABSTRACT

The predictive relationship between scapular kinematics and athlete's score on the SICK Scapula Static Measurements Scale

Context: Overhead athletes are predisposed to developing scapular malposition and dyskinesis due to the repetitive overhead motion patterns of sport. The SICK Scapula, Static Measurements, 0 to 20 point rating scale, was designed as a screening tool to aid clinicians in recognizing and quantifying shoulder and scapular pain, malposition and dyskinesis. Currently there is no research supporting the predictive value of this scale. **Objective**: To determine the predictive relationship between three-dimensional scapular kinematic data analysis and athlete's score on the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003). **Design**: Quasi-experimental in nature, specifically a nonequivalent one-group design with a counterbalancing of tasks. **Setting:** A university-based motor control laboratory. **Participants:** Forty subjects, NCAA Division I or club athletes, ages between 18 to 25 years old who participate in their overhead sport for a minimum of 30 minutes, three times a week. **Interventions:** The participants were screened using the SICK Scapula, Static Measurements Rating Scale. Scapulohumeral kinematics were recorded with an electromagnetic tracking device while participants performed ten repetitions of scapular plane humeral elevation and ten repetitions of sagittal plane humeral elevation. **Main-Outcome Measures:** Scapular anterior/posterior tilt, internal/external rotation, upward/downward rotation, elevation/depression and protraction/retraction were measured in degrees at 0, 30, 60, 90, and 120 degrees during the ascending phase of humeral elevation in the scapular and sagittal planes. An alpha level of .05 was set prior to the study. However, in order to control for inflation of the type I errors associated with multiple comparison analyses, an adjusted alpha level of 0.01 was used to determine statistical significance. Linear regression analyses were calculated to determine the predictive relationship between scapular kinematic variables and SICK scapula score. The analyses were run separately for each scapular kinematic variable at each humeral angle for both tasks. A total of fifty linear regressions were performed. **Results:** No significance was found with humeral elevation in the scapular plane (scaption) task. However, significance was found with the humeral elevation in the sagittal plane task. Scapular upward rotation at zero degrees of humeral elevation significantly predicts the overall SICK score: ($F(1,37) = 9.812$, $p = .003$, $r^2 = .210$). Scapular upward rotation at 30 degrees of humeral elevation significantly predicts the overall SICK score: ($F(1,37) = 8.107$, $p = .007$, $r^2 = .180$). Scapular elevation/depression at zero degrees of humeral elevation in sagittal plane significantly predicts the overall SICK score: ($F(1,35) = 8.040$, $p = .008$, $r^2 = .187$). **Conclusion:** Although significant, the relationships between scapular upward/downward rotation and scapular elevation/depression during sagittal plane humeral elevation with overall SICK score on the Static Measurements Scale have proven to be very weak with r^2 values less than or equal to 0.2. These results show that the SICK Scapula, Static Measurements Rating Scale may not be an accurate predictor of scapular malposition and dyskinesis. **Key Words:** SICK scapula, scapular kinematics, scapular dyskinesis

INTRODUCTION

Athletes may be predisposed to developing scapulothoracic and glenohumeral pathologies resulting from repetitive overhead movements that apply extreme stresses to active and passive structures of the shoulder (Burkhart, Morgan et al. 2003). Therefore, athletes may develop alterations in scapular static positioning, scapular movement (dyskinesis), or scapular muscle force couple production which eventually may manifest as pain (Fu, Harner et al. 1991; Glousman, Jobe et al. 1998; Kibler, WB, 1991).

Scapular dyskinesis is characterized by alterations of scapular position, at rest or with arm motion, that create clinical dysfunction of the shoulder and that are commonly associated with injuries (Kibler and McMullen, 2003). Scapular dyskinesis may result from excessive thoracic kyphosis and increased cervical lordosis which contribute to excessive scapular protraction and acromial depression (McClure, Michener et al. 2001). A lack of flexibility of the pectoralis minor or short head of the biceps brachii muscles, as well as, a tight posterior glenohumeral joint capsule may contribute to scapular malposition and dyskinesis. (Burkhart, Morgan et al. 2003).

Scapular dysfunction in athletes may be more accurately described as SICK scapula. SICK is an acronym referring to the objective findings common to the scapular syndrome: *Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition, and dysKinesis of scapular movement* (Burkhart et al., 2003). The trademark of SICK scapula is malposition characterized by a lowered scapula and prominence of the scapular inferior medial border of the involved shoulder. Coracoid pain and malposition may contribute to dyskinetic alterations in the position and the motion of the scapula relative to the thoracic cage.

The scapula serves as the stable base for glenohumeral motion; providing dynamic stability for the glenohumeral joint, elevating the acromion during throwing motions and serving as a pivotal link in the proximal-to-distal sequencing of velocity, energy, and forces of shoulder function (Kibler and McMullen 2003). Therefore, the presence of SICK scapula may alter scapular kinematics and muscle function; thereby rendering the scapula less effective in contributing to normal shoulder function and predisposing the athlete to glenohumeral joint injury. Abnormal scapular motion in one or multiple planes and associated abnormal muscle function are believed to contribute to shoulder pain and pathology (Fu, Harner et al. 1991; Glousman, Jobe et al. 1998; Kibler, WB, 1991). Furthermore, alterations in scapular positioning and motion occur in 68% to 100% of all patients with shoulder injuries (Warner, Micheli et al. 1992).

Currently, clinicians may utilize manual muscle testing, scapular special tests, soft-tissue mobility assessment and postural assessment in the evaluation of scapular dysfunction. Also, bilateral scapular dynamics may be observed while patients perform multiple repetitions of shoulder flexion with and without resistance (Sauers 2006). To aid clinicians in the assessment of scapular dysfunction, the SICK Scapula, Static Measurements, 0 to 20 point rating scale was devised in attempts to quantify the degree of scapular dysfunction. This scale contains subjective, objective and scapular measurement sections on which subjects earn points for reporting symptoms and displaying signs of SICK scapula (Burkhart, Morgan et al. 2003). According to this scale, scores of 10 and above indicate the presence of SICK scapula syndrome. This scale may be considered as an effective clinical tool; however, the scale's ability to detect scapular malposition and dyskinesis has not been proven significant.

The purpose of this study was to determine the predictive relationship between scapular kinematic data analysis and overhead athlete score on the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale. We hypothesized that subjects who displayed abnormal increases in the degree of scapular anterior tilt and scapular internal rotation would generate higher scores on the SICK Scapula, Static Measurements, 0 to 20 point rating scale. In addition, we predicted that abnormal decreases in scapular upward rotation, elevation and retraction would result in higher scores the SICK Scapula, Static Measurements, 0 to 20 point rating scale.

The results from this research should enhance understanding of the predisposing factors and dyskinetic scapular patterns associated with SICK scapula syndrome. If the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003) was proven to accurately predict scapular dysfunction, sports medicine professionals would be able to better assess scapular dysfunction and to prescribe athletes with more effective treatment and individualized rehabilitation programs to correct scapular malposition and to prevent dyskinesia.

METHODS

One group of forty overhead athletes (12 female swimmers, 9 male swimmers, 9 female volleyball players, 10 female softball players) participated in this study (Table 1). Subjects were selected from a population of male and female NCAA Division I and/or recreational club athletes, ages 18 to 25 years old, who participated in overhead athletic activity for a minimum duration of 30 minutes, three times a week. Overhead athletic activity was defined as a sport that requires the arm to be above shoulder height on a repetitive basis during throwing or striking activities (swimming, tennis, volleyball, baseball, softball). Subjects were excluded from this study if they had medical history of shoulder or neck surgery, cervical spine pathology, adhesive capsulitis of the shoulder, rotator cuff lesions, scoliosis, acute acromioclavicular joint injury, or glenohumeral subluxations or dislocations within the past six months.

Instrumentation

The researchers used the SICK Scapula, Static Measurements, 0-20 point Rating Scale to screen overhead athletes for the presence of SICK scapula (Burkhart, Morgan et al. 2003). Prior to the study, reliability and precision of the SICK scapula static measurements point scale were established from a small pilot study by the principal investigators. The inter-session reliability and precision were calculated and yielded an ICC of 0.682 and SEM of 1.44 points, respectively. The inter-tester reliability and precision were calculated and yielded an ICC of 0.684 and SEM of 1.18 points, respectively.

The Motion Star (Ascension Technology Corp, Burlington, VT) electromagnetic tracking device integrated with Motion Monitor (Innovative Sports Training, Inc, Chicago, Ill) motion-capture software was utilized to collect three-dimensional scapular kinematics. The Motion Star tracking system consisted of a transmitter and six miniature receivers, which were all hardwired to the systems main computer unit. The transmitter emitted a low-frequency electromagnetic field, which was detected by the receivers. Each receiver was able to calculate linear and rotational motion around three axes, thus allowing six degrees of freedom to be measured. The relative orientation and position of the receivers within the electromagnetic field were relayed to the computer, and were processed and displayed using the Motion Monitor motion-capture software.

The Motion Star system has been shown to be accurate within 1.8mm for linear displacements and 0.5º for angular displacements (Thigpen, Padua et al. 2006). Scapular and glenohumeral kinematics were sampled at a rate of 100 Hz. Three-dimensional scapular kinematic data were recorded in degrees of scapular anterior/posterior tilt, upward/downward rotation and internal/external rotation. Scapular position was recorded as degrees of elevation/depression and degrees of protraction and retraction.

Procedures

Subjects reported to the university-based laboratory for one session lasting approximately 90 minutes. Prior to participation, all subjects completed an informed consent form approved by the University Biomedical Institutional Review Board.

Female subjects wore a sports bra and males were shirt-less during testing to allow access to the scapula. Prior to the testing session, subjects were screened for both inclusion and exclusion criteria. The subjects who met the criteria proceeded to the testing procedures. All procedures were performed on the subjects' testing arm, determined by either the subjects' self-reported painful arm, or if no pain was reported, by dominant arm. Subjects were screened by both principal investigators who were blinded to each other's screening process and to the resulting SICK score until both screenings were completed. The subject's overall SICK score was taken as the mean of the two scores obtained from the blinded screenings.

In preparation for the collection of three-dimensional scapular kinematics, electromagnetic receivers were secured on the subject's body segments with double-sided adhesive tape, athletic tape and elastic pre-wrap over the following landmarks: the spinous process of the seventh cervical vertebrae, the flat, broad portion of the acromion process of the scapula (bilaterally), and the posterior aspect of humerus just distal to triceps brachii muscle belly (bilaterally) (Table 2). A fourth receiver was secured to a stylus that was used for digitization of landmarks (Myers, Laudner et al. 2005; Thigpen, Padua et al. 2006).

Once the sensors were secured, subjects stood with their arms hanging naturally beside their body while the investigator digitized the bony landmarks on the thorax, humerus and scapula to allow transformation of the receiver data from the global coordinate system to anatomically based local coordinate systems. The sensor placement and the landmarks used to define the local coordinate system were in accordance to the recommendation of International Society of Biomechanics Shoulder Group (Table 3).

Once preparation was completed, the subject performed two tasks: glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane. The researcher implemented counterbalancing of tasks by assigning task order prior to subject testing. Both motions occurred through a range of motion of approximately 0º of humeral elevation to approximately 180 º of humeral elevation in their respective planes of motion. Subjects elevated both arms to the terminal end point in the available range of motion while maintaining a neutral hand position throughout the entire range of motion.

The plane of humeral elevation and the speed of the movement during the two tasks were standardized across subjects with the use of PVC pipes and metronome. Tasks were performed bilaterally, from a standing position, feet at a comfortable width and eyes fixed forward. A pole made of PVC pipe was placed 30º anterior to the frontal plane of the thorax to serve as a guide for subjects performing glenohumeral elevation in the scapular plane.

The pole was placed in the humeral sagittal plane and used as a guide during glenohumeral elevation in the sagittal plane. Subjects were asked to complete their full range of motion bilaterally at a controlled movement velocity by moving in time with a digital metronome set at 1 Hz.

Subjects were allowed three practice trials of each functional task to be tested: glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane (30º anterior to the frontal plane of thorax). Each functional task consisted of ten continuous repetitions, with each repetition lasting approximately four seconds (two-second ascending phase, two-second descending phase). After the completion of the task, subjects were allowed a two-minute rest before starting the next task.

Data Reduction

Raw kinematic data were low pass filtered with a fourth-order zero-phase shift at a 6.6 Hz cut off frequency (Ludewig and Cook 2000; Borstad and Ludewig 2002; Myers, Laudner et al. 2005; Thigpen, Padua et al. 2006). Scapular position and orientation were analyzed at 0 º, 30 º, 60 º, 90 º and 120 º of the ascending phase of glenohumeral elevation in the sagittal plane and glenohumeral elevation in the scapular plane.

The position and orientation data of the thoracic, scapular, and humeral receivers were transformed into a local coordinate system for each of the respective segments. Definitions of the local coordinate systems are presented in Table 3. The coordinate systems used were in accordance with recommendations from the International Shoulder Group of the International Society of Biomechanics (Wu 2005).

Euler-angle decompositions were used to describe humeral and scapular orientation with respect to the thorax. Scapular orientation was defined using three axes with the acromial angle serving as the origin: the z-axis described the vector from thoracic spine to acromial angle; the x-axis described the vector perpendicular to the plane set by the thoracic spine, acromial angle and inferior angle of scapula; and the y-axis described the vector perpendicular to the x and z axes. Orientation of the scapula was described as rotation about the y-axis of scapula (internal/external rotation), rotation about the z-axis of the scapula (upward/downward rotation), and rotation about the x-axis of scapula (anteroposterior tilting). Each of these rotations was chosen based on the recommendations of the International Shoulder Group (Wu 2005).

The scapula's only point of attachment to the thorax is via the clavicle, a rigid body with a fixed length. As such, the position of the scapula was described by two degrees of freedom as if in spherical space, by both elevation/depression and protraction/retraction. The position of the scapula was calculated by the position vector between the acromioclavicular joint (AC) and incisura jugularis (IJ) points with respect to the coordinate system of the thorax. The angle of this vector relative to the transverse plane that bisects the IJ point represents elevation/depression of the scapula. For protraction/retraction, this vector was projected onto the transverse plane bisecting IJ and was calculated as the angle between this projection and the frontal plane that bisects IJ (Karduna, McClure et al. 2001; McClure, Michener et al. 2001).

Statistical Analysis

Simple linear regression analyses were performed implementing scapular kinematic variables as the predictor of the score on SICK Scapula, Static Measurements rating scale. The analyses were run separately for each scapular kinematic variable at each humeral angle for both tasks. A total of fifty linear regression analyses were performed. An alpha level of .05 was set prior to the study. Due to performing multiple comparisons within the five orthogonal humeral angles of the tasks' ascending phase, an adjusted alpha level of 0.01 was implemented in order to control for inflation of the type I errors.

RESULTS

Statistical significance was found only with humeral elevation in the sagittal plane task. A simple linear regression indicated that the scapular upward rotation at zero degrees of humeral elevation in sagittal plane significantly predicts the overall SICK score ($F(1,37) = 9.812$, $p = .003$, $r^2 = .210$). The mathematical prediction equation for this regression would be: Overall SICK score = .230 (UR_DR_0) + 4.167.

A simple linear regression indicated that the scapular upward rotation at 30 degrees of humeral elevation in sagittal plane significantly predicts the overall SICK score ($F(1,37) = 8.107$, $p = .007$, $r^2 = .180$). The mathematical prediction equation for this regression would be: Overall SICK score = .198 (UR_DR_30) + 3.015.

A simple linear regression indicated that the scapular elevation at zero degrees of humeral elevation in sagittal plane significantly predicts the overall SICK score ($F(1,35) = 8.040$, $p = .008$, $r^2 = .187$). The mathematical prediction equation for this regression would be: Overall SICK score = .247 (Elv_Dep_0) + 1.820.

Table 1. Study Participant Demographics

	Male Participants (n = 8)		Female Participants (n = 31)	
	Mean	**±SD**	**Mean**	**±SD**
Age (years)	19.14	1.07	19.97	1.08
Height (cm)	181.43	2.48	173.79	8.42
Mass (kg)	73.87	3.59	69.00	7.90
SICK Score [a]	5.29	2.23	4.32	3.44
Subjective [b]	2.14	1.25	1.66	1.64
Objective [c]	1.43	0.79	1.45	1.62
Malpositioning [d]	1.71	0.64	1.23	0.84

[a] SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale
[b] Self-reported pain of the coracoid process, AC joint, periscapular soft tissue, proximal lateral arm, and/or elbow (possible 5 points)
[c] Self-reported tenderness to palpation of the co racoid process, AC joint, superior medial angle; (+) provocative impingement test (Hawkins -Kennedy Impingement Sign), (+) scapular assistance test, and/or (+) thoracic outlet syndrome test (Allen Test) (possible 6 points)
[d] Scapular malposition based on 1) infera (i.e. the visual appearance of a dropped scapula due to scapular tilting or protraction), 2) lateral displacement, and 3) abduction (possible 9 points)

Table 2. Description of Bony Landmarks

Bony Landmarks	Description of Palpation Point
Thorax	
8^{th} Thoracic Spinous Process (T8)	Most dorsal point
Processus xiphoideus (PX)	Most caudal point of sternum
7^{th} Cervical Spinous Process (C7)	Most dorsal point
Incisura jugularis (IJ)	Most cranial point of the sternum (suprasternal notch)
Scapula	
Angulus acromialis (AA)	Most lateral-dorsal point of scapula
Trigonum spinae (TS)	Midpoint of triangular surface on the medial border of the scapula in line with the scapular spine
Angulus inferior (AI)	Most caudal point of scapula
Humerus	
Medial epicondyle (ME)	Most medial point on the medial epicondyle
Lateral epicondyle (LE)	Most lateral point on the lateral epicondyle
Glenohumeral joint center (GH) ∗	

∗ The glenohumeral joint center was not palpated but rather estimated with a least squares algorithm for the point on the humerus which moves the least during several short arc humeral movements.(Harryman, Sidles et al. 1990; Stokdijk, Nagels et al. 2000)

Table 3. Definitions of Local Coordinate Systems

Local Coordinate System	Axis	Definition
Thorax	y_t	Vector from the midpoint of PX and T8 to the midpoint between IJ and C7, pointing upward
	z_t	Vector perpendicular to the plane formed by IJ, C7, and the midpoint between PX and T8, pointing to the right.
	x_t	Vector perpendicular to z_t and y_t
	Origin	IJ
Scapula	z_s	Vector from TS to AA, pointing to AA.
	x_s	Vector perpendicular to the plane formed by TS, AA, and AI, pointing forward.
	y_s	Vector perpendicular to x_s and z_s.
	Origin	AA
Humerus	y_h	Vector connecting GH and the midpoint of EL and EM, pointing to GH
	x_h	Vector perpendicular to the plane formed by EL, EM, and GH, pointing forward.
	z_h	Vector perpendicular to y_h and x_h
	Origin	GH

Thorax: **C7**:spinous process of 7th cervical vertebrae; **T8**:spinous process of 8th thoracic vertebrae; **IJ**: deepest point of Incisura Jugularis (suprasternal notch); **PX**: Processus Xiphoideus (xiphoid process), most caudal point on the sternum
Scapula: **TS**: trigonum spinae scapulae (root of the spine), the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine; **AI:** Angulus Inferior (inferior angle), most caudal point of the scapula; **AA:** Angulus Acromialias (acromial angle), most laterodorsal point of the scapula
Humerus: GH: Glenohumeral rotation center; **EL:** most caudal point on lateral epicondyle; **EM:** most caudal point on medial epicondyle

Table 4: Scapular Kinematics Data during Humeral Elevation in Sagittal plane (Flexion)

	Mean	± SD	r^2	p
Scapular upward/downward rotation				
0° humeral elevation	1.34	6.53	.210	.003*
30° humeral elevation	7.40	7.09	.180	.007*
60° humeral elevation	22.0	7.66	.088	.067
90° humeral elevation	34.65	10.92	.058	.139
120° humeral elevation	45.72	14.34	.048	.181
Scapular external /internal rotation				
0° humeral elevation	25.44	11.38	.004	.713
30° humeral elevation	31.64	11.60	.004	.718
60° humeral elevation	40.26	12.43	.002	.797
90° humeral elevation	42.21	14.63	.001	.882
120° humeral elevation	37.82	20.02	.004	.702
Scapular posterior/anterior tilt				
0° humeral elevation	13.33	5.11	.027	.314
30° humeral elevation	10.74	6.01	.049	.177
60° humeral elevation	10.64	6.89	.070	.104
90° humeral elevation	9.05	11.22	.044	.202
120° humeral elevation	2.13	18.92	.007	.600
Scapular protraction/retraction				
0° humeral elevation	19.62	12.13	.001	.887
30° humeral elevation	19.26	12.98	.002	.819
60° humeral elevation	20.69	14.30	.046	.203
90° humeral elevation	26.30	15.44	.056	.160
120° humeral elevation	35.07	15.73	.083	.084
Scapular elevation				
0° humeral elevation	11.48	5.60	.187	.008*
30° humeral elevation	12.41	5.48	.118	.037
60° humeral elevation	18.76	5.43	.016	.452
90° humeral elevation	24.63	5.72	.000	.912
120° humeral elevation	27.93	5.80	.001	.840

* Statistically significant predictor of SICK Scapula Score ($p \leq .01$).

Table 5: Scapular Kinematics Data during Humeral Elevation in Scapular plane (Scaption)

	Mean	± SD	r^2	p
Scapular upward/downward rotation				
0^o humeral elevation	3.633	9.03	.069	.107
30^o humeral elevation	8.26	8.74	.040	.223
60^o humeral elevation	21.47	8.13	.072	.099
90^o humeral elevation	35.61	11.33	.055	.150
120^o humeral elevation	46.75	15.31	.092	.061
Scapular external /internal rotation				
0^o humeral elevation	25.74	15.06	.032	.273
30^o humeral elevation	27.29	18.95	.041	.217
60^o humeral elevation	28.54	16.88	.070	.151
90^o humeral elevation	32.17	25.51	.044	.258
120^o humeral elevation	36.38	25.39	.035	.311
Scapular posterior/anterior tilt				
0^o humeral elevation	12.53	5.57	.008	.583
30^o humeral elevation	10.70	5.27	.013	.482
60^o humeral elevation	8.60	5.95	.014	.470
90^o humeral elevation	6.52	8.83	.005	.670
120^o humeral elevation	4.30	15.54	.001	.870
Scapular protraction/retraction				
0^o humeral elevation	22.42	13.24	.015	.465
30^o humeral elevation	23.20	12.33	.004	.717
60^o humeral elevation	26.68	12.99	.008	.592
90^o humeral elevation	31.50	13.57	.018	.418
120^o humeral elevation	37.99	14.21	.027	.325
Scapular elevation				
0^o humeral elevation	11.40	6.18	.150	.018
30^o humeral elevation	12.91	5.86	.097	.061
60^o humeral elevation	19.08	5.67	.044	.214
90^o humeral elevation	25.54	5.70	.028	.324
120^o humeral elevation	30.60	5.84	.036	.259

Table 6. Breakdown of SICK Scapula Syndrome Score

			Subjective					Objective						Scapular Malposition								
Subject #	SICK Score Total	Subjective Pain Reported	Coracoid	AC Joint	Periscapular	Prox Lat Arm	Radicular	Coracoid	AC Joint	SM Scap Ang	Impingement Test	Scap Assist Test	TOS Parathesias	Infera 1 cm	Infera 2 cm	Infera 3 cm	Lat Prot 1 cm	Lat Prot 2 cm	Lat Prot 3 cm	Ab 5 degrees	Ab 10 degrees	Ab 15 degrees
1	1	Y			xx																	
2	0	N																				
3	0.5	N												x								
4	1.5	N												x			x			x		
5	2	N									x						xx			x		
6	2	N												x			x				x	
7	10.5	Y		xx	xx	xx	x	xx	x	x	xx	xx	x	x			xx			xx		
8	5.5	Y	xx		xx			xx		xx	xx	xx										
9	2	Y					x				xx			x								
10	2	N							x								xx			x		
11	1	N						xx														
12	6	Y			xx	xx		xx		xx				x			x			x		
13	6.5	Y		x	xx	xx		x		x	xx						xx			xx		
14	7	Y	xx			xx	xx	xx			xx		x	x						xx		
15	5	Y	x		x	x			xx	x				x			x			xx		
16	0.5	N															x					
17	10.5	Y	xx	xx	xx	x	xx	xx	xx	xx	xx		x				xx			x		
18	2.5	N		xx						xx				x								
19	5	Y	xx				xx	xx			xx									xx		
20	7	Y	xx	x	xx	x		x		xx				x			xx			xx		
21	6.5	Y					xx	x	x	x	xx			xx			xx				x	
22	11	Y	xx	xx	xx	xx	xx	xx	xx	xx	xx		x	x			xx					
23	2	N	x											x								
24	5	Y	xx		x	x	xx				x			xx			x					
25	7	Y	x		xx	xx	xx	xx		x								x		xx		
26	7	Y	x		xx		xx	x	x	xx				xx			x			xx		
27	1	N												x			x					
28	8.5	Y	x	xx	xx	xx	x	xx	xx	xx	xx									x		
29	0	N																				
30	7.5	Y	xx	x	xx	x		xx	xx		x			xx			x			x		
31	10	Y	xx	xx	xx	xx	xx	xx	xx	xx	xx		x				x			x		
32	3.5	N	xx														x	x		xx		
33	2.5	N			xx									xx						xx		
34	5.5	Y	xx		xx			xx			xx						xx			x		
35	2.5	N	x					x			xx						x					
36	5.5	Y	xx		x	x	x			x	xx			x						xx		
37	6.5	Y	x		xx		xx	x		xx	x			x			x					
38	0	N																				
39	3.5	N	xx							x				x			x			xx		
40	1	N												xx								
Total	**4.4**		**20**	**9**	**19**	**14**	**14**	**19**	**10**	**17**	**18**	**2**	**5**	**22**	**0**	**0**	**23**	**2**	**0**	**21**	**2**	**0**

x = identified by one investigator
xx = identified by two investigators
Prox lat arm = proximal lateral arm
SM scap ang = superior medial scapular angle

Scap assist test = scapular assistance test
Lat prot = lateral protraction
Ab = abduction

Figure 1. The SICK Scapula Static Measurements Point Rating Scale (Burkhart et al. 2003)

ORTHOPAEDIC SURGERY
MORGAN KALMAN
CLINIC
ARTHROSCOPIC SPECIALISTS

DATE ______________________ SPORT ______________________
NAME ______________________ POSITION ______________________
AGE ______________________ PRESENTING SX'S ______________________

SUBJECTIVE	PAIN	YES	NO	SCORE
	Coracoid	1	0	
	AC Joint	1	0	
	Periscapular	1	0	
	Prox. Lat. Arm	1	0	
	Radicular	1	0	
OBJECTIVE				
	Coracoid	1	0	
	AC Joint	1	0	
	Sup. Med. Scap. Angle	1	0	
	Impingement Test	1	0	
	Scapular Asst. Test	1	0	
	Tos Paresthesias	1	0	

SCAP. MALPOSITION	0cm	1cm	2cm	3cm	SCORE
Infera	0	1	2	3	
Lateral Protraction	0	1	1	3	
Abduction	0°	5°	10°	15°	
	0	1	2	3	
		TOTAL SCORE			

Figure 2. Predictive Relationship between Scapular Upward/Downward Rotation at Zero Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score

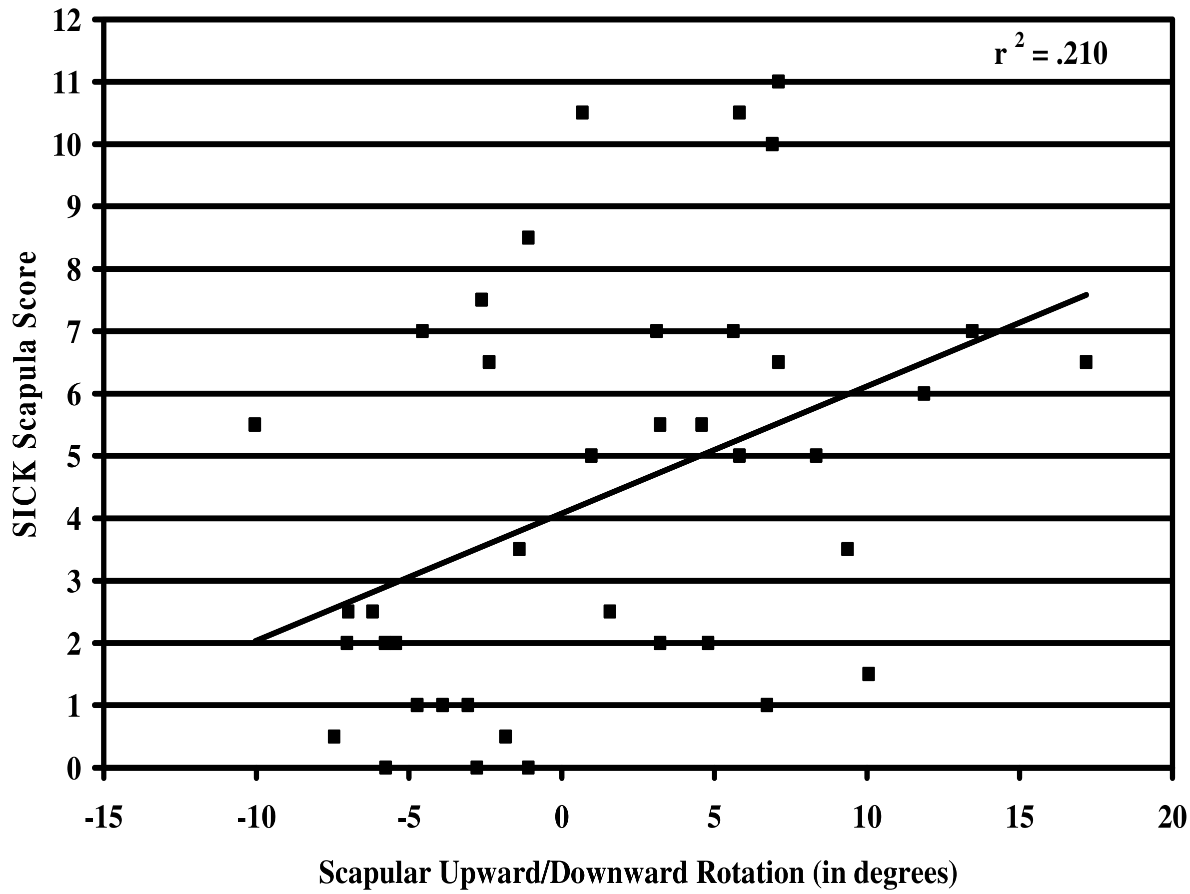


Figure 3. Predictive Relationship between Scapular Upward/Downward Rotation at Thirty Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score

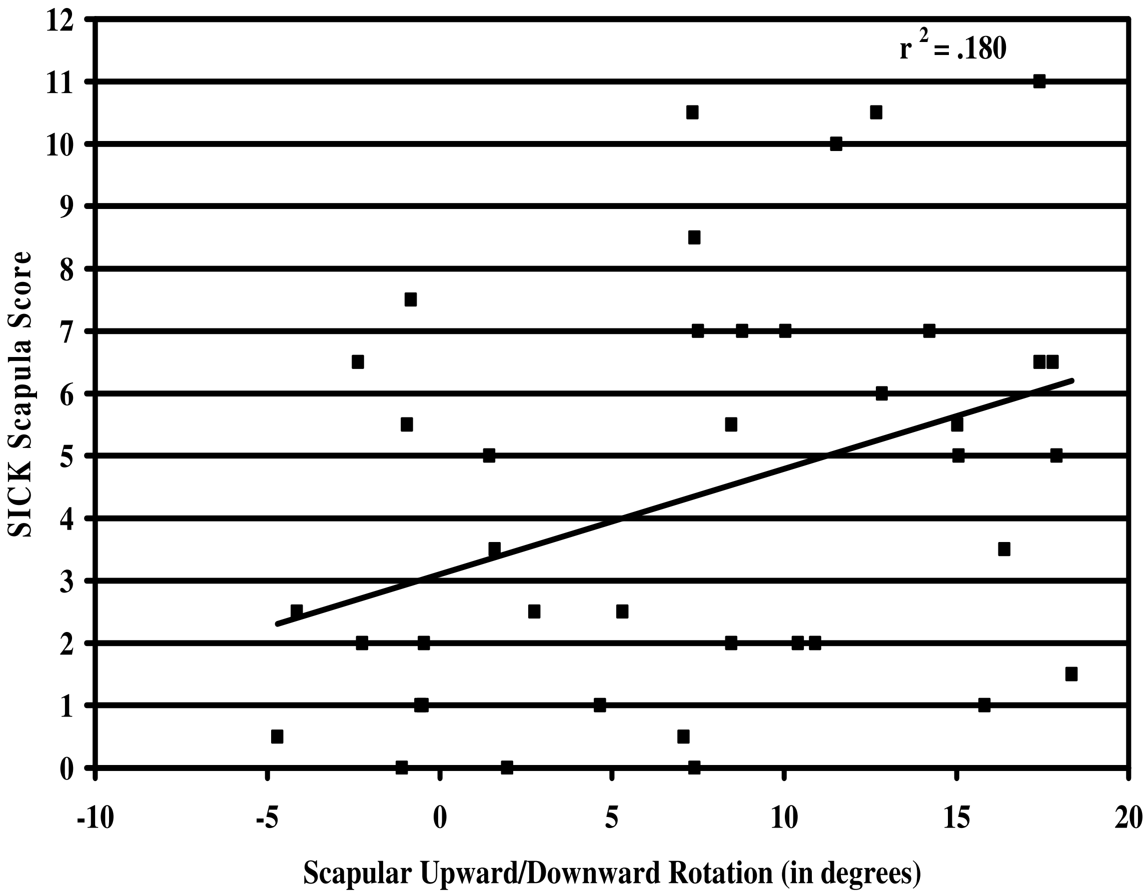
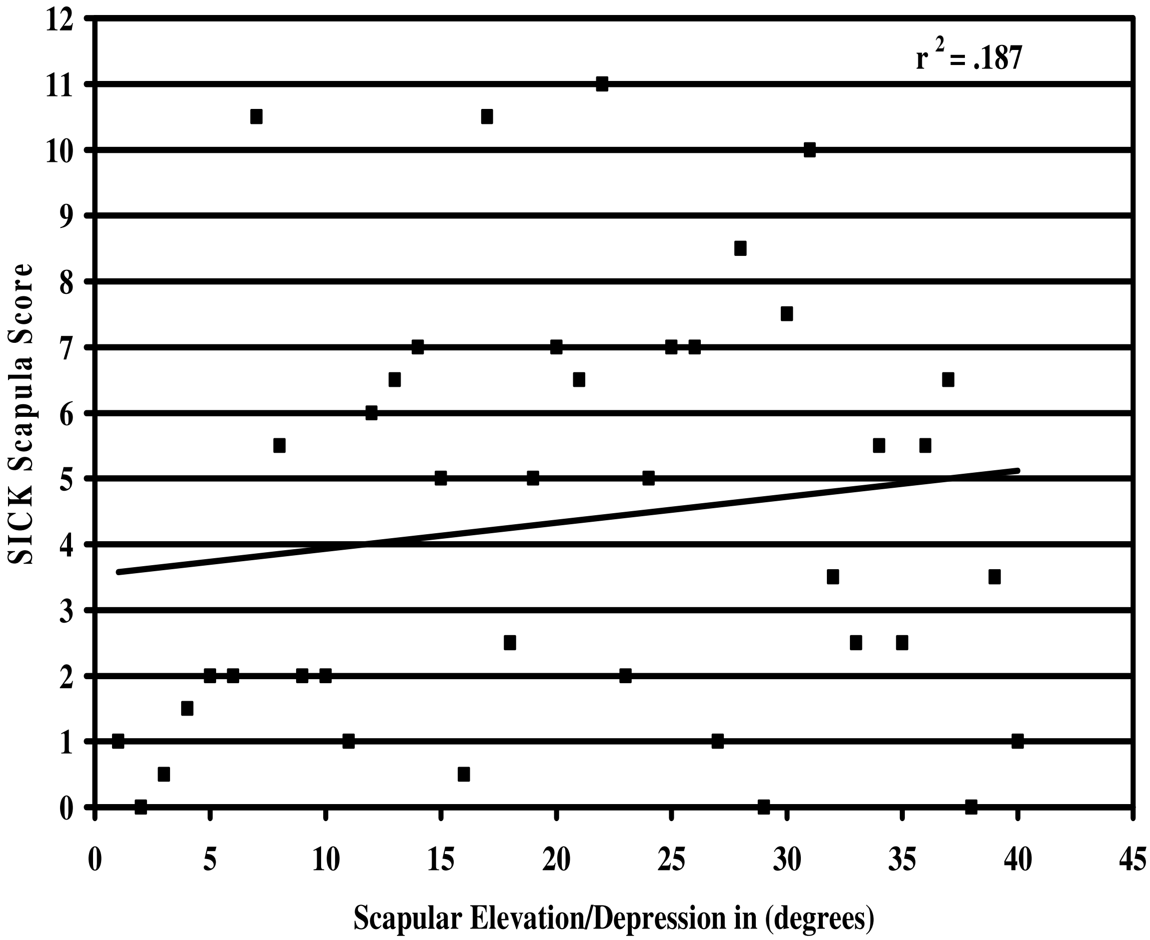


Figure 4. Predictive Relationship between Scapular Elevation/Depression at Zero Degrees of Humeral Elevation in the Sagittal Plane (Flexion) and SICK Scapula Score



DISCUSSION

The purpose of this study was to determine the predictive relationship between scapular kinematic data analysis and overhead athlete score on the SICK Scapula, Static Measurements, 0 to 20 point Rating Scale. Had this scale been proven to be a predictor of scapular dysfunction, results from three-dimensional scapular and humeral kinematic data would have illustrated the findings compromising the subject's SICK scapula score.

The most important finding of our study was that the SICK Scapula, Static Measurements, 0 to 20 point rating scale did not prove to be a strong predictor of scapular dysfunction in overhead athletes. During humeral elevation in the sagittal plane, scapular upward rotation at zero degrees, scapular upward rotation at thirty degrees, and scapular elevation at zero degrees were found to be statistically significant predictors of an increased SICK scapula score. We found no significant relationships between scapular kinematics and SICK scapula score during humeral elevation in the scapular plane. These findings were considered significant based upon obtaining a p-value of .01 or less; however, the strength of the significant relationship between scapular kinematic data and subject SICK score, represented by the r^2 value, proved to be extremely weak for all scapular variables.

Despite our hypotheses that increased scapular anterior tilt, increased scapular internal rotation and excessive protraction coupled with decreased scapular upward rotation and elevation would predict an increased SICK scapula score, no statistical significance was found for the relationship between scapular internal/external rotation, scapular anterior/posterior tilt, and scapular retraction/protraction on the subject's SICK scapula score. This lack of statistically significant relationships between the kinematic data of the SICK scapula trademark positions (increased anterior tilt, internal rotation and protraction) and subject score on the SICK Scapula Static Measurements scale questions the scale's predictive value and ability to detect scapular dysfunction. Moreover, the significant results found with scapular upward rotation and scapular elevation during the humeral flexion task were very weak predictive relationships.

We expected to see relationships between the scapular kinematic variables and the subjects' SICK scapula score based on the current literature describing the altered scapular kinematic patterns that are associated with repetitive overhead motions which cause shoulder pain and altered muscle force couple production. Current research shows that scapular kinematics may be altered by weak or dysfunctional scapular musculature (Ludewig and Cook 2000), fatigue of the infraspinatus and teres minor (Tsai 1998), and changes in thoracic and cervical spine posture (Ludewig, Cook et al. 1996; Kebaetse, McClure et al. 1999). The researchers recognized that the participants in this study may display one or several of the previously mentioned contributors to scapular dyskinesis due to muscular and postural changes induced by repetitive overhead motions.

Furthermore, recent research in patients with subacromial impingement syndrome has demonstrated decreased scapular posterior tilt, decreased scapular upward rotation and decreased scapular external rotation during glenohumeral elevation (Lukasiewicz, McClure et al. 1999; Ludewig and Cook 2000; Endo, Ikata et al. 2001). Based on this literature, we hypothesized that the participants in the current study would display decreased scapular upward rotation, decreased scapular external rotation and decreased scapular posterior tilt, similar to the patients with subacromial impingement, due to the participants' report of shoulder pain, the participants' observed posture of excessive scapular protraction and anterior tilt, and the frequency of overhead motion during the participants' sport training.

Our results regarding scapular kinematics in overhead athletes are in contrast to some findings of current research on subacromial impingement. Ludewig et al. (Ludewig and Cook 2000) demonstrated that subjects who reported symptoms of subacromial impingement displayed decreased scapular upward rotation, increased scapular anterior tipping, and increased scapular internal rotation during humeral elevation in the scapular plane. Similarly, Endo et al. (Endo, Ikata et al. 2001) reported decreased scapular posterior tilt and decreased scapular upward rotation in subjects with subacromial impingement. In contrast, we demonstrated that increases in scapular upward rotation and elevation at zero degrees and with scapular upward rotation at thirty degrees of humeral elevation in the sagittal plane were significant predictors of an increased SICK scapula score. Interestingly, we found no significant relationships for scapular anterior/posterior tilt or scapular internal/external rotation on SICK scapula score. However, our results demonstrating a weak predictive relationship between increased scapular elevation at zero degrees of humeral elevation and increased SICK scapula score are in agreement with findings of Lukasiewicz et al. (Lukasiewicz, McClure et al. 1999) which displayed increased scapular elevation in subjects reporting symptoms of subacromial impingement.

Our results are supported by the findings of McClure et al. (McClure, Michener et al. 2006) who displayed greater scapular upward rotation and clavicular elevation during mid-range humeral flexion in subjects with subacromial impingement. Interestingly, McClure et al. (McClure, Michener et al. 2006) found no differences between groups in forward shoulder posture; which is believed to capture potential tightness of the pectoralis minor muscle and to manifest as excessive scapular protraction and coracoid pain. Similarly, we also found no significant results regarding the degree of scapular protraction in predicting the presence of SICK scapula syndrome in overhead athletes.

Although the previously mentioned studies specifically address subacromial impingement and not SICK scapula syndrome, the results may be relevant to SICK scapula syndrome because scapular malposition and dysfunction are major contributors to subacromial impingement (Hebert, Moffet et al. 2002). Similarities in pathological signs and symptoms confirm that scapular malposition and dyskinesis are inherent to both SICK scapula syndrome and subacromial impingement. Therefore, the scapular kinematics observed in the subacromial impingement studies were considered to be relevant and applicable to the participants in our study of SICK scapular syndrome.

We demonstrated that increases in scapular upward rotation at zero degrees and at thirty degrees of humeral elevation in the sagittal plane were found to be weak predictors of an increased SICK scapula score. Although, these findings are in contrast to the results of the previously mentioned studies of patients with subacromial impingement, the increased scapular upward rotation of participants in the current study may be explained by the findings of Myers et al (Myers, Laudner et al. 2005). In a study of scapular position and orientation in throwing athletes, Myers et al. demonstrated that normal, healthy throwing athletes may develop an adaptive increase in scapular upward rotation to assist in subacromial clearance throughout the throwing movement pattern; thereby preventing subacromial impingement. In addition, Myers et al. acknowledged that scapular malpositioning may exist in the absence of and as a prevention to shoulder pain and dysfunction. These preventative adaptations could explain why there were participants in our study who did not report shoulder pain but who displayed increases in scapular upward rotation and elevation. Furthermore, current research displays that coordinated elevation and upward rotation of the scapula with the humerus is important for maintaining sufficient subacromial space as the humerus is elevated to approximately 90° during the throwing motion, thus avoiding impingement of the rotator cuff in this position (Dillman, Fleisig et al. 1993; Kibler 1998; Myers, Laudner et al. 2005).

Based on the literature describing these adaptations in overhead athletes, it is not surprising that we observed that increases in scapular upward rotation and elevation at zero degrees of humeral elevation in the sagittal plane and scapular upward rotation at thirty of humeral elevation in the sagittal plane were associated with slight increases in SICK scapula score. Although, these relationships were significant, they were extremely weak, as represented by the r squared values in Table 4. Perhaps the findings from this study further confirm the idea that overhead athletes may develop adaptations in scapular positioning without suffering from shoulder pain.

The discrepancy between the existence of shoulder pain, scapular malposition and shoulder or scapular dysfunction creates significant challenges in clinical assessment. Although the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale was designed to aid clinicians in the evaluation of scapular dysfunction, we recognized several potential flaws of the scale which may have resulted in skewed scoring.

Shoulder pain may exist without the presence of scapular malpositioning and/or dyskinesis; therefore, subjects could display no signs of scapular malposition, but may report "yes" responses to the subjective and objective portions of the scale. These subjects may earn up to 11 points; thereby being classified as having SICK scapula syndrome without actually presenting signs of scapular malposition or dyskinesis. This score would be a misrepresentation of SICK scapula in that the subject does not display the trademark characteristics of **S**capular malposition, **I**nferior medial border prominence, **C**oracoid pain and malposition, and dys**K**inesis of scapular movement.

As previously noted by the significant findings of Myers et al, overhead athletes may display asymptomatic scapular malpositioning presented as an adaptive increase in scapular upward rotation (Myers, Laudner et al. 2005). In this case, overhead athletes screened with the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale may earn high scores in the scapular malposition section, yet have no subjective or objective complaints of pain. This subject's SICK score would be a misrepresentation of pathology in that scapular malpositioning alone does not indicate a symptomatic shoulder.

In our study, over half of the subjects reported having a painful shoulder, yet only four were clinically diagnosed post-screening as having SICK scapula syndrome. This disconnection highlights the ambiguity of the relationship between shoulder pain and actual scapular malposition or dyskinesis. Furthermore, these results may potentially indicate that the SICK Scapula Static Measurements Scale is a weak predictor and detector of scapular dysfunction.

Considering that participants in this study were Division I overhead athletes (with the exception of two subjects who were recreational level) who participated in their sport at high intensities, for several hours a week; and that 22 of the 40 participants reported shoulder pain, we hypothesized that this sample of overhead athletes would produce moderate to high SICK scapula scores. However, upon examination of the distribution of SICK scapula scores, it is clear to see that the majority of overhead athletes scored below 10 and the highest SICK scapula score recorded was 11. Based on these SICK scapula scores, none of the participants would be identified as having moderate to severe scapular pain or dysfunction.

However, upon our observation of static and dynamic bilateral scapular asymmetry; as well as, standing cervical and thoracic posture, we would argue that nearly half of the participants displayed signs of scapular malposition and dysfunction. Therefore, we question the effectiveness of the items included in the SICK Scapula Static Measurements Scale in detecting the most prevalent signs and symptoms of scapular dysfunction. Perhaps, the subjective, objective and scapular malposition components that comprise the SICK Scapula Static Measurements Scale should be reassessed in their ability to detect scapular pain, malposition and dysfunction.

After screening nearly 100 subjects throughout the course of both pilot work and this research study, we recognized one potential obstacle of the SICK Scapula Static Measurements Scale to be the difficulty in scoring due to the scale's framework of point distribution and of screening components. Point distribution among the scale's sections is heavily weighted upon the subjective and objective portions of the scale; therefore, eleven of the scale's maximal twenty points are dependent upon the subject's report of shoulder or scapular pain. If the subject does not clearly identify the characteristics of pain, has a high pain tolerance or does not give an honest report of pain, the SICK score could be extremely misleading despite the results from the scapular malposition section. Also, in the case that subjective and objective reports of pain produce very low scores, only gross scapular malpositioning (i.e. > 15 degrees of scapular abduction) would result in a clinical diagnosis of SICK scapula syndrome. This degree of severe scapular malposition is very uncommon in both the overhead athlete and the common patient (Warner, Micheli et al. 1992; Lukasiewicz AC 1999; Ludewig PM 2000; Hebert, Moffet et al. 2002; Kibler and McMullen 2003; McClure, Bialker et al. 2004; McClure, Michener et al. 2006).

Imbalances in point distribution affect the scoring of the scapular malposition section as well. The scapular malposition scoring system, based on threshold values, creates a wide margin of error because scores can not be rounded up; despite being within one degree of the next scoring category. For example, if the researcher measures nine degrees of scapular abduction, the participant earns only one point (not rounding up to ten for two points) for the scapular abduction measurement because abduction has not met or exceeded ten degrees. Based on this threshold scoring system, mild scapular malposition would not likely yield more than a total score of three for the measurement section. This phenomenon reduces the clinical effectiveness of the SICK Scapula Measurement Scale because severe scapular malposition would have to exist in order to obtain significant scores. This severe degree of scapular malposition is uncommon in overhead athletes and in symptomatic patients.

Another potential flaw of the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale(Burkhart, Morgan et al. 2003) is that the scale contains items that screen for a wide variety of shoulder pathologies; instead specifically detecting scapular dysfunction, For example, the subjective portion includes assessing AC joint pain; proximal lateral arm pain, a symptom of subacromial impingement; and radicular pain, a symptom of thoracic outlet paresthesia. The objective portion re-assesses the AC joint pain, in addition to, testing for impingement and thoracic outlet syndrome. Because the scale includes assessment items to screen for such a wide range of shoulder pathologies, it sacrifices the ability to be highly specific and accurate in detecting the presence of the defining characteristics of SICK scapula. A subject may possess all of the classic characteristics of SICK scapula syndrome (i.e. **S**capular malposition, **I**nferior medial border prominence, **C**oracoid pain and malposition, and dys**K**inesis of scapular movement), but may not score any points for AC joint irritation, thoracic outlet paresthesias, or subacromial impingement syndrome. In this case, the subject would score relatively low for both the subjective and objective sections; therefore giving the illusion that the subject has no scapular dysfunction.

Potentially, the predictive value of the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale(Burkhart, Morgan et al. 2003) in detecting scapular pain and malposition must be challenged. Although this scale was designed to aid clinicians in detecting the potential, the presence, and/or the severity of SICK scapula syndrome, the scale's efficacy in specifically identifying scapular dysfunction may be hampered by the high dependency on subject self-reported pain, the inclusion of items that screen for other shoulder pathologies and the threshold scoring of scapular malposition.

We recognize a disconnection between the constructs of the SICK Scapula Static Measurements Scale and the actual presence of scapular malposition and dysfunction in overhead athletes. Although our statistical results showed that increased scapular upward rotation and elevation were predictive of an increased SICK scapula score, one must consider that increased scapular upward rotation and elevation could actually be healthy adaptations in overhead motion and that the increased SICK score could be attributed to factors, other than scapular position, that cause shoulder pain. We propose that the subject's SICK scapula score did not effectively indicate or describe scapular pain or malposition. Our significant findings indicating direct relationships between scapular upward rotation and elevation and an increased SICK scapula score are more than likely representative of a healthy adaptation in scapular position; instead of malpositioning that causes shoulder pain. We recognize that the presence of scapular malposition does not necessarily indicate scapular dysfunction. We are not convinced that our significant findings represent a true predictive relationship between increased scapular upward rotation and scapular elevation, and scapular pain and dysfunction in overhead athletes.

The discrepancy between the altered scapular kinematics we observed and the presence of scapular pain and dysfunction, which is supposedly indicated by the SICK scapula score, raises questions regarding the actual existence of SICK scapula syndrome. "SICK scapula" seems to be a catch-all, umbrella-term that has been misused to describe scapular malposition. We believe the characteristics of SICK scapula are neither closely related nor well-defined enough to be entirely exclusive in determining a specific pathology. The signs and symptoms included in the SICK Scapula Scale encompass several shoulder pathologies (subacromial impingement, AC joint pathology, thoracic outlet syndrome, and glenohumeral labral lesions); instead of delineating a separate condition. Because scapular dysfunction may be a component in many shoulder pathologies, it becomes difficult to establish a distinct syndrome based on the elements common to so many pathologies. A clinical diagnosis of SICK scapula syndrome reveals minimal information distinguishing the specific underlying anatomical and functional basis for shoulder pathology. Despite the argument for or against the presence of an actual SICK scapula syndrome, our research highlights the necessity for a more in-depth and specific scapular evaluation process.

Limitations

Perhaps the greatest limitation of this study was the narrow and low-end range of SICK scapula scores obtained when utilizing the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003). While subject recruitment made no distinction regarding a need for either symptomatic or asymptomatic shoulders, only four of forty subjects obtained scores from screening that qualified them to be clinically diagnosed with SICK scapula syndrome. Furthermore, no subject scored higher than an 11 out of a possible 20 points. Again, we attribute unexpected subject scoring to potential flaws with the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003).

The current study included athletes from several overhead sports: swimming, volleyball and softball. Unfortunately, two groups of overhead athletes not included in this study were baseball and tennis athletes. Despite extensive subject recruitment, the researcher was not able to obtain baseball or tennis athletes for testing due to the athletes' in-season sport. Therefore, we recognize the absence of baseball and tennis athletes in this study of overhead athletes as a limitation. These athletes are predisposed to shoulder and scapular pathologies; however caution must be used in extrapolating our findings to baseball or tennis athletes. Future studies should investigate the relationship between scapular kinematics and subject score on the SICK scapula scale present in baseball pitchers and field-players; as well as, tennis athletes.

A significant limitation in our study involves determining the variance between a subject's dominant and non-dominant shoulder. Due to instrumentation difficulties, we were limited to testing only the subject's dominant or painful shoulder. Therefore, we were not able to compare scapular kinematics bilaterally within each subject. A bilateral comparison would provide information regarding differences in scapular kinematics between a subject's healthy and pathological shoulder.

Future Research

Future research should seek to further identify scapular dysfunction in symptomatic overhead athletes. Based on our findings, we believe that it is necessary to conduct a much larger-scale research study including overhead athletes with ill-maintenance shoulders from a wide-variety of sports. Ideally, these athletes would better exemplify the SICK scapula syndrome in its most exaggerated form; thereby producing significant statistical and clinical findings.

In addition, future research should focus on collecting data to determine the most specific and valid objective assessments and measurements of scapular pain, malposition and dyskinesis. Once validity, reliability and specificity are determined, these items could be compiled and structured into a more effective, accurate and specific screening tool for clinicians. The designers should take precautions to ward against placing excessive emphasis on subjective reports of pain, to include items specifically sensitive to SICK scapula syndrome and to decrease the wide threshold scoring margin with scapular measurements.

We acknowledge the findings listed in Table 6 when offering sound recommendations regarding the development of a new and theoretically improved screening instrument. By dissecting SICK scapula syndrome score for each of the forty subjects screened, we were able to tease out exactly where the bulk of point allotment occurred, specifically among those with self-reported shoulder pain. Based on score breakdown, we conclude that ten characteristics of SICK scapula syndrome best exemplify the condition's signs and symptoms, thus serving as the most accurate predictors regarding its presence and severity. We recommend the following subjective questions for the presence of pain: coracoid process, periscapular, proximal lateral arm, and radicular symptoms. We recommend the following objective palpations and/or special tests for the presence of pain: coracoid process, superior medial scapular angle, and Hawkins-Kennedy Impingement Test. We recommend the following measurements for the determination of scapular malpositioning: infera 0 to 1 cm, lateral protraction 0 to 1 cm, and abduction 0 to 5 degrees.

We also recommend the implementation of a more detailed objective screening process; one which includes a postural assessment, observation and measurement of dynamic scapular positioning, soft-tissue mobility assessment, and scapular muscle strength assessment. Postural assessments should seek to identify and grade the presence of cervical lordosis, thoracic kyphosis, lumbar lordosis, pelvic rotations, and abnormal hip rotations that may affect scapular kinematics as energy is transferred through the kinetic chain from the lower extremity and core to the thorax and upper extremity (Sauers 2006). Clinicians may perform a quick and effective postural assessment utilizing a plumb-line while observing the patient from a side-view.

Scapular position should be observed at rest and during loaded and unloaded humeral elevation. While in resting position, clinicians should observe the scapulae for signs of winging (i.e. excessive scapular internal rotation, scapular anterior tilt, and scapular elevation). Dynamic scapular motion should be assessed in both loaded and unloaded conditions. Johnson et al.(Johnson 2004; Sauers 2006) developed a protocol to detect abnormal scapular motion via the repetitive challenging of the scapulae under loaded conditions. The authors data indicated that three tests were able to detect abnormal scapular motion: 1) observation of bilateral scapular motion during five to ten repetitions of unloaded humeral elevation in the scapular plane (scaption) to establish a baseline of scapular movement, 2) observation of bilateral scapular motion during five to ten repetitions of loaded

(0.5-5 kg) scaption, and 3) observation of unilateral scapular motion during resisted isometric external rotation with the arm at the side in neutral rotation (i.e. scapular flip sign) (Johnson 2004; Sauers 2006).

The scapular lateral slide test is a semi-dynamic, quantitative assessment of scapular position. This test has been shown to be reliable in assessing the bilateral position of the scapulae in relation to a fixed point on the spine as varying loads are placed on the supporting scapular musculature (Kibler 1998; Kibler and McMullen 2003). The test involves a series of three measurement positions.

Evaluation of the mobility of the posterior glenohumeral joint capsule, the posterior shoulder musculature, and the anterior coracoid musculature provides critical information regarding the pathomechanical assessment of scapular dysfunction. Posterior glenohumeral joint capsule contracture has been shown to produce excessive superior and anterior humeral head translation, thereby compromising the size of the subacromial space and altering glenohumeral and scapular kinematics.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) Posterior shoulder tightness is an additional commonly described flexibility characteristic of scapular dysfunction. (Fleisig, Barrentine et al. 1996; Ludewig and Cook 2000; Ludewig PM 2000; Pink and Tibone 2000; Hebert, Moffet et al. 2002; Burkhart, Morgan et al. 2003; Kibler and McMullen 2003; Su, Johnson et al. 2004; Myers, Laudner et al. 2005; McClure, Michener et al. 2006; Thigpen CA In Press) Myers et al. quantify posterior shoulder tightness utilizing supine and side-lying horizontal adduction assessments.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) One final flexibility measurement to consider during scapular evaluation is pectoralis minor mobility. Due to its proximal attachment on the coracoid process of the scapula, inflexibility of the pectoralis minor muscle may manifest as excessive scapular anterior tilt and internal rotation, thus resulting in coracoid process pain and scapular dysfunction.

Manual muscle testing of the scapular stabilizing muscles is critical in determining the presence of or potential for scapular dysfunction. Strength of the middle and lower trapezius, rhomboids major and minor, and the serratus anterior muscles should be assessed through manual muscle testing techniques. Additional scapular muscle strength and endurance tests include the isometric scapular retraction pinch and wall push up tests. Typically, patients are able to hold an isometric pinch of the scapulae in retraction for 15 to 20 seconds without the onset of burning pain or muscle weakness. An inability to hold this position due to pain or weakness provocation is a positive sign indicating scapular muscle dysfunction.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000) The ability of the serratus anterior muscle to stabilize the scapula on the thorax is easily evaluated with the wall push-up test. The patient performs 5-10 wall push-ups while the clinicians observes for abnormalities in scapular position and motion, specifically scapular winging.(Kibler 1998; Garrett WE 2000; Ludewig and Cook 2000)

Conclusion

This study is the first to assess the predictive relationship between scapular kinematics and overhead athlete's score on the SICK Scapula, Static Measurements, 0 to 20 Point Rating Scale (Burkhart, Morgan et al. 2003). Three-dimensional scapular kinematic data of overhead athletes performing humeral elevation in the sagittal plane revealed very weak significant prediction of SICK scapula score. Scapular upward rotation at zero degrees of humeral elevation in the sagittal plane, scapular upward rotation at thirty degrees of humeral elevation in the sagittal plane, and scapular elevation at zero degrees of humeral elevation in the sagittal plane were found to be weak significant predictors of SICK scapula score in overhead athletes. No significant predictive relationships were found between scapular kinematics during humeral elevation in the scapular plane and SICK scapula.

APPENDIX D: CONSENT FORM

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

IRB Study #________07-1689_____________
Consent Form Version Date: _______11/19/07_______
Title of Study: A Validation of the SICK Scapula Rating Scale in Overhead Athletes: Prediction of Score from Strength, Flexibility, Muscle Activation, and Kinematic Analysis
Principal Investigator: Karen Tankersley, BS, ATC-L ; Sarah Vizza, BS, ATC-L
UNC-Chapel Hill Department: Exercise and Sport Science
UNC-Chapel Hill Phone number: 919-962-2067
Email Address: ktankers@email.unc.edu; svizza@email.unc.edu
Co-Investigators: Kevin Guskiewicz, PhD, ATC-L; William Prentice, PhD, ATC-L; Steven Zinder, PhD, ATC; Shana Harrington, MPT; Johna Register Mihalik, MA, ATC-L; Saki Oyama, MS, ATC
Faculty Advisor: Joseph Myers, PhD, ATC
Funding Source:
Study Contact telephone number: 919-962-2067
Study Contact email: ktankers@email.unc.edu; svizza@email.unc.edu

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<u>What are some general things you should know about research studies?</u>
You are being asked to take part in a research study. To join the study is voluntary.
You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

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

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

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

<u>What is the purpose of this study?</u>
The purpose of this study is to validate a clinical shoulder assessment tool called the SICK Scapula Rating Scale. This study is designed to look at shoulder strength, flexibility, shoulder blade movement, and shoulder blade muscle activity in athletes who use their arms over their heads.

You are being asked to volunteer for this study because you actively participate in a physical activity at least 3 times per week for a minimum of 30 minutes each session, one in which your arms are required to be over your head for a significant period of time within each session. It is believed that physically active individuals participating in repetitive overhead activities are at greatest risk for exhibiting alterations of normal position or motion of the shoulder blades.

Are there any reasons you should not be in this study?
You should not be in this study if you have a history of shoulder or neck surgery, rotator cuff tear, cervical spine pathology, history of acute-onset shoulder pathology within the last six months, adhesive capsulitis, history of unstable episodes within the past six months (glenohumeral subluxation, dislocation, self-subluxation), or scoliosis.

How many people will take part in this study?
If you decide to be in this study, you will be one of approximately 60 people in this research study.

How long will your part in this study last?
If you participate in this study, you will spend approximately 90 minutes during one testing session. A follow up session is not required.

What will happen if you take part in the study?
You will be asked to report to the Motor Control Lab located in 123 Fetzer on the UNC-CH campus. Male subjects will be asked to remove their shirt, and female subjects will be asked to wear either an athletic bra or tank-top. You will be asked questions regarding your shoulder history to ensure that you meet this study's criteria. You will then be measured for both height and weight and briefed on testing procedures. Your shoulder will then be evaluated by two Certified Athletic Trainers. They will ask you questions regarding your shoulder pain and take measurements around your shoulder. Following your briefing session, you will select a random task completion order for two shoulder elevation tasks.

During testing, male subjects will be required to take off their shirt and female subjects will be in a tank-top or wearing an athletic bra. This is to allow exposure of your shoulder blades and arms for strength testing and sensor/electrode placement.

Band-aid like electrodes that measure muscle activity will be attached over muscles on back of your neck, below your shoulder blade, and on the side of your trunk, just below your armpit. Sensors that measure joint motion will be placed on back of your neck, your shoulder, and close to your elbow. All of these sensors will then be secured with tape.

Prior to testing, you will perform one sub-maximal contraction for each of the previously mentioned muscles around the shoulder and upper back to adequately familiarize yourself with proper form for each manual muscle test. Following this warm-up and learning session, an investigator will apply a small force to your forearm, and you will be asked to hold your arm as still as possible for approximately five seconds. This process will be repeated in four different arm positions and three trials will be recorded for each position.

After the setup and baseline measurement has been completed, you will complete two lifting tasks. The first lifting task will require you to raise your arms above your head while they're directly in front of you. The second lifting task will require you to raise your arms above your head while they're off to the side of your body. You will lift your upper arm at shoulder while keeping your elbow straight over your head as far as possible. This will be done at a controlled movement velocity while keeping in time with a digital metronome. Each lifting task will require ten continuous repetitions, with each repetition lasting approximately four seconds. You will be given a 2 minute rest period between each lifting task. Lastly, your shoulder flexibility will be measured.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. You may not benefit personally from participating in this study.

What are the possible risks or discomforts involved with being in this study?
If you are selected for participation in this study, there is a risk of common discomfort that may be experienced during and following each of the two functional tasks. You may potentially experience mild discomfort during and following each of the two functional tasks, which can be attributed to the onset of muscle soreness due to temporary overuse. The discomfort that may be experienced with participation is similar to that associated with overhead athletic participation and/or activities of daily living in which your arms are being used over your head. In addition, there may be uncommon or previously unknown risks that might occur. You should report any problems to the researchers. If such problems occur, the researchers will assist you in obtaining medical care. However, any costs for the medical care will be billed to you or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay for any such reactions or injuries, or for the related medical care. However, by signing this consent form, you do not give up any legal rights.

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

How will your privacy be protected?
You will not be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

What will happen if you are injured by this research?
All research involves a chance that something bad may happen to you. This may include the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury

from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

What if you want to stop before your part in the study is complete?
You can withdraw from this study at any time, without penalty. The investigators also have the right to stop your participation at any time. This could be because you have had an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

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

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

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

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

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

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IRB Study # 07-1689
Title of Study: A Validation of the SICK Scapula Rating Scale in Overhead Athletes: Prediction of Score from Strength, Flexibility, Muscle Activation, and Kinematic Analysis
Principal Investigators: Karen Tankersley, BS, ATC-L ; Sarah Vizza, BS, ATC-L

Subject's Agreement:

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

______________________________________	________________
Signature of Research Subject	Date
______________________________________	
Printed Name of Research Subject	
______________________________________	________________
Signature of Person Obtaining Consent	Date
______________________________________	
Printed Name of Person Obtaining Consent	

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