2017

Effectiveness of a Shoulder Strengthening Intervention on the Incidence Rate of Glenohumeral Joint Instability Injuries

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EFFECTIVENESS OF A SHOULDER STRENGTHENING INTERVENTION ON THE INCIDENCE RATE OF GLENOHUMERAL JOINT INSTABILITY INJURIES

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Nutrition and Exercise Science

Specialization in Exercise Science

South Dakota State University

2017

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This thesis is approved as a credible and independent investigation by a candidate for the Master of Science in Nutrition and Exercise Science and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ACKNOWLEDGEMENTS

Performing research and putting together a quality presentation of the information obtained from that research is a process that takes more than one person to complete. I would first like to thank my advisor, Dr. Mary Beth Zwart for everything she did to help me complete this project. She helped me settle on a relevant idea and she put in the time reviewing everything I did to ensure that I put together a quality thesis. Her input, ideas, and direction were invaluable towards someone writing their first thesis. I would also like to thank Dr. Lee Weidauer for his contribution to my project. His work with me on the statistical analysis of my data helped me put together a thesis that had empirical support. Without his help, this paper may have just been a long list of ideas without any statistical relevance. He helped me put together a quality product that helped show the significance of the work done on this project over the past two years.

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ABSTRACT

EFFECTIVENESS OF A SHOULDER STRENGTHENING INTERVENTION ON THE INCIDENCE RATE OF GLENOHUMERAL JOINT INSTABILITY INJURIES

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Context: Shoulder injuries are frequently sustained in American football due to the contact and collision aspect of the sport. Injuries to the shoulder account for about 10% to 20% of all musculoskeletal injuries that occur in football and the shoulder is the fourth most commonly injured joint behind the hand, knee and ankle. The effectiveness of the dynamic stabilizers of the glenohumeral joint is a factor that could affect the rate of injuries that occur at the joint. The CKCUEST has been shown to be an effective test for assessing the dynamic stability of the glenohumeral joint. **Objective:** The purpose of this study is to determine if identifying and treating players can decrease the incidence of shoulder injuries in collegiate football players with poor dynamic stability at the glenohumeral joint. **Design:** Retrospective chart review. **Participants:** 90 NCAA football players. The average age of subjects was 20.88 years (+/-1.52), the average height was 185.14 cm (+/-6.17), and the average weight was 99.92 kg (+/-18.42). **Intervention:** The closed kinetic chain upper extremity stability test (CKCUEST) was used to identify subjects at risk for glenohumeral joint instability injuries. A shoulder-strengthening program was implemented into the summer workout program before the 2015 college football season. The CKCUEST was administered immediately before the 2015 season in August, 2015 and it was administered again after the end of the 2015 season. The incidence rate for glenohumeral instability injuries was calculated for the season prior to and the season after the intervention. **Main Outcome Measures:** CKCUEST scores and incidence rate for glenohumeral joint instability injuries **Results:** The incidence rate for glenohumeral joint instability injuries after the 2014 season was 0.38 per 1000 athletic exposures. The incidence rate for glenohumeral joint instability injuries was 0.98 per 1000 athletic exposures. A logistic regression analysis indicated an odds ratio of 1.04 with a confidence interval of (0.87, 1.25) for individuals that were identified as at risk based on their CKCUEST score. This indicated that the CKCUEST was not a statistically significant predictor for instability injuries to the glenohumeral joint. Post-hoc analysis revealed no difference for CKCUEST results between the initial and final testing sessions. **Conclusion:** The results of this study would imply that the CKCUEST might not be the most effective tool for assessing dynamic stability at the glenohumeral joint in college football players. The shoulder strengthening intervention used in this study may not have been the most effective method for reducing the incidence rate of glenohumeral joint instability injuries. More sport-specific studies including player position or use of protective equipment could be considered when assessing the risk of instability injuries occurring in football players.

CHAPTER 1

Introduction

Shoulder injuries are frequently sustained in American football due to the contact and collision aspect of the sport. Shoulder injuries account for about 10% to 20% of all musculoskeletal injuries that occur in American football and the shoulder is the fourth most commonly injured joint behind the hand, knee and ankle.[1] Forty-nine percent of the athletes at the 2004 National Football League (NFL) scouting combine reported a history of some sort of shoulder injury and 34% of those reported injuries required surgery.[2]

The anatomical characteristics of the glenohumeral joint make it relatively unstable. In order to articulate and function properly, the static and dynamic stabilizers of the glenohumeral joint must be intact. Any pathology to the glenoid labrum, the ligaments or the joint capsule, or the rotator cuff muscles will affect the joint kinematics and the stability of the glenohumeral joint. The soft tissue structures surrounding the glenohumeral joint provide static and dynamic stability throughout the joint's range of motion.[3] These structures also help the head of the humerus articulate correctly in the glenoid fossa of the scapula throughout normal range of motion.[3] This articulation provides some stability to the glenohumeral joint without limiting range of motion. To prevent these injuries from occurring to football players, preseason performance testing should include a way to measure the stability of the glenohumeral joint. Performance testing should effectively identify players that are at-risk for shoulder instability injuries.

The closed kinetic chain upper extremity stability test (CKCUEST) is a screening tool that has been shown to reliably identify athletes that are at risk or that already have glenohumeral joint instability pathologies.[4] The CKCUEST is easy to administer and it does not require expensive equipment. Lee and Kim[4] assessed the reliability of the

CKCUEST by comparing it to hand grip strength and isokinetic strength tests for the rotator cuff muscles. Both of the CKCUEST and hand grip strength can be used to assess the activity of the dynamic stabilizers of the glenohumeral joint.[4] Multiple studies have found that the CKCUEST had a high intraclass correlation coefficient demonstrating good test-retest reliability.[4-6] A high correlation also exists between the CKCUEST, grip strength, and peak torque of internal and external rotation indicating a high validity of the CKCUEST for assessing dynamic stability.[4]

After identifying athletes at risk for glenohumeral instability pathologies, there are strengthening and neuromuscular control interventions which can be used to prevent these glenohumeral joint instability injuries from occurring. Strengthening the dynamic stabilizers of the glenohumeral joint is key to maintaining the stability of the glenohumeral joint. Closed-kinetic chain exercises have been shown to be effective in the rehabilitation of glenohumeral joint injuries.[3] They improve dynamic stability through joint approximation and co-contraction of the muscles responsible for stabilizing the glenohumeral joint.[3] The compression of the glenohumeral joint that occurs during closed-kinetic chain exercises stimulates the mechanoreceptors of the joint which improves proprioception.[4]

The purpose of this study is to determine if identifying and treating players can decrease the incidence of shoulder injuries in collegiate football players with poor dynamic stability at the glenohumeral joint. This study will analyze the incidence of shoulder injuries that occur in an NCAA Division I football team throughout the 2014 and 2015 seasons. During this period of time, the team performed a shoulder strengthening routine established by the team strength and conditioning coach and athletic trainer. The CKCUEST will be used to assess risk for glenohumeral joint instability pathologies.

Delimitations/Limitations

The delimitation of this study is the strong methodology. The limitation of this study was the subjects were not required to be at the summer lifting sessions. Another limitation is that all of the subjects performed the strengthening exercises, not just the subjects identified as at risk by the CKCUEST.

Assumptions:

This study assumes that maximum effort was given when performing the CKCUEST and that the athletes performed all sets and repetitions of the exercises included in the shoulder strengthening program with the proper mechanics.

Hypothesis:

Hypothesis 1: We hypothesize that the incidence of shoulder injuries will decrease when a strengthening intervention is included in the offseason strength and conditioning program of players identified as at risk for glenohumeral instability pathologies.

Hypothesis 2: We hypothesize that the number of at-risk players identified by the CKCUEST will display a statistically significant decrease from baseline testing to fall testing.

CHAPTER 2

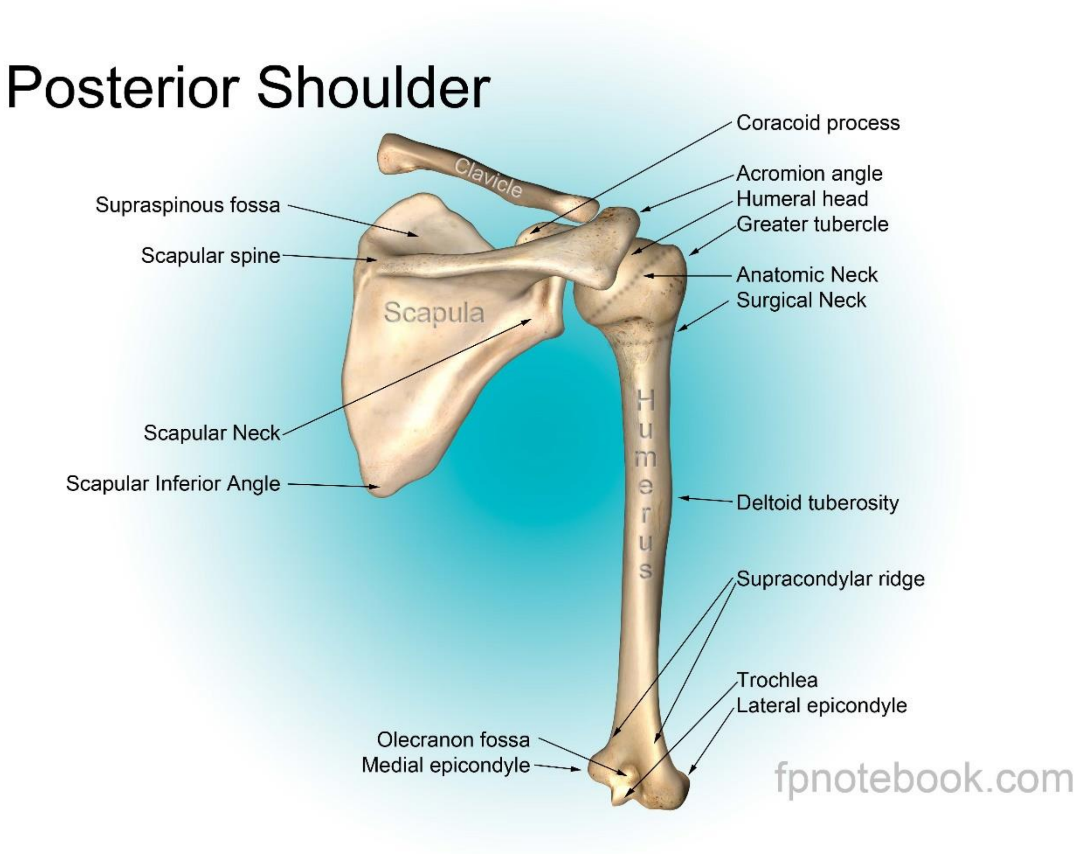
Review of Literature

Bone and Joint Articulations

The three bones responsible for movement at the glenohumeral joint are the scapula, clavicle, and humerus.[3] The clavicle is an s-shaped bone that articulates between the manubrium of the sternum at the sternoclavicular joint and the scapula at the acromioclavicular joint.[3] The medial two-thirds of the clavicle bend convexly anteriorly and the lateral one-third of the bone bends concavely posteriorly.[3] The scapula is completely suspended in muscle but provides movement and stability at the glenohumeral joint.[3] Anterior anatomical landmarks on the scapula are the subscapular fossa and the coracoid process.[3] The superior border, superior angle, acromion process, and the suprascapular notch are on the superior aspect of the scapula.[3] The spine of the scapula, the medial and lateral borders, and the inferior angle are located on the posterior aspect of the scapula.[3] The glenoid fossa is the site where the humerus articulates with the scapula.[3] The glenoid labrum is a fibrocartilaginous structure that sits on the glenoid fossa and functions to increase glenohumeral stability by increasing the depth of the articulating surfaces.[3]

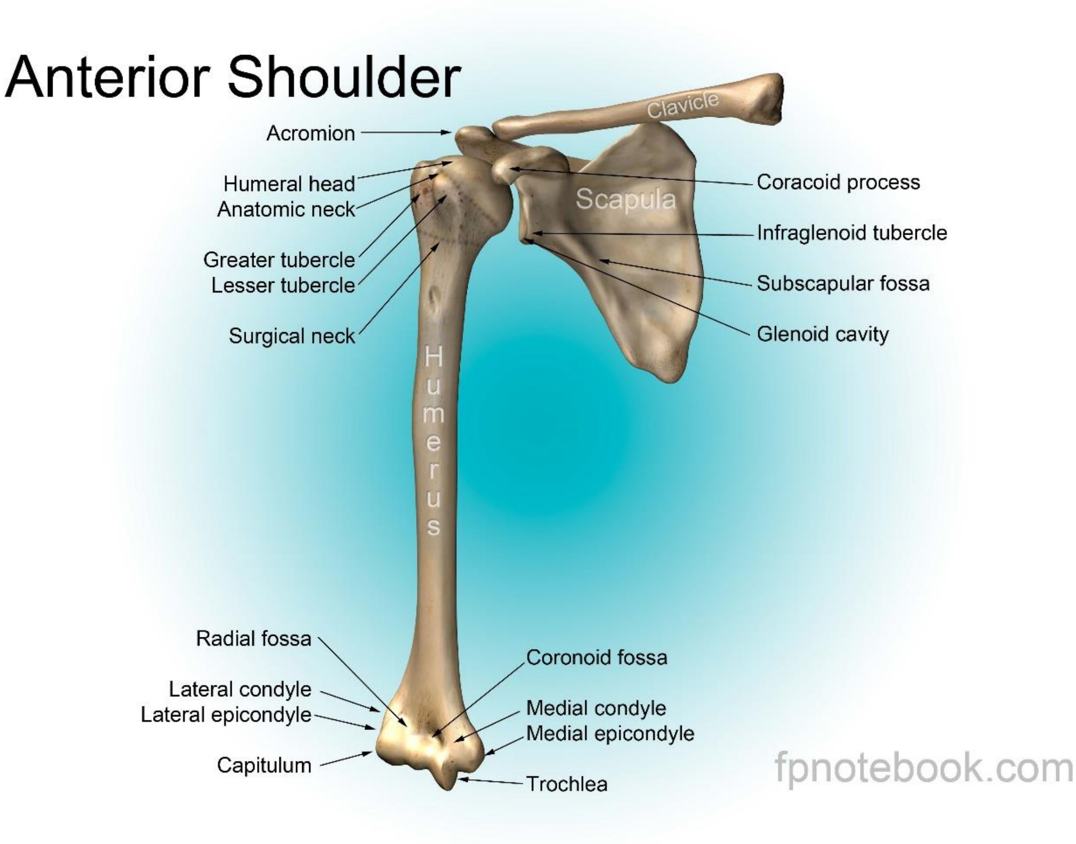
The head of the humerus articulates with the scapula at the glenoid fossa. The head of the humerus has a spherical, convex shape and is directed in a superior, medial, anterior direction.[3] There is a slight groove around the head of the humerus called the anatomical neck which serves as an attachment site for the articular joint capsules of the glenohumeral joint.[3] The greater and lesser tubercles of the humerus are located immediately inferior to the head of the humerus on the anterior aspect of the bone.[3] The lesser tubercle is on the anterior-medial portion and the greater tubercle is more superior and lateral.[3] The bicipital groove is created by the small gap between the greater and lesser tubercle. The function of the bicipital groove is to retain the long head of the biceps brachii tendon to maintain normal glenohumeral joint kinematics.[3] The deltoid tuberosity is also located on the humerus; it is towards the medial aspect of the bone on the lateral side of the humerus.[3]

Figure 1: Posterior Shoulder



Posterior Shoulder. Google Images. http://www.fpnotebook.com/_media/orthoPosteriorBoneShoulder_huge.jpg. Accessed May 12, 2016.

Figure 2: Anterior Shoulder



Anterior Shoulder. Google Images. http://www.fpnotebook.com/_media/orthoAnteriorBoneShoulder_huge.jpg. Accessed May 12, 2016.

There are four different joint articulations important to the movement and stability of the glenohumeral joint. The clavicle articulates with the manubrium of the sternum to form the sternoclavicular joint.[3] There is a fibrocartilaginous disk between the articulating surfaces of the clavicle and the manubrium which serves as a shock absorber against medial forces and prevents superior displacement of the clavicle.[3] The articulation between the clavicle and the manubrium is relatively unstable because the medial aspect of the clavicle is larger than the concave articulating surface on the manubrium.[3] The sternoclavicular joint is stabilized by four ligaments. The anterior and posterior sternoclavicular ligament prevent superior displacement of the clavicle.[3] The interclavicular ligament prevents lateral displacement and the costoclavicular ligament prevents both lateral and superior displacement.[3]

The lateral aspect of the clavicle and the acromion process of the scapula articulate to form the acromioclavicular joint.[3] There is a fibrocartilaginous disk between these two bones with a thin fibrous capsule that surrounds the joint.[3] The acromioclavicular ligament helps maintain the position of the clavicle relative to the position of the acromion process of the scapula.[3] The acromioclavicular ligament is made up of the anterior, posterior, superior, and inferior portions.[3] The coracoclavicular ligament also functions to stabilize the articulating surface between the clavicle and acromion process.[3] It is divided into the conoid and trapezoid ligaments.[3] The coracoacromion ligament connects the coracoid to the acromion.[3] The coracoacromion ligament and the acromion form the coracoacromial arch.[3]

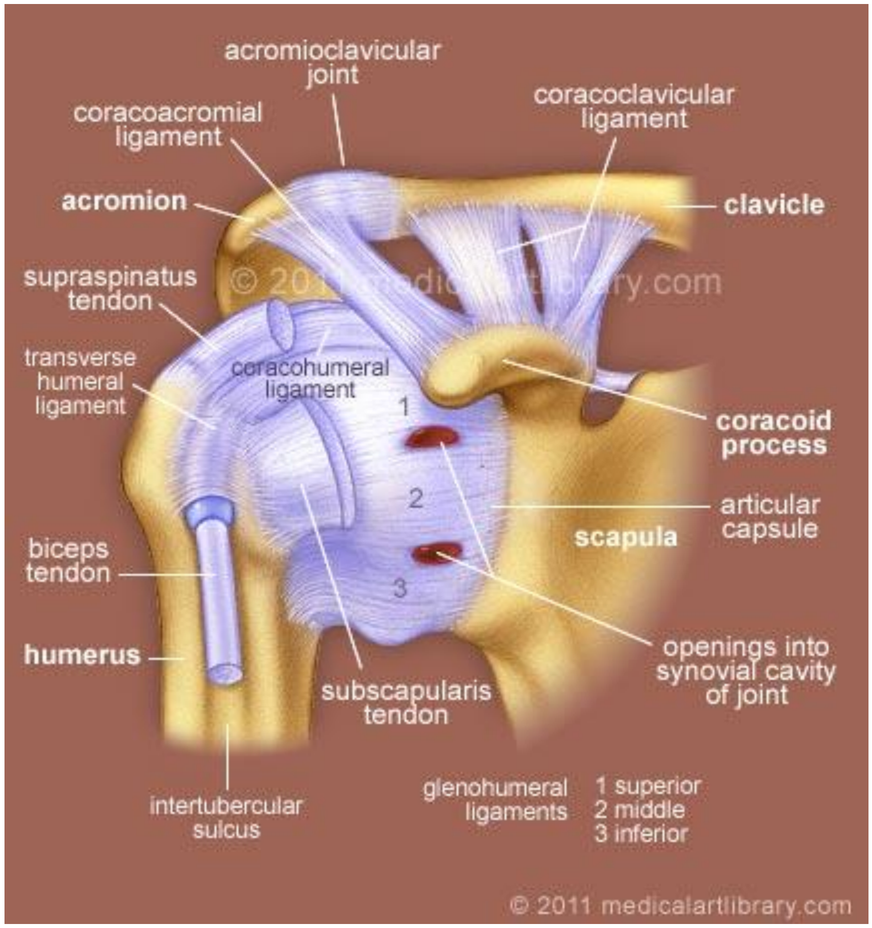
The scapulothoracic articulation of the glenohumeral joint occurs between the scapula and the posterior wall of the body. There are no ligaments supporting this articulation but the function of the muscles that attach to it can greatly affect the stability and function of the glenohumeral joint.[3]

Ligaments

The glenohumeral ligaments and the joint capsule provide static stabilization at the glenohumeral joint; they limit range of motion in specific directions.[3] The muscles of the rotator cuff provide dynamic stability of the glenohumeral joint.[3] They help the head of the humerus articulate correctly on the glenoid fossa of the scapula throughout normal range of motion. The glenoid labrum deepens the articulating surface between the head of the humerus and the glenoid fossa.[3] This also provides some stability to the glenohumeral joint without limiting range of motion.[3]

The head of the humerus articulates with the glenoid fossa of the scapula at the glenohumeral joint.[3] The glenoid labrum and the glenohumeral ligaments act as static stabilizers of the glenohumeral joint.[3] A loose articular joint capsule surrounds this articulation and it is reinforced by the superior, inferior, anterior, posterior, and middle glenohumeral ligaments.[3] The coracohumeral ligament also supports this joint and it attached at the coracoid process and the greater tubercle of the humerus.[3] Each ligament limits a specific motion. The anterior ligament is taut during glenohumeral joint abduction, extension, or external rotation.[3] The posterior ligament is taut during extension and external rotation.[3] Flexion and external rotation will increase tension on the middle ligament.[3] During abduction, extension or external rotation, the inferior ligament becomes taut.[3] The primary function of the inferior ligament though is to prevent anterior and posterior dislocations of the head of the humerus.[3] The joint capsule will also become taut and prevent certain glenohumeral joint motions.[3] The posterior capsular aspect limits flexion, abduction, and internal rotation.[3] Internal rotation is limited by the superior and middle aspects of the joint capsule.[3]

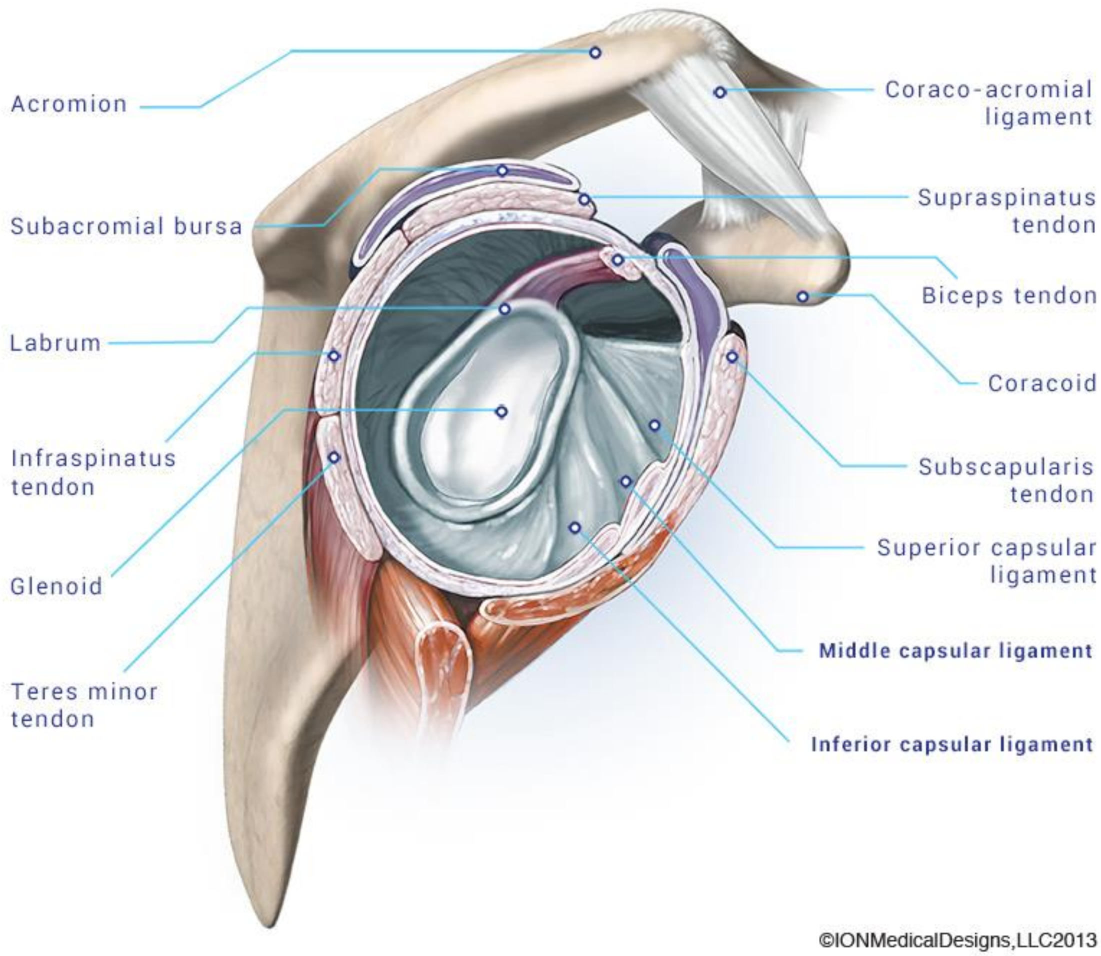
Figure 3: Shoulder Joint Ligaments



Shoulder Joint Ligaments: Google Images.

http://www.medicalartlibrary.com/images/shoulder-joint-ligaments.jpg. Accessed May 12, 2016.

Figure 4: Shoulder Muscles, Tendons, Ligaments, Joint



Shoulder Muscles, Tendons, Ligaments, Joint. Google Images. http://www.danereese.com/jpc/wp-content/uploads/2013/06/glenoid-shoulder-anatomy.jpg. Accessed May 12, 2016.

Glenohumeral Joint Flexion

The muscles responsible for glenohumeral joint flexion are the coracobrachialis, the anterior fibers of the deltoid, and the long and short head of the biceps brachii.[7] The coracobrachialis originates at the apex of the coracoid process of the scapula and inserts on the medial aspect of the humerus at the middle of the bone directly opposite of the deltoid tuberosity.[7] The coracobrachialis will all assist with glenohumeral adduction.[7]

The anterior fibers of the deltoid originate on the clavicle on the anterior border, the superior surface, and the lateral third of the bone.[7] It shares a common insertion site with the middle and posterior fibers at the deltoid tuberosity.[7] The anterior fibers of the deltoid will also assist with glenohumeral abduction and internal rotation.[7]

The long head of the biceps brachii originates on the supraglenoid tubercle of the scapula.[7] The muscle shares a common insertion with the short head of the biceps brachii at the radial tuberosity and the aponeurosis of the biceps brachii.[7] The short head of the biceps brachii originates at the coracoid process of the scapula.[7] It inserts with the long head of the biceps at the radial tuberosity and the aponeurosis of the biceps brachii.[7] The long head of the biceps tendon runs through the bicipital grove on the anterior humerus and some fibers of the tendon insert on the superior aspect of the labrum.[7] The tendon is held in the bicipital groove by the transverse humeral ligament.[7] The long head of the biceps tendon has some fibers insert on the superior aspect of the glenoid labrum.[3]

Glenohumeral Joint Extension

The muscles responsible for extension of the glenohumeral joint are the long head of triceps brachii, the posterior fibers of the deltoid, teres major, and the latissimus dorsi.[7] The long head of the triceps brachii originates on the infraglenoid tubercle of the scapula.[7] It shares a common insertion with the lateral and medial heads of the triceps brachii at the posterior surface of the olecranon process on the ulna and the antebrachial fascia.[7] The long head of the triceps will also assist with glenohumeral joint adduction.[7]

The posterior fibers of the deltoid originate on the inferior lip of the posterior border on the spine of the scapula.[7] It shares a common insertion with the anterior and middle fibers of the deltoid at the deltoid tuberosity on the lateral aspect of the humerus.[7] The posterior deltoid also assists with scapular stabilization during glenohumeral abduction and assists with external rotation in a prone position.[7]

Teres major originates at the inferior angle and the lower 1/3 of the lateral border of the scapula.[7] It inserts at the lesser tubercle on the proximal, medial aspect of the humerus.[7] Teres major also assists with internal rotation and adduction at the glenohumeral joint.[7]

The latissimus dorsi originates on the spinous processes the T6 through T12 vertebrae, the last three ribs, the thoracolumbar fascia, and the posterior third of the iliac crest.[7] A small portion also originates from the inferior angle of the scapula.[7] This muscle inserts at the intertebercular groove on the proximal, medial aspect of the humerus.[7] The latissimus dorsi also assists with internal rotation and adduction of the glenohumeral joint.[7]

Glenohumeral Joint Internal Rotation

The muscle responsible for internal rotation of the glenohumeral joint is the subscapularis.[7] The subscapularis originates on the scapular fossa on the anterior aspect of the scapula.[7] It inserts on the lesser tubercle at the proximal, medial aspect of the humerus.[7] The subscapularis also provides dynamic stabilization for the articulation between the humeral head and the glenoid fossa.[7] The anterior fibers of the deltoid, the upper fibers of pectoralis major, teres major, and the latissimus dorsi all assist with internal rotation.[7]

Glenohumeral Joint External Rotation

The muscles responsible for external rotation of the glenohumeral joint are the infraspinatus and teres minor.[7] Infraspinatus originates on the medial 2/3 of the infraspinous fossa on the posterior aspect of the scapula.[7] It muscle inserts on the middle facet of the greater tubercle on the humerus.[7] The infraspinatus also provides dynamic stabilization at the glenohumeral joint during motion.[7] Teres minor originates on the upper 2/3 and the dorsal surface on the posterior aspect of the scapula.[7] Teres minor also serves as a dynamic stabilizer for the glenohumeral joint.[7] The posterior fibers of the deltoid and the supraspinatus will also assist the infraspinatus and teres minor with external rotation.[7]

Glenohumeral Joint Abduction

The muscles that perform abduction at the glenohumeral joint are the supraspinatus and the middle fibers of the deltoid.[7] It originates at the medial 2/3 of the supraspinatus fossa on the superior, posterior aspect of the scapula and inserts on the greater tubercle of the humerus.[7] The supraspinatus also serves as a dynamic stabilizer of the glenohumeral joint during motion and also assists with external rotation of the glenohumeral joint.[7]

The middle fibers of the deltoid originate on the lateral margin and superior aspect of the acromion process of the scapula.[7] They share a common insertion with the anterior and posterior deltoid fibers at the deltoid tuberosity on the lateral aspect of the humerus.[7] The long head of the biceps brachii muscle can also assist with abduction at the glenohumeral joint.[7]

Glenohumeral Joint Adduction

The muscles responsible for adduction of the glenohumeral joint are the upper and lower fibers of pectoralis major.[7] The lower fibers of the pectoralis major originate at the anterior surface of the sternum, the cartilage of the first six ribs, and the aponeurosis of the external oblique.[7] It inserts with the upper fibers of pectoralis major on the greater tubercle of the humerus.[7] The lower fibers obliquely adduct the glenohumeral joint toward the opposite iliac crest.[7]

The upper fibers of the pectoralis major originate on the anterior surface of the medial half of the clavicle, close to the sternum.[7] These fibers insert on the superior aspect of the greater tubercle of the humerus.[7] The secondary action of the upper fibers of the pectoralis major is glenohumeral joint flexion and internal rotation.[7] The short head of the biceps brachii, teres major, the coracobrachialis, latissimus dorsi, and the long head of the triceps also assist with adduction at the glenohumeral joint.[7]

Scapula Elevation

The muscles responsible for elevation of the scapula are the upper fibers of the trapezius, the levator scapulae, and the rhomboids major and minor.[7] The upper fibers of the trapezius originate on the external occipital protuberance, the medial 1/3 of the superior nuchal line, the ligamentum nuchae, and the spinous process of the seventh cervical vertebrae.[7] These fibers insert on the lateral 1/3 of the clavicle and the acromion process of the scapula.[7] The levator scapulae originate on the transverse processes of the first four cervical vertebrae.[7] It inserts on the medial border of the scapula between the superior angle and the medial aspect of the spine of the scapula.[7] The levator scapulae muscle also assists with downward rotation of the scapula.[7]

The rhomboids major fibers originate at the spinous processes of the second through fifth thoracic vertebrae and the rhomboids minor fibers originate on the ligamentum nuchae and the spinous processes of the seventh cervical and first thoracic vertebrae.[7] The rhomboid major fibers insert at the medial border of the scapula between the inferior angle and the spine of the scapula.[7] The rhomboid minor fibers insert on the medial border of the scapula at the spine.[7] The rhomboids also assist with downward rotation of the scapula.[7]

Scapula Depression

The muscle responsible for depression of the scapula is the lower fibers of the trapezius.[7] The lower fibers of the trapezius originate on the spinous processes of thoracic vertebrae six through twelve.[7] They insert on the tubercle at the apex of the spine of the scapula.[7] These fibers stabilize the scapula during retraction and they assist with upward rotation of the scapula.[7] The lower fibers of the serratus anterior will also assist with depression of the scapula.[7]

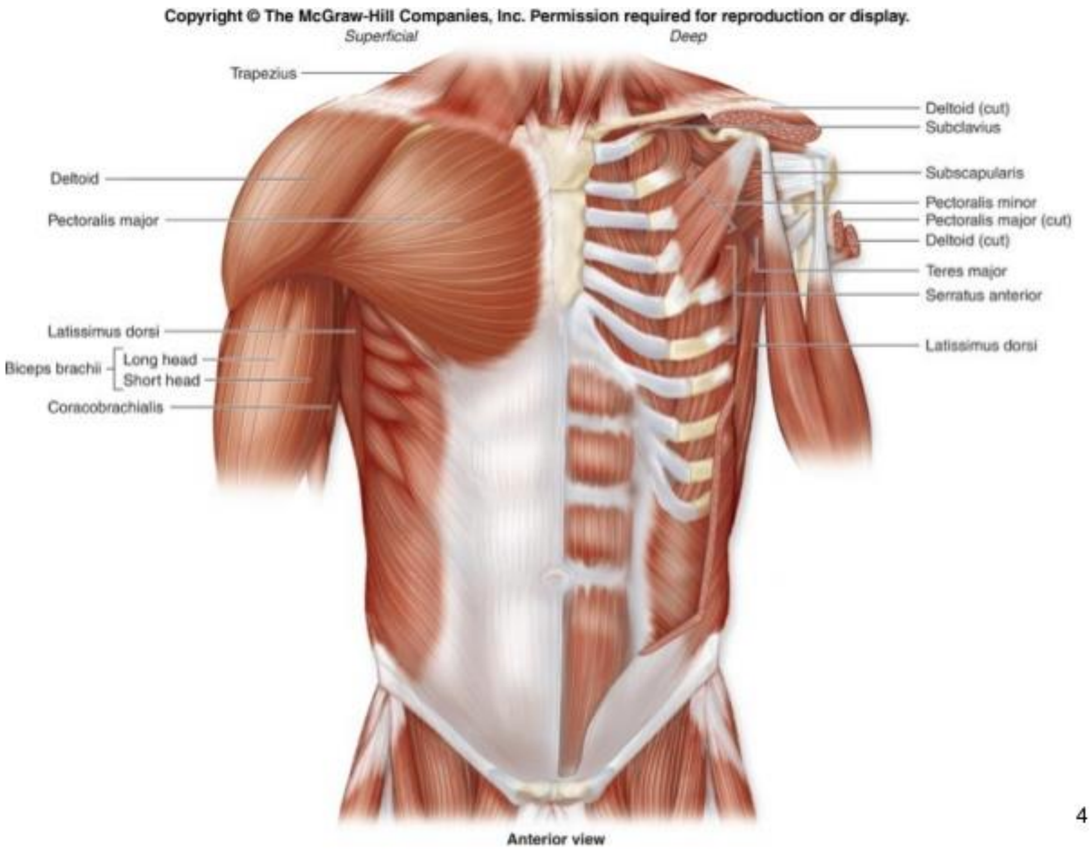
Scapula Protraction

The muscle responsible for protraction of the scapula is the serratus anterior.[7] The serratus anterior originates on the outer surface and the superior border of the first eight ribs and inserts on the costal surface of the medial border of the scapula.[7] The serratus anterior is also responsible for upward rotation of the scapula and holding the scapula against the ribs.[7]

Scapula Retraction

The muscles responsible for retraction of the scapula are the middle fibers of the trapezius and both rhomboids major and minor.[7] The middle fibers of the trapezius originate on the spinous processes of the first through the fifth thoracic vertebrae.[7] They insert on the medial aspect of the acromion process of the scapula and the superior aspect of the spine of the scapula.[7] The rhomboids are also responsible for scapular retraction.[7]

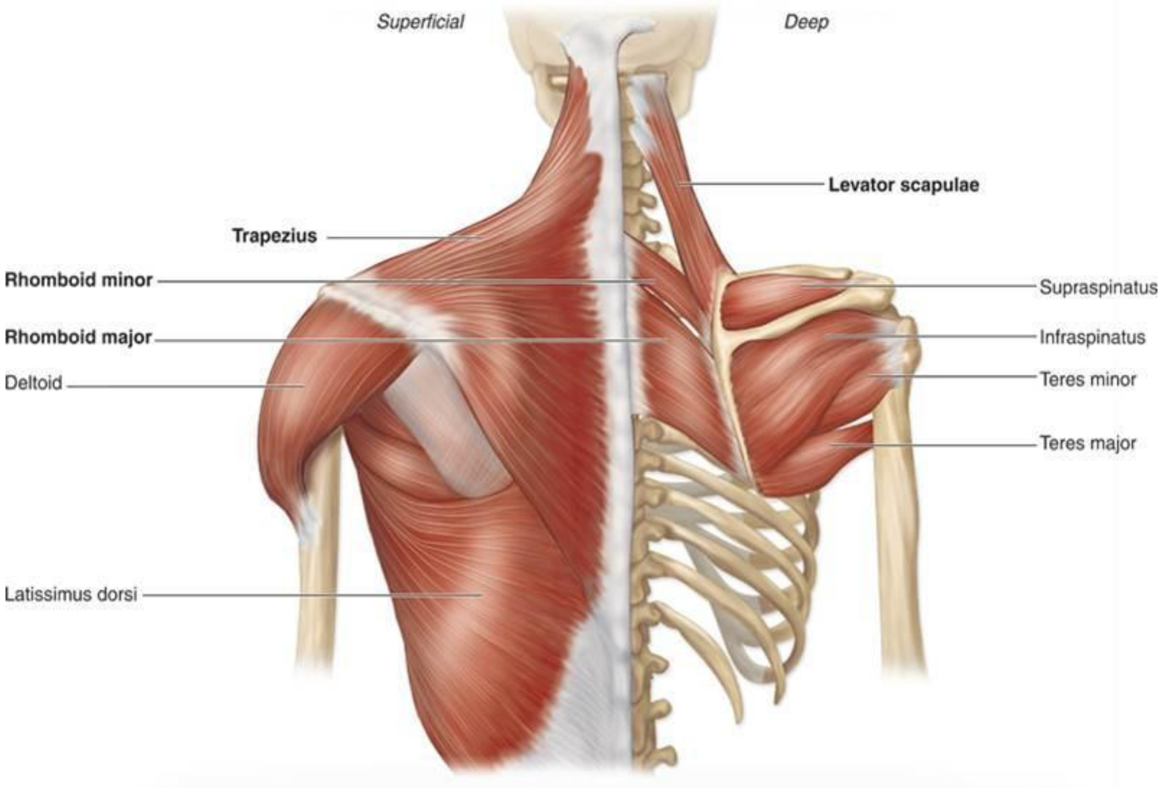
Figure 5: Appendicular Muscles



Appendicular Muscles. Google Images.

http://image.slidesharecdn.com/ch12appendicularmuscles-140721072518-phpapp01/95/appendicular-muscles-4-638.jpg?cb=1405927800. Accessed May 12, 2016.

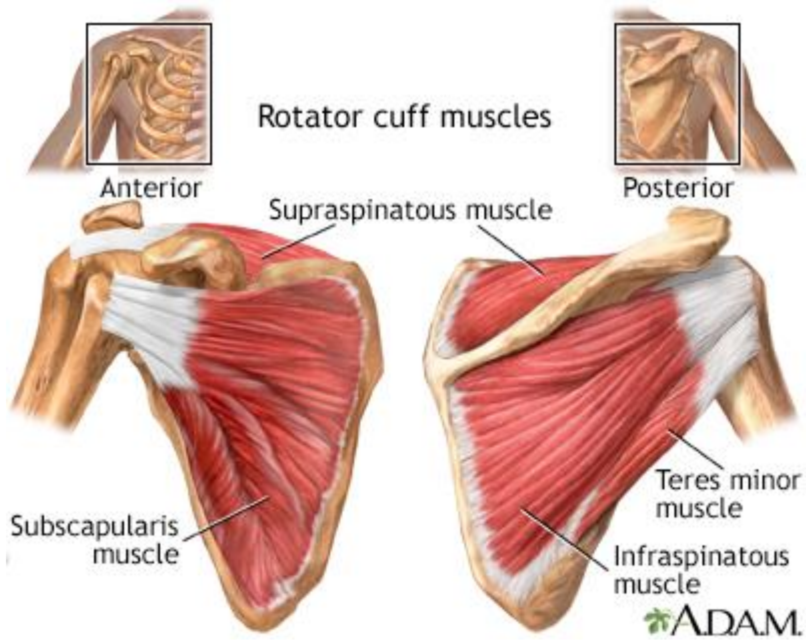
Figure 6: Pectoral Girdle and Upper Limb Muscles



Pectoral Girdle and Upper Limb Muscles. Google Images.

http://classconnection.s3.amazonaws.com/914/flashcards/1119914/jpg/picture181340648956408.jpg. Accessed May 12, 2016.

Figure 7: Rotator Cuff Muscles



Rotator Cuff Muscles. Google Images. https://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/19622.jpg. Accessed May 12, 2016.

Etiology

Instability of the glenohumeral joint is defined as instability in at least one anatomic direction with or without associated injury to the glenohumeral joint.[8] Instabilities can happen after an acute subluxation or dislocation of the humeral head.[3] They can occur in an anterior, posterior, and inferior directions or they can be multidirectional.[3]

Anterior and posterior instability of the glenohumeral joint is graded by the amount of translation that occurs between the head of the humerus and the glenoid fossa.[9] In Grade I instability, the humeral head can be translated to the glenoid rim.[9] Grade II instability occurs when the head of the humerus translates over the glenoid rim but spontaneously reduces when the translational force is removed.[9] Grade III instability occurs when the head of the humerus translates over the glenoid rim and remains dislocated when the translating force is removed.[9]

Inferior instability is characterized by three different grades. When an inferior translational force is applied to the humerus, an indentation called a sulcus sign will appear directly inferior to the acromion process.[10] The size of this sulcus characterizes the different grades of inferior instability. Grade I instabilities show a sulcus that is less than 1 cm.[9] Grade II instabilities show a sulcus that is 1-2 cm in length.[9] A Grade III instability will show a sulcus that is greater than 2 cm in length.[9] Multidirectional instability injuries can also occur. Multidirectional instability is characterized by a combination of anterior or posterior instability and inferior instability.[8]

Translation of the head of the humerus in any direction will place stress on the glenohumeral ligaments and the muscles of the rotator cuff. A greater amount of humeral head translation will place a greater stress on these structures which will cause them to fail, leading to injury.[8] This translation will also create a shear force on the glenoid labrum which will cause damage to both the humeral head and the labrum.[8] Dislocations and subluxations of the glenohumeral joint are the main cause of instability injuries.[10] This mechanism of injury can lead to glenohumeral ligament sprains, glenoid labrum tears, and rotator cuff tears.[8]

Glenohumeral Ligament Sprains

The glenohumeral ligaments do not experience any significant tension during motion of the glenohumeral joint in all directions.[10] They do not become taught until the glenohumeral joint reaches the end ranges of motion.[10] Sprains are characterized by the percentage of fibers torn in a ligament when it experiences some degree of pathology. A first degree sprain will be characterized by overstretching of the ligament without any significant tearing occurring.[10] A second degree ligament sprain will display moderate tearing of the ligament without a complete tear occurring.[10] A third degree sprain of a ligament will be characterized by a significant or complete tear of the injured ligament.[10]

First and second degree sprains of the glenohumeral ligaments are uncommon because other structures will support the glenohumeral joint throughout most of the range of motion at the joint.[10] The muscles of the rotator cuff will provide stabilization throughout most of the range of motion that occurs at the glenohumeral joint.[10] The forces that occur at the glenohumeral joint at the end ranges of motion cause more damage to the ligament resulting in more third degree sprains.[10]

The superior glenohumeral ligament prevents instability in the posterior and inferior direction.[11] It is assisted by the coracohumeral ligament, transverse humeral ligament, subscapularis tendon, and the long head of the biceps tendon.[11] As a result, pathology to the superior glenohumeral ligament by itself is uncommon.[11] This ligament is usually injured with the other structures.[11] The middle glenohumeral ligament limits external rotation of the glenohumeral ligament.[11] When injured, this ligament commonly tears away from its insertion on the glenoid labrum or the tear occurs longitudinally through the ligament.[11] The anterior band of the inferior glenohumeral ligament limits abduction and external rotation of the glenohumeral joint.[11] The posterior band of the inferior glenohumeral ligament limits posterior translation during abduction and internal rotation of the glenohumeral joint.[11] The anterior band of this ligament is most commonly injured because, when the glenohumeral joint dislocates or subluxes, it usually occurs in an anterior direction.[11]

The glenohumeral ligaments are most susceptible to injury when the glenohumeral joint is in extreme horizontal abduction and external rotation.[12] This same joint position is described as the position of athletic function.[12] When throwing a football, the anterior band of the inferior glenohumeral ligament experiences the most strain during the late cocking phase of this overhead throwing motion.[12] The position that the arm is in when tackling during football will also place the glenohumeral joint in this abducted position which increases the chance of injury occurring.[10] There is no specific degree of abduction or external rotation associated with an increased risk of injury.

At the glenohumeral joint, sprains to the ligaments and joint capsule commonly occur with a subluxation or dislocation of the humeral head.[3] A glenohumeral dislocation occurs when a force placed on the glenohumeral joint causes the head of the humerus to translate outside the glenoid fossa of the scapula.[3] A subluxation of the glenohumeral joint occurs when the head of the humerus dislocates then spontaneously reduces.[10] The likelihood of a glenohumeral joint subluxation or dislocation occurring are based on a factor called joint translational stiffness.[13] This factor is based on the curvature of the humeral head and the size of the glenoid.[13] If the enclosed curvature of the humeral head is smaller, the joint translational stiffness will be less.[13] Another factor affecting the stability of the glenohumeral joint is the percentage of enclosed curvature between articular surfaces. A higher percentage of coverage between the humeral head and the glenoid labrum will increase the stability of the joint and lower percentage of coverage will decrease the stability of the joint.[13]

Glenoid Labrum Pathology

Tears of the glenoid labrum are caused by subluxations or dislocations of the glenohumeral joint, chronic instability of the glenohumeral joint, and repetitive microtrauma.[10] When the labrum is torn, the articulation between the humeral head and the glenoid fossa becomes less stable leading to decreased stability at the glenohumeral joint. There are different types of labrum tears that occur and they are characterized by the location of the tear. Tears of the glenoid labrum can occur with associated pathologies to the ligaments or tendons at the glenohumeral joint. The location of tears on the glenoid labrum are identified as though the labrum sits on the face of a clock.[14] For example, a tear to the anterior aspect of the labrum could occur between the two to four o'clock region. There is no difference between the left and right shoulder, 3 o'clock is always anterior and 9 o'clock is always posterior.[14] The most common area of the labrum injured is the eleven to three o'clock region.[14] There are certain positions of the glenohumeral joint range of motion that will create a greater chance for injury to the labrum when acted on by a significant external force. In football, glenoid labrum tears occurs most often when tackling another player with the glenohumeral joint in extension and abduction.[2] Another common mechanism of injury for labrum tears is a direct blow to the superior aspect of the shoulder with the glenohumeral joint in abduction.[15]

Different mechanisms of injury will cause different types of injury to the glenoid labrum. Superior labral anterior posterior (SLAP) lesions occur at the superior aspect of the labrum and are usually associated with some degree of pathology to the long head of the biceps tendon due to this tendon's insertion on the anterior aspect of the labrum.[14] The biceps tendon can place enough strain on the superior aspect of the labrum to cause an injury to occur to the labrum.[14] A strong concentric or isometric contraction or eccentric load placed on the labrum by this tendon can cause the labrum to tear.[14] The biceps tendon will place the highest amount of strain on the labrum between 40 degrees of extension and flexion at the glenohumeral joint.[16] There are four types of SLAP lesions that are classified by the degree of damage to the glenoid labrum and to the long head of the biceps tendon.[14] A combination of the different types of SLAP lesions can occur and a combination of type II and IV lesions is the most common.[14]

A type I lesion is a fraying of the labrum with no obvious tear of the glenoid labrum and an intact biceps tendon.[14] These lesions occur most commonly with degenerative changes and from repetitive microtrauma from overhead throwing.[14] There is a reported frequency of 9.5-21 percent.[14] Type II lesions show labral fraying and stripping of the superior labrum and biceps tendon from the superior aspect of the glenoid.[14] These injuries are associated with repetitive microtrauma and occur in 41-55 percent of SLAP lesions.[14] Type II tears are further divided into three different subgroups based on the location of the labral lesion. Type IIA lesions are at the anterior-superior aspect of the labrum.[14] Type IIB lesions are at the posterior-superior aspect of the labrum.[14] Type IIC lesions are at the superior aspect of the labrum and they extend both anteriorly and posteriorly.[14] Type III SLAP lesions are bucket-handle tears to the superior labrum with the torn portion of the labrum displaced into the articulating surface of the glenohumeral joint.[14] There is no pathology to the biceps tendon with this type of SLAP lesion.[14] This type of lesion occurs in 3-15 percent of SLAP lesions.[14] Type IV SLAP lesions also have a bucket-handle tear but there is associated pathology to the biceps tendon.[14] These lesions also occur in 3-15 percent of SLAP lesions.[14]

Another type of labrum tear is a Bankhart lesion. Bankhart lesions are tears to the anterior-inferior aspect of the glenoid labrum.[14] They occur most often when the humeral head subluxes or dislocates in an anterior-inferior direction.[10] Bankhart lesions are commonly associated with pathology to the anterior and posterior bands of the inferior glenohumeral ligament.[11] These injuries are apparent in 79 percent of glenohumeral dislocations that occur as a result of a collision in contact sports.[11,12] Reverse Bankhart lesions can also occur in cases where the humeral head dislocates or subluxes posteriorly.[17] Reverse Bankhart lesions occur when the tear is at the posterior-inferior aspect of the labrum.[10] A dislocation or subluxation of the humeral head can cause damage to the osteochondral surface of the humeral head when it relocates into the glenoid fossa.[10] This type of injury is called a Hill-Sachs lesion.[10] A study conducted on injury incidence found that these injuries were reported in 75 percent of subjects in the study presenting with anterior instability injuries.[17] This statistic indicates a high likelihood that athletes reporting with an anterior instability injury could have a Hill-Sachs lesion. A Hill-Sachs lesion occurs on the posterior aspect of the humeral head and it is caused by an anterior dislocation of the humeral head.[17] A reverse Hill-Sachs lesion occurs on the anterior aspect of the humeral head and is caused by a posterior dislocation of the humeral head.[10]

There are some less common labrum injuries that will also cause instability at the glenohumeral joint. An anterior labroligamentous periosteal sleeve avulsion (ALPSA) lesion is a variant of a Bankhart lesion.[18] ALPSA lesions are an avulsion of the inferior glenohumeral ligament complex from the anterior-inferior glenoid.[17] The periosteum on the glenoid fossa remains intact with these injuries.[17] The avulsed portion of the anterior-inferior labrum can displace medially and rotate inferiorly and then heal in this position if it goes untreated leading to recurrent anterior instability of the glenohumeral joint.[17]

Humeral avulsions of the glenohumeral ligament (HAGL) lesions also cause shoulder instability.[17] This lesion is usually associated with tears to the subscapularis tendon and recurrent anterior glenohumeral instability.[17] The anterior band of the inferior glenohumeral ligament is most commonly avulsed with these lesions and, in some cases, the ligament can avulse a bony fragment from the attachment to the humerus.[17]

Rotator Cuff Pathology

The rotator cuff is a group of four muscles inferior to the deltoid that provide dynamic stability for the glenohumeral joint. The supraspinatus, infraspinatus, teres minor, and subscapularis are the muscles of the rotator cuff.[7] These muscles create a concavity-compression mechanism that stabilizes the glenohumeral joint throughout middle ranges of motion and at terminal ranges of motion through muscle activity that limits excess motion.[19] This helps reduce the amount of strain on the glenohumeral ligaments.[19] This mechanism prevents translational forces from occurring at the glenohumeral joint by pulling the head of the humerus into the glenoid fossa during motion at the joint.[19] The depth of the glenoid fossa will prevent the humeral head from excessive amounts of translation. The muscles of the rotator cuff pulling the head of the humerus into the glenoid fossa helps facilitate the stabilizing function of the glenoid fossa.[19] At these middle ranges, the joint capsule and glenohumeral ligaments are lax creating the need for the rotator cuff muscles to stabilize the joint.[19] The middle ranges of the glenohumeral joint are the degrees of motion that the joint most commonly moves through.[19] This range is anywhere between the initial and end ranges of motion. A cadaver study showed that a 50 percent decrease in rotator cuff muscle activity lead to a 50 percent increase in the rate of dislocations at all positions of the glenohumeral joint.[19]

Injuries to the rotator cuff muscles are caused by excessive traction forces that cause the muscle fibers to fail, the fibers of the muscle stretch and eventually fail and tear.[10] Rotator cuff injuries also occur when the muscles fail to handle the deceleration forces associated with an overhead throwing motion.[20] Rotator cuff injuries in contact sports are caused by the high tension and shear forces placed on the tendons of the rotator cuff muscles during collisions.[12] Tears in the rotator cuff can vary in severity from partial to full thickness tears of the muscle belly or tendon.[1] Anterior and posterior dislocations can cause tears to the subscapularis tendons.[17] Posterior dislocations can also cause tears to occur in the teres minor and infraspinatus tendons.[17]

Tears to the supraspinatus and infraspinatus are most common in contact sports.[12] These injuries can be caused by repetitive microtrauma or by acute dislocations of the glenohumeral joint.[12] In cases of repetitive microtrauma, the tears to these two tendons occur when they experience shear and tension forces during collisions.[12] These forces cause the supraspinatus and infraspinatus tendons to translate over the posterior rim of the glenoid fossa causing small microtrauma to occur.[12] In collision sports, these forces occur at the glenohumeral joint when tackling with the joint in a position of extension and abduction.[15] Injuries to the rotator cuff in collision sports can also occur when direct contact occurs between two players.[1] Falling onto the superior aspect of the shoulder is another common mechanism of injury for rotator cuff tears found in football.[1]

Tears to the subscapularis can be classified based on the degree of pathology to the muscle. Type I tears are a partial lesion involving the upper third of the muscle.[21]

Type II tears are a completed tear to the upper third of the muscle.[21] Type III tears are a complete lesion of the upper two-thirds of the muscle.[21] Type IV tears are complete lesions of the muscle with no displacement of the head of the humerus.[21] Type V tears are complete tears of the muscle with humeral head displacement causing coracoid impingement.[21]

Scapula Anatomical Abnormalities

In a resting anatomical position, the scapula is in a position of 35 degrees of internal rotation and varying degrees of frontal plane inclination.[8] Frontal plane inclination affects the articulation between the glenoid fossa and the humeral head. Inclination in the frontal plane means that the inferior portion of the glenoid fossa has a greater angle in relation to the superior portion of the glenoid fossa.[8] An increased angle of inclination will help prevent inferior instability injuries.[8] The glenoid fossa will be at a greater slope and this will create a bony cam that tightens the superior joint capsule and prevents inferior humeral head displacement.[8] This cam provides the glenohumeral joint with a bony block that prevents inferior displacement of the humeral head.[8] Decreased inclination will decrease the slope of this articulation, making it flatter.[8] There will be a smaller angle between the superior and inferior aspects of the glenoid fossa.[8] This will predispose the glenohumeral joint to inferior instability injuries.[8]

Epidemiology

Glenohumeral joint instability injuries are one of the most common injuries sustained in contact sports. Anterior instability injuries were seen primarily in defensive players; specifically, linebackers and defensive backs. The high rate of anterior instability injuries in this group could be a result of the high number of tackles they make during a game and the higher velocity at impact when making tackles. Posterior instability injuries occurred at a higher rate in offensive linemen because of the loads placed on their outstretched arms when they are blocking.[1] Rotator cuff pathologies are also common in football and affect the dynamic stability of the glenohumeral joint. In a study of 51 full thickness rotator cuff tears in NFL athletes, 43% were in offensive lineman, 27% were in linebackers, 12% were in defensive backs, and 10% were in defensive lineman.[1] Acromioclavicular sprains are another shoulder injury that will affect the joint kinematics and stability of the glenohumeral joint. These injuries are most often the result of a direct blow to the superior aspect of the acromioclavicular joint. In players at the 2004 NFL combine, acromioclavicular separations occurred in 40% of the athletes' surveyed and direct contact with the ground or another player was directly responsible for the injury in 80% of the cases.[1]

The following studies took information from an injury surveillance system from schools with football programs at the NCAA DI, DII, and DIII levels. A study conducted by Owens, et al. looked at the rate of glenohumeral joint instability injuries in 16 college sports over a 15 year period.[22] Over 32.8 million athletic exposures occurred in the time frame of this study and glenohumeral joint injuries accounted for 9.7 percent or 17,799 of all of the injuries that occurred.[22] Shoulder injuries were the third most common injury reported after ankle and knee injuries.[22] Athletic exposures were defined in this study as any practice or game in which the athletes participated in throughout the season.[22] Out of the 17,799 shoulder injuries reported throughout this study, glenohumeral instability injuries made up 23 percent of all of these injuries.[22] Glenohumeral instability injuries occurred at a rate of 0.12 per 1000 athletic exposures.[22] This statistic means that, there could be 0.12 instability injuries for every 1,000 athletic exposures for one subject.

Of the 17,799 glenohumeral joint injuries reported, spring football showed the highest rate of glenohumeral instability injuries with a reported incidence rate of 0.40 per 1000 athletic exposures.[22] The incidence rate of glenohumeral instability injuries during the football season was 1.01 per 1000 athletic exposures during games and 0.11 per 1000 athletic exposures during practice.[22] Out of the 4080 glenohumeral joint instability injuries reported in this study, 68 percent were the result of contact with another athlete and 20 percent were the result of contact with an object.[22] The object that caused the injury was not identified in this study. Out of these 4080 glenohumeral joint instability injuries reported, men's fall and spring football accounted for 76 percent of all of the contact injuries that were documented.[22] Six percent were non-contact injuries and five percent did not have a known mechanism of injury.[22]

Another study conducted by Dick, et al examined the rate of specific injuries in college football over a 16 year period from the 1988-1989 season through the 2003-2004 season.[23] During this 16 year period 30,979 injuries occurred during 18,000 games, 42,355 injuries occurred during 128,000 fall practices, and 10,943 injuries occurred during 15,000 spring practices.[23] This adds up to 84,277 reported injuries over about 161,000 athletic exposures. During fall football games, sprains of the glenohumeral ligaments accounted for 2.6 percent of all of the injuries reported across this time period and occurred at a rate of 0.91 per 1000 athletic exposures.[23] Subluxations of the glenohumeral joint accounted for 2.1 percent of all injuries and occurred at a rate of 0.73

per 1000 athletic exposures.[23] This study also found that injuries to the glenohumeral joint displayed a higher incidence rate during games than during practice.[23]

Out of the 84,277 reported injuries during this study, subluxations during fall practices accounted for 2.4 percent of injuries recorded and occurred at a rate of 0.09 per 1000 athletic exposures.[23] Strains of the muscles and tendons of the glenohumeral joint accounted for 2.7 percent of injuries and occurred at a rate of 0.08 per 1000 athletic exposures.[23] Glenohumeral ligament sprains accounted for 2.0 percent of injuries and occurred at a rate of 0.08 per 1000 athletic exposures.[23] During spring practices subluxations of the glenohumeral joint accounted for 3.1 percent of injuries and occurred at a rate of 0.30 per 1000 athletic exposures.[23] Sprains to the glenohumeral ligaments accounted for 2.0 percent of injuries and occurred at a rate of 0.19 per 1000 athletic exposures.[23] Strains to the muscles and tendons of the glenohumeral joint accounted for 1.8 percent of injuries and occurred at a rate of 0.17 per 1000 athletic exposures.[23] Dislocations of the glenohumeral joint accounted for 1.0 percent of injuries and occurred at a rate of 0.09 per 1000 athletic exposures.[23]

A third study was also conducted during the 2009-2010 through the 2013-2014 academic years examining injury occurrence in college sports. During this period, 1,053,370 injuries were estimated to have occurred during about 176.7 million athletic exposures.[24] This study defined injuries as events that occurred during organized NCAA-approved practices or competitions that required medical attention from a physician or athletic trainer.[24] An athletic exposure was defined as a student-athlete's participation in one practice or one competition.[24] Injury rates were calculated by dividing the number of injuries by the number of athletic exposures.[24] This study found that men's football accounted for the largest average estimated annual number of injuries and it also showed the highest competition injury rate. Men's football players sustained an average of 47,199 injuries each year and this sport displayed an injury rate of 39.9 per 1000 athletic exposures.[24] This study did not report specific injuries to the shoulder.

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

The closed kinetic chain upper extremity stability test (CKCUEST) is used to quantify the performance of the upper extremity during a closed kinetic chain activity.[6] It can be used to identify risk for any dynamic instability injuries to occur. A common protocol for the CKCUEST was used by Lee, et al.[4] Two strips of 1.5 inch athletic tape were placed parallel to each other and 36 inches apart on an indoor track surface.[4] A standard tape measure was used to measure the distance between the two strips of tape.[4] The distance was measured from the inside edge of each strip of tape.[4] The subject started this test in a push-up position with one hand on each strip of tape.[4] They then reached across their body and touched the strip of tape on the opposite side.[4] The subject touched the right strip of tape with their left hand and they touched the left strip of tape with their right hand.[4] The subject was instructed to get as many touches as they could in 15 seconds, alternating hands each time.[4] Each subject performed the test two times. The number of touches for each trial was counted and recorded by the testers.[4] The number of touches the two trials were then averaged together to obtain a final score for the CKCUEST.[4]

Figure 8: Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST). (a) Start position; (b) in progress

Prediction of In-Season Shoulder Injury From Preseason Testing in Division I College Football Players. Google Images. http://sph.sagepub.com/content/6/6/497/F6.large.jpg. Accessed May 12, 2016.

The CKCUEST is also easy to administer, it doesn't require any expensive equipment, and studies have been conducted showing the CKCUEST has good sensitivity and specificity as well as good test-retest reliability. Lee and Kim[4] assessed the reliability of the CKCUEST by comparing it to hand grip strength and isokinetic strength tests for the rotator cuff muscles. Both of these tests can be used to assess the activity of the dynamic stabilizers of the glenohumeral joint.[4] EMG studies conducted on shoulder activity during isometric hand grip strength testing show increased activity of the supraspinatus and the infraspinatus during this test.[25] A high reliability exists when using isokinetic strength testing to assess the peak torque values of internal and external rotation of the glenohumeral joint.[26] Both concentric and eccentric testing showed an intraclass correlation coefficient above 0.85 indicating good reliability when assessing internal and external rotation using isokinetic testing.[26]

Multiple studies have found that the CKCUEST had a high intra-class correlation coefficient demonstrating good test-retest reliability.[4-6] The intra-class correlation coefficient of the test-retest reliability was 0.97.[4] When using a score of 21 touches, the CKCUEST had a sensitivity of 0.83 and a specificity of 0.79.[27] A high correlation also exists between the CKCUEST, grip strength, and peak torque of internal and external rotation indicating a high validity of the CKCUEST for assessing dynamic stability.[4]

CHAPTER 3

Methods

Study Design

The present study was a retrospective chart review of every player on the same division I-AA football team. All attendance, strength and conditioning, and injury data were retrospectively collected for the 2014 and 2015 NCAA Division I-AA football seasons.

Subjects

All subjects were male and participated on the same NCAA Division I-AA football team. Subjects were excluded if they had any injury that prevented them from being able to maintain the push-up position required by the test or if they only performed one testing session throughout testing time frame. This provided a sample size of 90 subjects.

Testing Procedure

A Certified Athletic Trainer compiled strength and conditioning testing data, after the completion of the 2015 college football season. The outcome data used for the study was the CKCUEST. The athletic training staff completed CKCUEST testing during the strength and conditioning testing periods at the university. The CKCUEST was already being used as part of the strength and conditioning testing periods. The initial test was performed in December 2014 after the 2014 football season was completed. The second testing session was performed in July, 2015, following the shoulder strengthening intervention, and before fall practice began for the 2015 football season. The third testing session was performed in December 2015 after the 2015 football season was completed.

CKCUEST Testing procedure

The CKCUEST was administered on an indoor track surface. The test was set up using a tape measure and two pieces of athletic tape. Two pieces of tape were placed 36 inches apart from the inside edge of each piece. To perform the test, the subject began in a push-up position, knees off of the ground, with one hand on each piece of tape. Hands were directly under their shoulders in the frontal plane. A standard stopwatch was used to time the trials and each test was performed for 15 seconds. To perform the test, the subject touched the piece of tape on the opposite side of the hand then moved it back to the starting position. Then the subject repeated this movement with the opposite hand. The test was performed as fast as possible for the entire 15 seconds. The subject could start with either hand. The test was started with a cadence of “ready, go” and timed by one of two testers.

Two certified athletic trainers administered the test; one counted the number of touches with the right hand and timed the trial while the other counted touches with the left hand and recorded the total number of touches. One of these athletic trainers measured the touches during the first testing session. The same athletic trainers administered the CKCUEST for the second and third testing sessions. The number of touches were added together to obtain the total number of touches the subject had in 15 seconds. Touches did not count if the subject failed to reach all of the way over and touch the strip of tape. If the ground became too wet with sweat from subjects performing the test, two new pieces of tape were measured out and laid down on a dry spot on the track. The tape was only moved if it was deemed necessary by the testers.

The number of touches from the right and left hand were added together for the first trial. The same was done for the second trial. These two values were then averaged together to obtain an average number of touches for the testing sessions. This was done for all three testing sessions throughout the year. As stated in Pontillo, et al.[27], if the subjects displayed an average number of touches under 21, they were considered at risk for glenohumeral joint instability injuries. Every player performed the exercises included in the shoulder intervention program, even if they were not considered at risk for glenohumeral joint instability injuries.

Strength and Neuromuscular Control Interventions

A shoulder-strengthening program was implemented into the football team's offseason workouts by the strength and conditioning coaches at the university. The head strength and conditioning coach and the athletic trainer working with the football team selected 13 exercises shown in Table 1. The interventions focused on muscles responsible for dynamic shoulder stability. The strength and conditioning intervention began in February 2015 and ended in July 2015. The strength staff selected five different exercises for each lifting session. One or two exercises were performed during the warm-up and two to three exercises were used after the workout was completed. Appendix A shows a sample workout program, including strengthening exercises, intensity and volume, used during the intervention period. Table 1 also includes the volume of each exercise. During school in January, February and the first three weeks of March 2015, the team had workouts four times weekly until spring football started in the last week of March 2015. During spring football, the team only worked out twice during the week. The team had the month of May 2015 off from all organized football activities between the end of spring football and the beginning of summer workouts. Summer weight lifting sessions were in June 2015 and July 2015. The team worked out four times each week. The shoulder strengthening exercises were added to their normal strength and conditioning program during the period between the first and second testing sessions. During the season, the shoulder strengthening intervention was not included in the lifting program by the strength and conditioning staff. The strength staff used a maintenance program using more multi-joint exercises during the season. Exercises like those listed in Table 1 that were specific to the rotator cuff were not used during the season.

Table 1: Shoulder Intervention Exercises

Shoulder Strengthening Exercises	Volume (sets x reps)
Push Up hold & Tap/touch across	2 x 20
Med. Ball Push Up & Walk Over	2 x 5
Slideboard or Furniture slider Push Up and Reach	2 x 4-5 ea arm
Bench Supported Y and T Raise	3 x 10
One Arm Supported (on box) and One Arm Row	4 x 8 ea
Push Up with a Plus	2 x 10-12
Bench Supported Rows	3 x 8-10
Dumbbell Full Can	2-3 x 10-12
Dumbbell Side Laying External Rotation	2-3 x 10-12
Band Pull Aparts	2 x 12
Plate Bent Over T Raise	3 x 12
Bent Over Band Row	3 x 15
Standing Scapula Protraction and Retraction	2 x 10
Blast Strap Row and T-Raise	2-3 x 8 ea
Incline Y Bench	3 x 10

Injury Reporting

A Certified Athletic Trainer retrospectively accessed the Sports Injury Monitoring System (SIMS) (Flantech, Iowa City, IA) documentation system to record the number of athlete exposures and shoulder injuries for the 2014 and 2015 seasons. An athlete exposure was defined as 1 athlete participating in 1 game or practice event, regardless of the time associated with that participation.[22] A glenohumeral joint instability injury is defined as instability in at least one anatomic direction with or without associated injury to the glenohumeral joint.[8] An injury was defined as loss of one practice, game or underwent post season surgical intervention.

Data Analysis

The incidence rate of glenohumeral joint instability injuries was calculated by determining the number of instability injuries that occurred for every 1,000 athlete exposure. Incidence rate ratios were used to compare injury rates between the two seasons.

After obtaining the data from the three testing sessions, the data was analyzed using STATA Release 12 (StataCorp LP, College Station, TX). Linear mixed models were used to determine if the CKUEST scores changed at any of the time points. Post-hoc mean comparisons were performed using Tukey's HSD. Finally, logistic regression was used to determine if the odds of suffering a shoulder injury were increased or decreased depending on how an athlete performed on the CKUEST.

CHAPTER 4

Results

The demographic information for the subjects of this study is shown in Table 2.

Table 2: Average characteristic information for subjects

Characteristic	**Value (std dev)**
Age (years)	20.88 (±1.52)
Height (cm)	185.14 (±6.17)
Weight (kg)	99.92 (±18.42)

Incidence Rate

The first aim of this study was to determine the incidence rate of shoulder instability injuries following the implementation of a shoulder strengthening and neuromuscular control intervention. Table 3 shows the results from the statistical analysis used to determine the incidence rate for instability injuries for this study. In 2014, there were 23,546 athletic exposures during the season and there were 9 injuries to the glenohumeral joint and 10 glenohumeral joint instability injuries documented. The incidence rate during the 2014 season was 0.38 glenohumeral instability injuries per 1,000 athlete exposures. The incidence rate was 1.05 glenohumeral instability injuries per 1,000 athlete exposures if only practices and games are included. In 2015, there were 19,442 athletic exposures during the season. There were 19 injuries to the glenohumeral joint and 13 glenohumeral joint instability injuries recorded. The incidence rate of glenohumeral joint instability injuries was 0.98 per 1,000 athlete exposures. The incidence rate of instability injuries if only practices and games are included in the analysis was 2.36 per 1,000 athlete exposures. When all athlete exposures were included, the incidence rate ratio between 2014 and 2015 was 0.39 (0.18, 0.84 95% CI). When only practice and games were included, the incidence rate ratio was 0.45 (0.21, 0.97, 95% CI)].

Table 3: Incidence rate for glenohumeral joint instability injuries

Year	Rate	Confidence Interval
2014	All AE: 0.38 per 1,000 AE P/G AE: 1.05 per 1,000 AE	(0.13, 0.63) (0.36, 1.74)
2015	All AE: 0.98 per 1,000 AE P/G AE: 2.36 per 1,000 AE	(0.54, 1.42) (1.30, 3.41)

All AE- all recorded athletic exposures
P/G AE- practice and game athletic exposures only

Table 4 shows the athletic exposures throughout the 2014 and 2015 football seasons.

Table 4: Athletic exposures

2014 Athletic Exposures		**2015 Athletic Exposures**	
Weightlifting	10,406	Weightlifting	8,748
Conditioning	4,588	Conditioning	2,627
Practice	7,697	Practice	7,373
Game	855	Game	694
Total	23,546	Total	19,442

CKCUEST At-Risk Subjects

The second aim of this study was to determine the at risk subjects for glenohumeral joint instability injuries before and after the intervention. The diagnostic tool used for determining risk for injuries was the CKCUEST. This test suggested that two subjects were at risk for instability injuries before the intervention and there were zero subjects at risk for injury after the intervention. An odds ratio of 1.04 (0.87, 1.25

95% CI) was obtained from this logistic regression analysis. The confidence interval indicated that the subjects' baseline performance on the CKCUEST was not a significant predictor of risk for glenohumeral joint instability injuries.

Table 5 shows additional data obtained from the CKCUEST that shows scores on the test were higher during the second testing session compared to the first and third testing session. There was no statistically significant difference between scores on the CKCUEST when comparing results from the first and third testing sessions. This data was calculated using a Tukey's post-hoc test.

Table 5: Tukey's post-hoc analysis between results from each testing session

Session vs Session	**Mean 1**	**Mean 2**	**Mean Difference**	**HSD-test**
1 vs 2	28.9194	33.1695	4.2501	8.6772*
1 vs 3	28.9194	29.2340	03147	0.6421
2 vs 3	33.1695	29.2340	3.9354	0.0301*

* = *denotes statistical significance*

CHAPTER 5

Discussion

The purpose of this study is to determine if identifying and treating players can decrease the incidence of shoulder injuries in collegiate football players with poor dynamic stability at the glenohumeral joint. The CKCUEST was used to assess dynamic stability at the glenohumeral joint. The CKCUEST has been shown to have good sensitivity, specificity, and odds ratio values for determining the risk for instability injuries at the glenohumeral joint in college football players.[27] The exercises implemented in the subjects' workouts in the weight room all targeted muscles responsible for stabilization of the glenohumeral joint.

Incidence Rate

The first aim of this study was to determine the incidence rate of shoulder instability injuries following the implementation of a shoulder strengthening and neuromuscular control intervention. The first hypothesis of this study was the incidence rate for instability injuries at the glenohumeral joint would be lower during the 2015 football season compared to the incidence rate of the same injuries from the 2014 football season. The results of this current study did not support this hypothesis. The incidence rate almost doubled for glenohumeral joint injuries per 1,000 athlete exposures between the 2014 and 2015 football seasons.

The muscles of the rotator cuff were the focus of the shoulder strengthening exercises implemented into the subjects' workouts in this study. EMG studies have shown that the strengthening exercises used in this study were appropriate for strengthening the dynamic stabilizers of the glenohumeral joint.[28] The function of the rotator cuff muscles is to provide dynamic stability for the glenohumeral joint throughout the joint's range of motion.[29] Strengthening the muscles of the rotator cuff is a common method for the initial rehabilitation of glenohumeral joint instability injuries.[12] Based on prior research, it was postulated that using rotator cuff strengthening exercises would improve the effectiveness of the dynamic stabilizers of the glenohumeral joint. It was also then postulated that this would decrease the number of instability injuries at the glenohumeral joint that occurred between the 2014 and 2015 football seasons. However, this was not the case, therefore, since this current study did not assess muscle strength of each individual player, the increase in shoulder injuries cannot be attributed to strength deficits.

Exercise selection did not affect results either. One study evaluated the isokinetic strength changes of subjects after going through different shoulder strengthening exercise programs that targeted the rotator cuff musculature. The first group used multi-joint dynamic resistance training that included exercises like pull-ups, overhead press, and push-ups.[32] The second group used a 2 kg (4.4 lbs) dumbbell for different glenohumeral internal rotation and external rotation exercises.[32] Both groups showed improved isokinetic strength after the exercise intervention.[32] The shoulder strengthening exercises used in this study were similar to the exercises used in the study conducted by Malliou, et al. In this study, an increase in performance on the CKCUEST was also shown between the first and second testing sessions. Based on this, it could be implied that the exercises chosen for this study would have been effective at increasing the strength and effectiveness of the dynamic stabilizers of the glenohumeral joint. There are other factors regarding the CKCUEST that could have led to the results obtained in this study.

Player position may have accounted for the increase in shoulder injuries. There may be an increased risk for a linebacker compared to a wide receiver based on the requirements of the position. The glenohumeral joint of a linebacker will be placed in positions and experience forces that may increase the likelihood for instability injuries to occur. This study examined results for an entire football team. No comparison was made between position groups due to the small number of injuries that would occur within position group if we stratified. Table 6 shows the number of glenohumeral joint instability injuries that occurred during the 2015 football season.

Table 6: Breakdown of number of glenohumeral joint instability injuries during the 2015 season

Position	QB	RB	WR	TE	OL	DL	LB	DB	ST
# of injuries	2	1	0	1	2	2	3	2	0

A study conducted on injury rates in the NFL between 2012 to 2014 showed that certain position groups were more prone to all shoulder injuries than others. They found an injury incidence rate for all injuries of 395.8 per 1,000 athletes at risk.[31] Out of the 4,284 injuries that were recorded over the course of this study, wide receivers displayed the highest all-cause injury rate.[31] In order by position after wide receivers for injury rate was tight ends, defensive backs, running backs, and linebackers.[31] Shoulder injuries accounted for 8.4 percent of all of the injuries documented in this study.[31] The results from this study could imply that the position of the athlete could have affected the injury rate ratio observed for glenohumeral instability injuries. Another study that assessed the number of all injuries that occurred to the shoulder in football players found that differences were found based on the position. This study showed offensive linemen were more prone to injuries to the rotator cuff.[1] Defensive backs, defensive linemen, linebackers, and offensive linemen were the groups that showed the highest rates for surgery to repair instability injuries to the glenohumeral joint.[1]

Protective equipment used in football is different, based on the position demands of the athlete. Shoulder pad design specifically can affect the rate at which shoulder injuries occur. One function of shoulder pads is to disperse forces that occur at the glenohumeral joint during play. Shoulder pads can be designed differently to offer more protection at the glenohumeral joint. A cantilever strap can be added to shoulder pads to help disperse the force that occurs from direct blows to the shoulder across a wider surface area. This cantilever strap prevents the glenohumeral joint from experiencing the full force of a direct impact from the ground or from another player during athletic exposures. The strap extends from the front of the shoulder pads over the acromion process and to the back of the shoulder pads. Cantilevered shoulder pads are recommended for football players that experience a high number of impacts to the shoulder throughout a practice or game.[3] This would include positions like offensive and defensive linemen, linebackers, and running backs where the athletes do a lot of tackling or blocking maneuvers. Non-cantilevered shoulder pads are recommended for football players that need more mobility at their glenohumeral joint to perform effectively during play.[3] This would include positions like wide receivers, quarterbacks, and defensive backs. The current study did not assess football shoulder pad type.

At-risk participants

The second aim of this study was to determine the at risk subjects for glenohumeral joint instability injuries before and after the intervention. We hypothesized that the number of participants designated as at risk by the CKCUEST would significantly decrease after the strengthening intervention was implemented. The results did not support this hypothesis. They showed an initial improvement in the average number of touches between the first and second testing sessions indicating improved strength of the dynamic stabilizers of the glenohumeral joint. There was no change in the number of subjects identifies as “at risk”. A lower number of subjects were determined to be at risk after the intervention, but the number was not statistically significant. The results also indicated that the CKCUEST was not a good predictor for injury in this study.

There have been other studies that have obtained results that support the use of the CKCUEST to determine the risk for instability injuries at the glenohumeral joint.[27, 4, 30, 6] Using 21 touches to identify subjects at risk is associated with reliable sensitivity and specificity values. 21 touches were also associated with good values for positive and diagnostic odds ratios.[27] There are many factors that could have caused the results obtained from this study.

While the CKCUEST assesses dynamic stability at the glenohumeral joint, it does not replicate the forces that can occur at the joint during contact while participating in football practices and games. The amount of force placed on the glenohumeral joint and the direction of the force could lead to greater risks for instability injuries than the CKCUEST can identify. More sport-specific testing could be utilized along with the strengthening program implemented in this study to assess any changes in risk for instability injuries.

Delimitations/Limitations

The delimitation of this study is the strong methodology. The limitation of this study was the subjects were not required to be at the summer lifting sessions. Every player performed the exercises included in the shoulder intervention program, even if they were not considered at risk for glenohumeral joint instability injuries.

Future Research

Future studies should evaluate the difference in shoulder strengthening interventions specific to position groups in sports. This could be done over several years or with several teams to allow for a larger number of injuries to occur within each position strata. They could also evaluate a shoulder strengthening intervention using only subjects that are identified as “at risk” for shoulder instability injuries. The effectiveness of different types of protective equipment at decreasing the risk for glenohumeral joint instability injuries could also be evaluated.

Conclusion

The results of this study would imply that the CKCUEST might not be the most effective tool for assessing dynamic stability at the glenohumeral joint in college football players. More sport-specific testing could be considered when assessing the risk of instability injuries occurring in football players. Articles have been published that show that the CKCUEST can provide a valid assessment for risk of sustaining instability injuries to the glenohumeral joint.

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Appendix A- Definition of Terms

Acromioclavicular Joint (ACJ): articulation between the lateral aspect of the clavicle and the acromion process of the scapula.[3]

Acromioclavicular Ligament: maintain the position of the clavicle relative to the position of the acromion process of the scapula.[3]

Biceps Brachii: performs flexion of the glenohumeral joint.[7]

Clavicle: an s-shaped bone that articulates between the manubrium of the sternum at the sternoclavicular joint and the scapula at the acromioclavicular joint.[3]

Coracobrachialis: flexes and assists with adduction of the glenohumeral joint.[7]

Deltoid (Anterior Fibers): performs flexion and assists with abduction and internal rotation of the glenohumeral joint.[7]

Deltoid (Middle Fibers): performs abduction of the glenohumeral joint.[7]

Deltoid (Posterior Fibers): performs extension and assists with external rotation and abduction of the glenohumeral joint.[7]

Glenohumeral Joint (GHJ): the articulation between the head of the humerus and the glenoid fossa of the scapula.[3]

Glenohumeral Joint Capsule: a loose ligamentous tissue that surrounds the glenohumeral joint and provides static stability.[3]

Glenoid Labrum: deepens the articulating surface between the head of the humerus and the glenoid fossa.[3]

Glenohumeral Ligament (Anterior): prevents excess glenohumeral joint abduction, extension, and external rotation.[3]

Glenohumeral Ligament (Inferior): divided into anterior and posterior bands. Prevents excess abduction, extension, and external rotation of the glenohumeral joint.[3]

Glenohumeral Ligament (Middle): prevents excess flexion and external rotation of the glenohumeral ligament.[3]

Humerus: One of the bones that makes up the glenohumeral joint. The humeral head articulates with the glenoid fossa of the scapula.[3]

Infraspinatus: performs external rotation and provides dynamic stabilization at the glenohumeral joint.[7]

Latissimus Dorsi: performs extension and assists with internal rotation and adduction of the glenohumeral joint.[7]

Levator Scapulae: performs elevation and assists with downward rotation of the scapula.[7]

Pectoralis Major: divided into upper and lower fibers. Performs adduction and assists with flexion and internal rotation of the glenohumeral joint.[7]

Rhomboids (Major and Minor): performs retraction and elevation of the scapula and assists with downward rotation of the scapula.[7]

Rotator Cuff: provides dynamic stability of the glenohumeral joint. Consists of the supraspinatus, infraspinatus, teres minor, and subscapularis.[7]

Scapula: A flat, triangular bone that serves as an articulating surface for the head of the humerus. It is located on the dorsal aspect of the humerus.[3]

Scapulothoracic Articulation: the articulation between the scapula and the posterior wall of the body.[3]

Serratus Anterior: performs protraction and upward rotation of the scapula. It also stabilizes the scapula against the ribs.[7]

Sternoclavicular Joint (SCJ): articulation between the manubrium of the sternum and the medial aspect of the clavicle.[3]

Subscapularis: performs internal rotation and provides dynamic stabilization at the glenohumeral joint.[7]

Supraspinatus: performs abduction and provides dynamic stability at the glenohumeral joint.[7]

Teres Major: performs extension and assists with internal rotation and adduction of the glenohumeral joint.[7]

Teres Minor: performs external rotation and provides dynamic stabilization at the glenohumeral joint.[7]

Trapezius (Lower Fibers): performs depression and assists with upward rotation of the scapula.[7]

Trapezius (Middle Fibers): performs retraction of the scapula.[7]

Trapezius (Upper Fibers): performs elevation of the scapula.[7]

Triceps Brachii: performs extension and assists with adduction of the glenohumeral joint.[7]