Biomechanics of Shoulder Injury in Athletes

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Abstract : Balancing mobility and stability, the biomechanics of the shoulder provides optimal use of the thumb and hand. More than a glenohumeral joint, the shoulder complex consists of four joints and numerous muscles and ligaments. Injuries to the shoulder result from overuse, extremes of motion, and excessive forces. This review describes basic shoulder biomechanics, their role in impingement and instability, and how imaging can detail shoulder function and dysfunction.

1 INTRODUCTION

The shoulder is an engineering marvel, designed to allow humans to maximize use of the opposable thumb and hand in three-dimensional space. The term shoulder is often used interchangeably with glenohumeral joint, but the shoulder complex actually consists of four joints and many ligaments and muscles working synergistically. Limited bony contact between the humeral head and glenoid fossa allows extended range of motion at a cost of relative instability. There must be a balance between mobility and stability to maintain proper func- tion, and it is this balance that embodies the biomechanics of the shoulder complex.

Mechanical shoulder pathology typically results when overuse, extremes of motion, or excessive forces overwhelm intrinsic material properties and disrupt the delicate balance of the shoulder complex resulting in tears of the rotator cuff, capsule, and labrum.

By reviewing basic biomechanical fundamentals of the shoulder complex, we hope to further provide the reader with a background to more fully understand typical causes of more common shoulder problems, such as impingement and instability, as well as complex problems in the overhead athlete, who often exhibits combined features of impingement and instability.

2 DISCUSSION

2.1 Basic Biomechanics Of Shoulder

The glenohumeral joint is fundamentally the central component of the shoulder complex, and yet, like most successful groups and teams, it does not work alone but rather depends on many individual efforts. The other joints of the shoulder complex include the sternoclavicular (SC), acromioclavicular (AC), and scapulothoracic joints. The purpose of these joints of the shoulder complex is to move and stabilize the glenoid optimally during upper extremity movement, similar to the coordinated effort required to balance a spinning basketball on your finger or a book on your head (Armfield et al, 2003).

2.2 Sternoclavicular Joint

The SC joint is a saddle joint that is a true synovial joint. It is the only articulation of the shoulder with the axial skeleton. Its saddle shape allows clavicular elevation and depression (45 to –10 degrees), anterior and posterior translation of about 15 degrees (also called protraction and retraction, respectively), and 50 degrees of posterior rotation along the long axis of the clavicle. The bony articulation of the joint consists of the primarily convex surface of medial clavicle with the mostly concave surface of the clavicular facet of the sternum. The SC joint

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contains an intra-articular disc that helps with shock absorption. The joint is strongly reinforced by the anterior and posterior SC ligaments and capsule as well as the interclavicular ligament and costoclavicular ligaments (Armfield et al, 2003).

2.3 Acromioclavicular Joint

The AC joint is a plane joint. This type of joint allows limited translation and rotation of two relatively flat surfaces. The two surfaces of the acromion and proximal clavicle are relatively congruent but contain a variably sized intra-articular disc that helps transmit forces evenly. The joint provides a link between SC motion and scapular positional changes via the strut configuration of the clavicle. Because there is little motion at this joint, movement initiated at the SC joint is transmitted into scapular sliding and rotation along the scapulothoracic plane. Joint stability results from the AC joint capsule and its superior thickening called the superior AC ligament. The connection between the scapula and clavicle is further reinforced via the coracoclavicular ligaments. In the past the joint capsule was considered to be a relatively weak structure, but cadaver studies have shown that surgical transection of the capsule leads to increased translation across the joint and these excess forces may predispose the coracoclavicular ligaments to failure (Debsi et al, 2001).

2.4 Scapulothoracic Joint

The scapulothoracic articulation is not a true joint but rather the interface of the sliding scapula on the thoracic cage. Scapular movement is essential for upper extremity movement and it provides a stable base for movement at the glenohumeral joint. Scapular movement has been described in multiple planes, including upward elevation and downward depression, upward and downward rotation, anterior and posterior movement along the thoracic cage termed protraction and retraction as well small adjustments along the AC joint plane. The major muscles responsible for scapular movement include the trapezius, levator scapulae, serratus anterior, and rhomboids. Although often not considered a part of the shoulder complex, spinal positioning is also important for optimum scapular positioning.

2.5 Glenohumeral Joint

The fundamental central component of the shoulder complex is the glenohumeral joint. It has a ball and socket configuration with a surface area ratio of the humeral head to glenoid fossa of about 3:1 with an appearance similar to a golf ball on a tee. Overall, there are minimal bony covering and limited contact areas that allow for extensive translational and rotational ability in all three planes via combinations of several muscles.9 Stability is created through both static (passive) and dynamic (active) mechanisms. Static stabilizers include concavity of the glenoid fossa, glenoid fossa retroversion and superior angulation, glenoid labrum, which enhances glenoid fossa depth by about 50%, the joint capsule and glenohumeral ligaments, and a vacuum effect from negative intra-articular pressure. It is estimated that the labral structures represent 10 to 20% of stabilization forces. Rotator cuff and deltoid muscle mass also help compress the joint at rest. All of these static restraints are important at rest, except for the glenohumeral ligaments, which seem to be important at extremes of motion.

During upper extremity movement the effects of static stabilizers are minimized and dynamic or active stabilizers become the dominant forces responsible for glenohumeral stability. Dynamic stabilization is merely the coordinated contraction of the rotator cuff muscles that create forces that compress the articular surfaces of the humeral head into the concave surface of the glenoid fossa. This phenomenon is known as concavity compression and must occur during glenohumeral motion or unwanted humeral head translation and instability may occur, which can create forces that overload native structures causing pathologic conditions. Determining exact range of each movement is difficult due to accompanying shoulder girdle movement (Armfield, et al, 2003).

2.6 Arm Elevation

Although simply raising one's arm is a complex task, this motion occurs via the combination of glenohumeral and scapulothoracic motion, together known as scapulohumeral rhythm. This motion usually takes place in the scapular plane, which is about 40 degrees anterior to the coronal plane. Overall, the ratio of glenohumeral to scapulothoracic motion is 2:1. Initially, most motion in the first 25 to 30 degrees occurs at the glenohumeral joint. Beyond this point, scapulothoracic motion begins and movement at both joints occurs with a nearly 1:1

ratio (Armfield et al, 2003). In addition, the humerus must undergo external rotation to not only clear the greater tuberosity posteriorly but also loosen the inferior glenohumeral ligaments (IGHLs) to allow maximum elevation. These osteokinematics require appropriate coordinated contraction of the rotator cuff muscles and the scapular stabilizers. The anterior deltoid and supraspinatus muscles contract in a coordinated fashion to initiate abduction. The upper trapezius, lower trapezius, rhomboids, and serratus anterior work together to create scapular rotation.

The remainder of the rotator cuff muscles work together to provide dynamic stability by ensuring that the humeral head is compressed against the glenoid fossa (concavity-compression principle). This combined effect of rotator cuff muscular forces results in net force effect (or summation vector) known as a net joint reaction force. The joint reaction forces must remain balanced during motion via proprioreceptive feedback. If unbalanced stability is compromised. The notion of a force couple can be thought of in its simplest terms as a tug of war contest between two teams. The sum force (or vector) of the winning team causes the rope to move in their direction. Imagine if there were three teams; the rope would travel in a different direction based on the strongest two teams. Now try to imagine the complexity of the upper extremity movement with over 20 different-sized muscles contracting at slightly different times in all three planes to create a desired motion.

2.7 Pitching Mechanics

Although there are many other sports that involve overhead activity, baseball pitchers have been studied as the prototypical overhead athlete. Most information about the mechanics of throwing was obtained with electromyographic analysis, high-speed videography, and three dimensional motion analysis in baseball pitchers. The motion of pitching has been divided into different phases, including wind up, early cocking, late cocking, acceleration, deceleration, and follow-through (Armfield et al, 2003).

The critical stages with respect to the shoulder are late cocking, acceleration, and deceleration phases. During these phases shoulder muscle activity and load are maximized and the shoulder is most vulnerable to injury. Coordination with the lower legs and trunk is essential. During early arm cocking, scapular stabilizers are active. Deltoid and supraspinatus activity allows abduction with the supraspinatus compressing the humeral head in the glenoid fossa to prevent displacement. In the late arm-cocking phase, increased activity in the infraspinatus and teres minor creates extreme external rotation and helps keep the humeral head centered within the glenoid fossa, preventing anterior displacement. This phase is also characterized by activity in the subscapularis, pectoralis major, and latissimus dorsi to help stabilize and strengthen the anterior aspect of the shoulder to prevent anterior translation of the humeral head. it also forces the head of the humerus forward which places significant stress on the ligaments in the front of the shoulder. Over time, the ligaments loosen, resulting in greater external rotation and greater pitching speed, but less shoulder stability (Armfield et al, 2003).

During the acceleration phase there is high activity of the internal rotators (latissimus dorsi, pectoralis major, and subscapularis) with complimentary activation of teres minor posteriorly in an effort to center the humeral head. At the same time scapular stabilizers are actively contracting to create a stable base for humeral movement during which time large angular and torsional forces are created. During deceleration all posterior muscles are active, especially teres minor, which eccentrically contracts to limit internal rotation. Once the ball is released, follow-through begins and the ligaments and rotator cuff tendons at the back of the shoulder must handle significant stresses to decelerate the arm and control the humeral head.

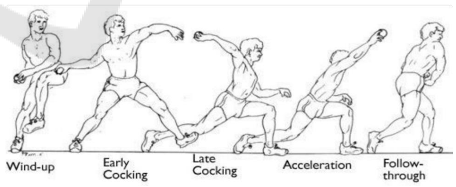

Figure 1: Pitching Mechanism.

2.8 Mechanical Abnormalities of the Shoulder

Many people believe that many overhead athletes experience subclincal instability (i.e., no subluxation or dislocation on physical exam), which leads to contact of the humeral head and labrum causing pathology of the rotator cuff and surrounding labrum. This subclinical instability is known as functional or microinstability and different theories regarding the pathomechanics exits.

The two most commonly described mechanical dysfunctional abnormalities of the shoulder are rotator cuff impingement and glenohumeral instability. Typical connotations of impingement include individuals over 40 with pain during movement. Instability stereotypically affects young athletic males with gross instability resulting in dislocation. For rotator cuff dysfunction that can be intermingled, particularly in the overhead athlete (Armfield et al, 2003).

2.9 Rotator Cuff Dysfunction

Most rotator cuff tears are due to end-tage mechanical impingement of the cuff by the coracoacromial arch during arm elevation has been the cornerstone of diagnosis and treatment of rotator cuff dysfunction. Bigliani correlated acromial morphology, Aoki analyzed acromial slope, and others have identified factors that cause narrowing of the supraspinatus outlet that leads to impingement and cuff tears. The coracoacromial ligament is attached to the undersurface of the acromion and the tip of the coracoid. It is often enlarged in patients with rotator cuff pathology. It also serves as a restraint to glenohumeral superior migration in end-stage cuff tears. Traction forces at its acromial and coracoid attachments may lead to spur formation, resulting in subacromial and subcoracoid impingement. Impingement involving narrowing of the supraspinatus outlet is known as extrinsic or outlet impingement.[6] Secondary extrinsic impingement results from inferior narrowing of the outlet from the rising humeral head in the setting of instability or scapulothoracic dysfunction. Regardless of primary or secondary types, both forms repetitively damage the cuff tissue and predispose it to eventual failure (Armfield et al, 2003).

This concept emphasizes the need for a biomechanically stable rotator cuff. A person could have a small cuff tear and be highly symptomatic depending upon the location of the tear and its effect on the balance of forces in the shoulder. Small tendon tears can induce reflex inhibition of muscle contractility, which can further lead to cuff imbalance and symptoms, whereas a small perforative full-thickness tear may be biomechanically silent and clinically meaningless. Consequently, it is important to describe not only the type of tear but also its size, extent, and exact location for the referring surgeon (Pandev and Jaap, 2015).

Muscles of the rotator cuff are active during various phases of the throwing motion.[16] During the late cocking and early acceleration phases, the arm is maximally externally rotated, potentially placing the rotator cuff in position to impinge between the humeral head and the posterior-superior glenoid. Known as “internal impingement” or “posterior impingement,” this may place the rotator cuff at risk for undersurface tearing (articular sided). Conversely, in the deceleration phase of throwing, the rotator cuff experiences extreme tensile loads during its eccentric action, which may lead to injury (Dugas and Andrew, 2003). Rotator cuff tears in the overhead athlete may be of partial or full thickness. The history of shoulder pain either at the top of the wind-up (acceleration) or during the deceleration phase of throwing should alert the examiner to a rotator cuff source of pain or loss of function. Any history of trauma, changes in mechanics, loss of playing time, previous treatments, voluntary time off from throwing, and history of previous injury should be noted. Rotator cuff tears may be caused by primary tensile cuff disease (PTCD), primary compressive cuff disease (PCCD), or internal impingement. PTCD results from the large, repetitive loads placed on the rotator cuff as it acts to decelerate the shoulder during the deceleration phase of throwing in the stable shoulder. The injury is seen as a partial undersurface tear of the supraspinatus or infraspinatus (Lynn and Lippert, 2003). PCCD is found on the bursal surface of the rotator cuff in throwers with stable shoulders. This process occurs secondary to the inability of the rotator cuff to produce sufficient adduction torque and inferior force during the deceleration phase of throwing. Processes that decrease the subacromial space increase the risk for this type of pathology. Partial-thickness rotator cuff tears can also occur from internal impingement (Dugas and Andrew, 2003).

2.10 Clinical Significance Rotator Cuff Injury

Rotator cuff tears are either partial thickness or full-thickness tears. Partial thickness tears occur at the articular (most commonly) or bursal side of the rotator cuff tendons.

The patient's age, baseline shoulder function,tear size, chronicity, and degree of tendon r etraction are several critical elements to be considered when deciding how to manage each patient most appropriately. The supraspinatus tendon is the tendon most commonly injured of the rotator cuff muscles, followed by infraspinatus, subscapularis, and teres minor. The teres minor tendon is only rarely involved in rotator cuff injuries. The subscapularis tendon tear can be associated with a biceps tendon dislocation from the bicipital tendon groove moving into the subscapularis tendon medially (Eovaldi et al, 2018).

Confirmation of intra-articular tendon tears is by the absence of the biceps tendon in the empty bicipital groove.18 Labral injuries and Dislocations Multiple types of shoulder labral injuries can occur in different patient populations. One particularly common injury subgroup includes young athletes afflicted with a traumatic shoulder dislocation. In the setting of glenohumeral instability, clinicians should recognize the importance of not only a recurrent dislocation, but the risk of increased bone loss and soft tissue compromise which may ultimately affect the outcome following surgical repair (Eovaldi et al, 2018).

Glenohumeral instability, especially in the setting of trauma, is most commonly seen anteriorly. Posterior shoulder instability can be seen in weightlifter or football linemen. Rare dislocation patterns include the superior and inferior glenohumeral dislocation (luxatio erecta). It is important to note that in the setting of multidirectional instability (MDI), especially in the case of bilateral ligamentous laxity or in a patient with a personal or family history of a connective tissue disorder, the probability of recurrent instability is relatively common. The mainstay treatment for these injuries centers on physical therapy and shoulder strengthening programs (Eovaldi et al, 2018).

Para-labral cysts are most often seen in association with glenoid labral tears. Para-labral cyst formation can cause subsequent nerve compression and denervation of shoulder muscles. The suprascapular nerve is susceptible to compression from a para-labral cyst due to its location as it passes through the suprascapular and spinoglenoid notches adjacent to the anterior-inferior labrum. The subscapular nerve is also susceptible to compression from a para-labral cyst in the subscapular recess. Isolated atrophy of the teres minor implies injury to the axillary nerve (Cowan et al, 2018).

2.11 Adhesive Capsulitis

The cause of frozen shoulder is deposition of hydroxyapatite crystals into the muscle tendon. The shoulder is the most common site of hydroxyapatite calcification in the human body. The supraspinatus tendon is the most common site of hydroxyapatite crystal deposition. Frozen shoulder is associated with diabetes mellitus but may also be associated with coronary artery disease, cerebral vascular disease, rheumatoid arthritis, and thyroid disease (Friedman et al, 2015).

There are numerous lesions that may occur in the overhead athlete. Tendonitis, tendonosis, and bursitis are 3 separate clinical entities for which the names are often incorrectly used interchangeably. Tendonitis is inflammation of the tendon. In many cases, it is actually the tendon sheath that is inflamed and not the tendon itself. Bursitis is inflammation of the subacromial bursa. Tendonosis implies intratendonous disease, such as intrasubstance degeneration or tearing. The patient clinical presentation of tendonitis or tendonosis of the rotator cuff are pain with overhead activity and weakness secondary to pain. The symptoms in the thrower are pain during the late cocking phase of throwing, when the arm is in maximal ER, or pain after ball release, as the muscles of the rotator cuff slow the arm during the deceleration phase (Wilk et al, 2009).

Weakness of the supraspinatus and infraspinatus are common findings in throwers with shoulder pathology; but asymmetric muscle weakness in the dominant shoulder is often seen in the healthy thrower. Differential diagnosis of tendonitis versus tendonosis is based on MRI and duration and frequency of symptoms. On MRI, the patient with tendonitis will exhibit inflammation of the tendon sheath (the paratenon); conversely, when tendonosis is present, there exists intrasubstance wear (signal) of the tendon. Tendonitis/tendonosis is most frequently an overuse injury in the overhead athlete and does not usually represent an acute injury process. The symptoms frequently occur early in the season, when the athlete's arm is not conditioned properly. These injuries may also occur at the end of the season, as the athlete begins to fatigue. If the athlete does not participate in an in-season strengthening program to continue proper muscular conditioning, tendonitis/tendonosis may also develop. Specific muscles (external rotator muscles and scapular muscles) may become weak and painful due to the stresses of throwing (Wilk et al, 2015).

2.12 Internal Impingement

Internal impingement was first described in 1992 by Walch and associates in tennis players. They presented arthroscopic clinical evidence that partial, articular-sided rotator cuff tears were a direct consequence of what they termed "internal impingement." Internal impingement is characterized by contact of the articular surface of the rotator cuff and the greater tuberosity with the posterior and superior glenoid rim and labrum in extremes of combined shoulder abduction and ER. In overhead throwing athletes, it appears that excessive anterior translation of the humeral head, coupled with excessive glenohumeral joint ER, predisposes the rotator cuff to impingement against the glenoid labrum. Repeated internal impingement may be a cause of undersurface rotator cuff tearing and posterior labral tears. It is important that the underlying laxity of the glenohumeral joint be addressed at the time of treatment for an internal impingement lesion to prevent recurrence of the lesion (Manske et al, 2013).

Burkhart et al have proposed that restricted posterior capsular mobility may result in IR deficits and may cause pathologic increases in internal rotator cuff contact and injury. Patients with internal impingement usually describe an insidious onset of pain in the shoulder. Pain tends to increase as the season progresses. Symptoms may have been present over the past couple of seasons, worsening in intensity with each successive year. Pain is usually dull and aching, and is located over the posterior aspect of the shoulder. Late cocking phase seems to be most painful. Loss of control and velocity is often present secondary to the inability to fully externally rotate the arm without pain. On physical examination, pain may be elicited over the infraspinatus muscle and tendon with palpation. Pain to palpation is more often posterior, in contrast to rotator cuff tendonitis, which usually elicits pain to palpation over the greater tuberosity. With internal impingement, patients usually have full ROM. In both the normal and pathologic thrower's shoulder the dominant arm tends to have 10° to 15° more ER and 10° to 15° less IR with the arm abducted to 90°, compared with the nondominant arm. The most common presentation is for the overhead athlete to have 1+ to 2+ anterior laxity and 2+ posterior laxity. Inferior laxity is often present. Most provocative tests are negative. The most frequent provocative exam to elicit pain is the internal impingement sign, described earlier (Rose et al, 2018).

2.13 Superior Labrum Anterior to Posterior (SLAP) Lession

SLAP lesions are a complex of injuries to the superior labrum and biceps anchor at the glenoid attachment. Patients who have SLAP lesions fall into 2 basic categories. The first consists of overhead athletes, most commonly baseball players, with a history of repetitive overhead activity and no history of trauma. The second category involves patients with a history of trauma. Burkhart et al have described the peel-back lesion of the superior labrum, which frequently occurs in the overhead athlete. Peel-back lesions are considered a type II SLAP lesion. The athlete often presents to the practitioner with complaints of vague onset of shoulder pain and possibly problems with velocity, control, or other throwing complaints. The patient may complain of mechanical symptoms or pain in the late cocking phase, often poorly localized. This sign occurs when the arm is placed in abduction and external rotation, which causes the biceps anchor to twist posteriorly because of its loose attachment. Typical symptoms are a catching or locking sensation, and pain with certain shoulder movements. Pain deep within the shoulder or with certain arm positions is also common. The diagnosis of SLAP lesions can be very difficult, as symptoms can mimic rotator cuff pathology and glenohumeral joint instability. Definitive diagnosis can only be made by arthroscopy (Wilk et al, 2013).

2.14 Thrower's Exostosis

Thrower's exostosis is an extracapsular ossification of the posteroinferior glenoid rarely seen except in older longtime throwers. This condition is a result of secondary ossification involving the posterior capsule, probably due to repetitive trauma. The osteophyte is thought to originate in the glenoid attachment of the posterior band of the inferior glenohumeral ligament, possibly from traction during deceleration. Patients often have a tight posterior capsule, with capsular contracture and asymmetric shoulder motion with an IR deficit. This lesion can often mimic internal impingement. Pain is often found in the posterior part of the shoulder and is worse in late cocking. Patients often describe a pinching sensation during throwing. Pain usually is relieved by rest. Plain radiographs will assist in differentiating this lesion from internal impingement (Wilk et al, 2009).

2.15 Acromioclavicular Joint Injury

Acute acromioclavicular joint (ACJ) injuries can occur due to a direct force to the acromion typically with the shoulder adducted, or from an indirect force elsewhere in the body, for example, a fall onto an outstretched arm. Patients present with acute localised pain, swelling and sometimes redness. Injuries can range from a simple acromioclavicular ligament sprain that can be managed conservatively, to ligament tears with ACJ displacement that often require surgery. Chronic ACJ pain can occur following acute ACJ injuries or from repeated irritation to the joint that can develop into osteolysis or osteoarthritis. These chronic changes can be caused by sports that involve throwing or lifting weights. The symptoms will be similar to acute ACJ, but the pain develops insidiously (Leung, 2016).

2.16 Clavicle Fracture

Clavicle fractures, particularly the mid-third of the clavicle, are the most common acute shoulder injuries and account for one in twenty adult fractures. Fractures located more laterally can disrupt the acromioclavicular joint. Over 80% of clavicle fractures can be managed conservatively These injuries usually occur from a fall onto the clavicle or, less frequently, a direct blow to the clavicle. Patients may be involved with contact sports or other at- risk sports such as horse-riding and cycling. They present with acute localised pain with swelling and sometimes visible deformity. Acute injuries are more likely to present to the hospital Accident & Emergency Department than primary care (Leung, 2016).

2.17 Glenohumeral Internal Rotation Deficit (GIRD)

GIRD is defined as a loss of internal rotation in excess of the adaptive gain in external rotation in the throwing shoulder (Lin et al, 2018). Clinically relevant GIRD has been defined as a loss of greater than 25° of internal rotation in the throwing shoulder relative to the nonthrowing side (Bukhart, 2003). The biomechanical model of GIRD is based on the contractures of the posterior capsule and posterior band of the inferior glenohumeral ligament discussed previously. On magnetic resonance (MR) images, thickening of the posteroinferior capsule is present, which can be an important clue to look for concurrent findings in the labrum and rotator cuff. The proposed pathologic cascade due to GIRD starts with posterior soft tissue contractures causing posterosuperior shift of the humeral head, resulting in excessive external rotation.

This "peels back" the biceps anchor under extreme tension, subjecting the posterosuperior structures, including the labrum, to injury. The extreme external rotation also submits the rotator cuff to torsional or twisting injury, leading to eccentric fiber failure and undersurface tearing, which is distinct from the compressive injury in the internal impingement model. While prior data suggested an association between GIRD and an increased risk for shoulder injuries, specifically superior labrum anteroposterior (SLAP) tears, a more recent study proposes that external rotation insufficiency 5° difference in external rotation between throwing and nonthrowing arms) rather than GIRD is associated with shoulder injury. Nevertheless it is still current practice to manage the majority of athletes with GIRD via a stretching regimen, with the 10% who fail conservative treatment pursuing posterior capsulotomy and SLAP tear repair (Lin et al, 2018).

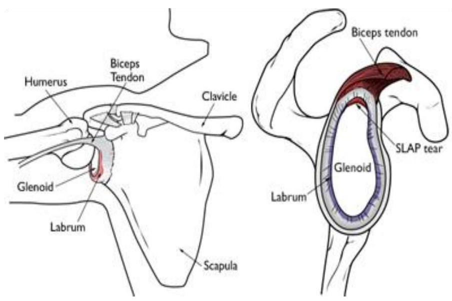

Figure 2: The Labrum and SLAP Tear (Left: Labrum helps to deepen the shoulder socket; Right: cross section view of shoulder socket shows tipical SLAP tear)

Table 1: Muscle Actions at the Shoulder

Muscle	Action													
	Humerus							Scapula						
	Flexion	Extension	Internal rotation	External rotation	Abduction	Adduction	Horizontal adduction	Elevation	Depression	Downward rotation	Upward rotation	Protraction	Retraction	Anterior tilt
Biceps brachii—short head	•													
Biceps brachii—long head*	•				•									
Triceps brachii—long head		•				•								
Supraspinatus					•									
Deltoid														
Anterior	•		•											
Middle					•									
Posterior†		•		•		•								
Coracobrachialis	•					•								•
Latissimus dorsi		•	•			•				•				
Pectoralis major			•			•						•		
Upper fibers	•						•							
Lower fibers		•				•	•							
Subscapularis			•											
Teres major‡		•	•		•	•								
Infraspinatus				•										
Teres minor				•										
Pectoralis minor									•	•		•		•
Rhomboids								•		•			•	
Levator scapulae								•		•				
Trapezius														
Upper								•			•			
Middle													•	
Lower§									•	•	•		•	
Serratus anterior														
Upper fibers								•			•	•		
Lower fibers									•		•	•		

* Biceps brachii long head may abduct the humerus if the humerus is externally rotated.
† The joint angle will determine whether posterior deltoid can adduct the humerus.
‡ The joint angle will determine whether teres major abducts or adducts the limb.
§ The joint angle will determine whether the lower trapezius upwardly or downwardly rotates the scapula.

Table 2: Sports-related shoulder conditions and their possible clinical signs.

Rotator cuff tendinopathy	• Asymmetry and muscle wasting • Palpation tenderness at the • greater tubercle (insertion sites of • three rotator cuff muscles) • Reduced active ROM • Passive ROM intact • Reduced power on resisted movements • Impingement signs
Rotator cuff tears	• Shoulder shrug appearance • Partial or no active ROM • Passive ROM often intact • Reduced power on resisted movements • Drop-arm sign in complete tears if arm cannot be actively maintained at 90° abduction • Impingement signs
Glenoid labral injury	• Palpation tenderness in the anterior shoulder structures • Swelling if acute • Reduced external rotation and or abduction ROM • Reduced power on resisted movements • Biceps load 2 test positive if superior labrum anterior posterior (SLAP) tear • Speed's test positive if SLAP • Yergason's test positive if SLAP • Jerk's test positive if postero-inferior labral injury
Shoulder instability and dislocation	• Prominent humeral head if anterior dislocation • Swelling if acute • Reduced active and passive ROM if dislocated • Increased active or passive ROM if instability with laxity • Apprehension test positive if anterior dislocation • Jerk's test positive if postero- inferior dislocation • Upper arm axillary nerve sensation can be reduced in anterior dislocations
Clavicle Fracture	• Localised swelling with deformity • Clavicle shortened or angulated • Localised bony tenderness
ACJ Injury	• Step deformity and swelling if acute • Localised ACJ tenderness • Scarf test positive • Impingement signs if chronic
Biceps tendinopathy	• Bicipital groove tenderness • Speed's test positive • Yergason's test positive

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