The Thrower's Shoulder

Throwers, or athletes who engage in repetitive overhead motions, are a unique subset of athletes that experience distinct injuries of the shoulder. The majority of athletes who present with a throwing related injury are baseball players. Pitchers and fielders alike engage in drills and game scenarios where throws are made at high velocities, long distances, and in a repetitive nature, all of which increase the strain on the arm of the young athlete. Baseball remains one of America's favorite pastimes and youth engage in this sport often by the age of six or seven. This early participation in overhead throwing increases the likelihood that orthopedic surgeons may encounter patients with shoulder pain. Injuries peculiar to throwers most commonly involve the labrum and the undersurface of the rotator cuff. Material changes in both the anterior and posterior glenohumeral capsule can occur with repetitive overhead motions. These capsular changes may change shoulder kinematics and subsequently contribute to both labral and rotator cuff injury. Furthermore, the glenohumeral joint and the scapula are inextricably linked – what effects one will affect the other. Abnormal scapular kinematics may herald the development of tissue breakdown in the shoulder. This article will discuss the pathomechanics of injuries to throwers, examine the throwing motion, and correlate this to its long term effects on the glenohumeral joint and scapular kinematics.

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The Act of Throwing

Throwing a baseball over 90 mph generates great demands of the shoulder girdle, with humeral angular velocities estimated to exceed 7000deg/sec[1] and external rotation torques as high as 67 N·m[2]. The act of throwing has been elegantly described as occurring in several distinct phases: wind up, early cocking, late cocking, acceleration, deceleration, and follow through (Figure 1). The phases of the throwing motion in which forces to the glenohumeral joint are greatest are the late cocking, ball release (end of acceleration and beginning of deceleration), and follow through. It is during these phases where injury risk is greatest.

In late cocking, the anterior capsule is under significant strain to prevent the humerus from translating forward. Tensile failure and stretching of the anterior capsule is thought to occur from repetitive "hard throwing." Throwers demonstrate increased passive external rotation in the abducted externally rotated position than controls. During follow through, the posterior capsule and posterior cuff undergoes tremendous eccentric loads – up to 108% body weight[3]—in order to decelerate the rapidly internally rotating arm and to restrain the significant distractive forces seen at the posterior shoulder joint. These repetitive strains across the posterior cuff and capsule may result in a fibroblastic healing response, increase collagen deposition, and loss of tissue compliance. All of these elements converge and are thought to give the overhead thrower a stiff posterior cuff and capsule.

In order to attain the arm velocity required to pitch effectively, throwers must attain increased external rotation. A recent analysis of both youth and professional pitchers showed that youth pitchers can achieve 118.0 +/- 23.4 degrees of external rotation during the throwing motion compared to 151.9 +/- 17.0 in professional pitchers[4]. The greater the arm can externally rotate, the more time the arm has to accelerate before ball release. Pitchers who are able to pitch at great velocities not only possess great muscle strength and "fast twitch" muscle capability but also inordinate degrees of external rotation.

Humeral Retroversion

Fetal humeri demonstrate significantly increased degrees of retroversion, approximating an average of 78 degrees. During development and growth, retroversion slowly decreases until the adult average of roughly 30 degrees is attained[5]. On the other hand, immature throwers, by virtue of Wolf's law, impose external rotatory stresses across the proximal humeral physis which inhibit loss of retroversion[6]. It is not unusual for a thrower, experienced since Little League, to present with over 45 degrees of retroversion in adulthood. Increased retroversion simply "resets the clock" in terms of arc of motion for the thrower; external rotation is gained, while a symmetric loss of internal rotation occurs concomitantly. Osbahr et al showed a correlation between humeral retroversion and increased external rotation in the throwing shoulder and concluded that both osseous and soft tissue adaptations contribute to the changes seen in the throwing athlete[7]. The increased retroversion allows a great amount of external rotation to occur before the greater tuberosity abuts the posterior superior labrum in the abduction external rotation (ABER) position. This contact, sustained repetitively, can lead to posterior cuff and labral injury in many throwers. In fact, this contact has been shown to occur normally in overhead athletes[8]. However, contact pressures between the posterior cuff and labrum are assumed to be less in those throwers endowed with increased retroversion.

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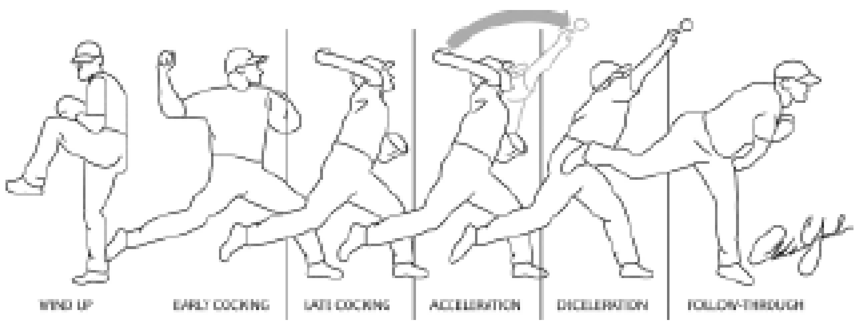

Figure 1. The phases of the throwing motion.

Increased retroversion may, on the other hand, predispose the thrower to increased posterior capsular strain during follow through. Thomas et al (unpublished data) have demonstrated increased posterior inferior capsular thickness in throwers with increased retroversion, as determined with ultrasound. It appears that the loss of internal rotation seen with greater degrees of retroversion impose more demand on the posterior capsule during deceleration.

While there is much discussion about the role of number of pitches thrown in order to avert injury, little is said about not throwing enough pitches during formative years in order to retard the natural progression to less retroversion in adulthood. Those who embrace throwing after skeletal maturity, by virtue of lessened retroversion, may be more susceptible to cuff and labral injury than a "lifetime" thrower. The clinician is to be mindful of the potentially increased likelihood of injury in those that commence pitching in high school versus those who have thrown since early childhood.

Pathomechanics

The thrower's shoulder can result in injury from the convergence of the following factors: attenuation of the anterior capsular constraints, the acquisition of a posterior capsular contracture, scapula dyskinesis, kinetic chain breakdown, and repetitive contact of the posterior superior labrum and greater tuberosity.

Anterior Capsule

Biomechanical studies demonstrate that the anterior capsule, particularly the anterior band of the inferior glenohumeral ligament, is the principle restraint to anterior translation of the humerus when the arm is abducted and externally rotated[9,10,11]. Therefore, repetitive stress to this area, and the thrower's unconscious desire to attain extreme external rotation (the "slot"), will conceivably lead to anterior capsular laxity or attrition. Although the attributed causes are somewhat controversial, throwers demonstrate more passive external rotation compared to the contralateral arm[12,13].

If this excessive rotation exceeds that which is expected to occur from increased retroversion (i.e. excessive rotation gain is greater than internal rotation loss), then the soft tissue restraint is lax. In support of this notion is the work of Jobe et al, which describes the tensioning of the anterior capsule, or anterolabral capsular reconstruction, as a means of returning pitchers to throwing[14]. This open procedure was successful for many, but violation of the subscapularis and excessive tightening are potential reasons why not all subjects were able to throw at pre-injury levels. Levitz et al, in a series of patients who underwent labral repair, reported that those who underwent subtle thermal shrinkage of the anterior capsule, in addition to superior labral repair, had greater success than those who had superior labral repairs alone[15].

Furthermore, as anterior laxity evolves, external rotation will increase and further increase contact of the posterior cuff and labrum, thereby facilitating injury[16]. Recently, Rizio et al demonstrated increased superior labral strain in cadaveric shoulders placed in the ABER position after surgically creating subtle anterior laxity[17]. These studies lend support to the notion of anterior capsular laxity as one contributing factor to shoulder pathology in the thrower.

Posterior Capsule

Throwers will, in time, demonstrate a decrease of internal rotation, especially when measured in the abducted position. This diminished rotation is thought to occur for two reasons. First, as mentioned previously, increased humeral retroversion will manifest as a loss of internal rotation. However, this loss, due to bony remodeling, is accompanied by a symmetric gain of external rotation. This "resetting the clock" of rotation usually accounts for no more than 10 to 17 degrees of rotational loss[18,19]. The second means of internal rotation loss is ascribed to a posterior capsular/cuff contracture. Termed Glenohumeral Internal Rotation Deficit (GIRD), this is thought to occur as a healing response to chronic distractive forces applied to the posterior capsule during follow through. Rotational loss due to capsular contracture is evident when the GIRD exceeds that which can be explained by boney remodeling alone (over 12 degrees) and when the internal rotational loss exceeds the external rotational gain compared to the contralateral shoulder. Thus, a young thrower who presents with GIRD of 35 degrees likely has more than increased retroversion to explain the internal rotational loss. Furthermore, many throwers, particularly less mature athletes, often demonstrate dramatic increases in internal rotation after a dedicated stretching regimen[20]. Bony restraints will not respond to stretching programs.

Biomechanical Consequences of GIRD

Recent clinical and biomechanical studies lend credence to the notion that GIRD may be the sentinel event in the pathologic cascade which many throwers experience. Burkhart et al noted that professional throwers who presented to preseason with GIRD values less than 25 degrees, as compared to the contralateral shoulder, experienced less shoulder difficulties during the ensuing season[21]. Others have noted that throwers who present with superior labral injuries invariably exhibit GIRD greater than 25 to 30 degrees.

The association between GIRD and labral/cuff injury can be at least partially explained by cadaver studies. Clabbers et al imbricated the posterior capsule of cadaver shoulders and placed them in the late cocking position. They noted a non-significant trend towards posterior capsule tightening to encourage relative posterior/superior migration of the humeral head[22]. Grossman and Huffman more elegantly demonstrated the same phenomenon and introduced anterior laxity, in addition to posterior capsular tightness, to a compressively loaded joint, which better mimicked the in vivo condition[23,24]. All three studies suggested that posterior capsular tightness, with or without anterior capsular laxity, promoted a relative shift of the humeral head contact point on the glenoid in the abducted, externally rotated position. This shift in contact should theoretically bring the humeral head closer to the superior labrum in late cocking, promoting increased contact of these two structures. Myers et al have recently shown that throwers with internal impingement presented with significantly more GIRD than asymptomatic throwers[25]. Secondly, a more posterior vector could conceivably increase the posterior force vectors on the labrum in late cocking. This increased "peelback" force may incur a higher incidence of posterior labral injury. Indeed, Kuhn et al have shown that the posterior labrum is more prone to failure in the late cocking, rather than the follow through phase, of throwing[26].

The posterior superior "shift" that occurs with GIRD is thought to result from the inferior tether that posterior/inferior capsular contractures produce (Figure 2). In other words, a contracted posterior/inferior capsule will not permit full external rotation of the humerus. In an effort to "find the slot" the thrower will begin to rotate around a new instant center of rotation – one that is more posterior and proximal. In essence, a tightened posterior inferior capsule will drive the humerus more proximally and posteriorly. Burkhart et al liken this to a "yo-yo" on a string[27]. In support of this tethering phenomenon, the author has noted several pitchers who have presented with both posterior superior and posterior inferior labral tears, confirming the notion that GIRD increases both the capsular tether inferiorly and labral shear posterior superiorly. The concomitant posterior shift in humeral head contact, tightening of the posterior capsule, and anterior laxity can also result in significant rotator cuff pathology by a mechanism termed posterior superior glenoid impingement[28].

Scapula Dyskinesis

An abnormality of either the static or dynamic position of the scapula is termed a "scapula dyskinesis." The scapula normally accommodates the proximal humerus closely so that a stable platform (glenoid) and "concavity compression" of the cuff is optimally attained[29]. Kibler likened this relationship

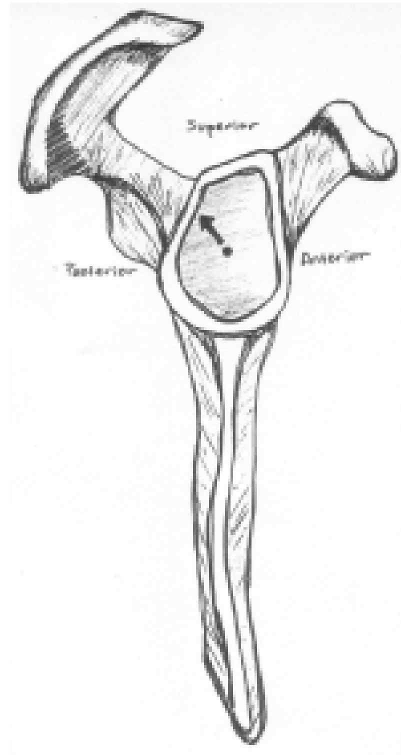

Figure 2. Posterior superior migration of the humeral head within the glenoid as the posterior capsular structures tighten in the throwing athlete.

to a seal balancing a ball on its nose[30]. In time, throwers may develop a scapula dyskinesis which may, in turn, potentiate further cuff or labral injury.

Origins of Dyskinesis

Muscles commonly respond to proximate joint afflictions with atrophy or contracture. Consider, for example, the quad atrophy that accompanies knee pain, or the hamstring tightness that is seen with low back discomfort. Shoulder pain commonly results in inhibition of the lower trapezius and serratus anterior, while tightening of the upper trapezius is frequently seen[31,32]. It has also been shown that in the setting of muscular fatigue, such as after prolonged throwing sessions, scapular movement is increased, which alters its relationship to humeral motion[33]. The net effect of this muscular imbalance is a protracted scapula, one that deviated away from the midline. Since the thorax is ellipsoid, a protracted scapula will essentially follow the contour of the rib cage and rest in a relative internally rotated and inferior position[34,35]. In support of the above, Myers has noted that throwers who suffer from internal impingement demonstrate increased scapular protraction during humeral elevation[36].

Kibler and Pink have advanced the concept of "scapula windup" (secondary to GIRD) as a means to increasing scapular protraction[28]. In essence, throwers with loss of capsular internal rotation will rely more on scapular internal rotation as a means of attaining "follow through." In time, as the scapula "winds up" and over the ellipsoid thorax, it will loosen its static restraints and perhaps overwhelm dynamic stabilizers. The net effect is a scapula that is deviated from the midline, or protracted.

Thomas et al have looked at adolescent and collegiate pitchers and have noted a temporal relationship between GIRD and dyskinesis[37,38]. Less mature pitchers developed GIRD without scapular dyskinesis, while more mature throwers tended to develop more GIRD and began to manifest scapular changes in the throwing shoulder. GIRD over 15 degrees seemed to herald the onset of scapular changes. Thus, there appears to be a dose response of GIRD; more severe levels of posterior capsular contracture seem to become associated with scapular changes.

Effects of Excessive Protraction

A scapula that is protracted, or excessively internally rotated, has numerous biomechanical consequences. First, a protracted scapula will lead to rotator cuff weakness. Since the rotator cuff complex essentially originates on the scapula, a dyskinetic or protracted scapula will serve as an unstable platform and not afford optimal length tension relationships to the cuff muscles. Kibler's "scapular retraction test" affirms the importance of scapula position in optimizing cuff strength. To perform this test, the examiner checks supraspinatus strength testing both with and without manual stabilization of the medial border of the scapula against the thorax. Patients with dyskinesis of the scapula will demonstrate often striking increases in strength upon affixing the medial border of the scapula to the thorax[39].

Secondly, increased protraction anteverts the glenoid, virtually "uncovering" the humeral head anteriorly and thereby leading to anterior destabilization and increased strain on the anterior ligaments[40]. Excessive protraction also increases the degree of impingement between the posterior superior glenoid and posterior rotator cuff by positioning the posterior glenoid closer to the greater tuberosity during external rotation and abduction[41]. Increased 'pinching' or contact of the posterior superior glenoid and posterior suprapinatus occurs more readily in an anteverted glenoid. This "internal impingement" can result in posterior shoulder pain and eventuate in posterior labral or cuff injury. Recently, Myers et al demonstrated that throwers with pathologic internal impingement exhibit a more protracted scapula, supporting this notion[42].

Adolescent Pitchers

Adolescent pitchers are at particular risk for overuse injury and some evidence suggests an increase in surgical rates for pitching related injuries in immature throwers[43]. The use of "breaking ball" pitches as a risk factor for injury in youth is controversial, but many argue against their usage until age 13. The following recommendations for adolescent throwers have more consensus agreement: 1) avoid pitching with arm fatigue or pain, 2) avoid exceeding 80 pitches per game or 2,500 pitches per year, 3) avoid competitive pitching more than 8 months a year, and 4) exercise caution and restraint in pitching "showcases"[44].

Interventions

The throwing athlete can be spared much disability if interventions on throwing mechanics, evaluation of kinetic chain abnormalities, and correction of GIRD and scapular dyskinesis are addressed early. Posterior capsular stretches, especially the "sleeper stretch" is to be performed regularly. Serratus anterior strengthening as well as scapular retraction exercises should be part of a throwers practice regime in order to maintain a healthy scapula position. Kinetic chain abnormalities, including pelvic abductor weakness, lead leg quad tightness, and hip internal rotation loss should be recognized and addressed with timely rehabilitation. Proximal kinetic chain abnormalities evoke distal limb "catch up" and merely increase demand on the shoulder girdle.

Conclusion

The shoulder of the throwing athlete adapts to the stresses which are placed on it. In general, excessive external rotation with a loss of internal rotation occurs with repetitive throwing. Such increased rotation develops from both an alteration in the soft tissue stabilizers of the shoulder as well osseous changes which may occur in the throwing athlete before skeletal maturity is reached. This constellation of changes can be maladaptive when they result in injury or damage to structures such as the labrum and rotator cuff. Scapular motion is also affected secondary to pain originating within the shoulder or secondary to fatigue of the muscles which stabilize the scapula. General guidelines for youth pitchers may help prevent injury and certain maladaptive patterns must be recognized. Unfortunately, the treating physician who will often see patients only after injury has occurred with the surgical treatment of cuff and labral injury yielding less than predictable outcomes.

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