John D. Kelly IV
Editor

Elite Techniques in Shoulder Arthroscopy

New Frontiers in Shoulder Preservation

Springer

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I dedicate this book to my family.

To my daughters, Mary Elizabeth
and Ann Marie: I thank God
for you daily. I could not have "scripted"
better daughters. You both exude kindness,
compassion, and dignity. You both will
truly effect meaningful change
in your lifetimes.
To Marie, the love of my life, the answers
to my prayers: You are the greatest
exemplar of compassion I have known.
You continually provide me with wise
counsel, unwavering loyalty,
and steadfast support.
You will always be my soul mate.

Foreword

One of the big challenges in teaching shoulder arthroscopy today is that many of the techniques are so sophisticated that the craftsmanship necessary to perform these procedures can be difficult to convey. Yet the burden of craft that is incumbent upon arthroscopic shoulder surgeons is greater than ever.

Dr. John D. Kelly IV has assembled a formidable group of authors to elucidate the fine points of *Elite Techniques in Shoulder Arthroscopy*, incorporating the title of his book into the mission of this important work. However, the subtitle of his book, *New Frontiers in Shoulder Preservation*, is equally a statement of this mission. In my opinion, shoulder arthroscopy is the single greatest tool that the orthopedic surgeon can implement toward the goal of joint preservation for any joint in the body. And joint preservation is particularly important in this day of conflicting expert opinions in which the surgeon may be confused as to whether to treat a large or massive rotator cuff tear with arthroscopic repair (joint preserving) or reverse total shoulder replacement (joint sacrificing).

John Kelly has been my friend for more than 15 years, and I have always admired his determination to do the right thing for his patients. He does the right thing whether or not it is easy. And as my fellows have often heard me say, "There's the easy way and there's the cowboy way." I am glad to confirm that Dr. Kelly is preserving and advancing the "cowboy way" of shoulder arthroscopy with his excellent new book. Strong work!

San Antonio, TX
June 28, 2015

Stephen S. Burkhart, MD

Preface

This book is a mere reflection of the graces and blessings I have received from my teachers, mentors, and those involved in my formation.

I wish to acknowledge the sage teachers who enriched my ability to provide ethical and up-to-date care of my patients.

John Lachman taught me the ethics of patient care like no other. Ray Moyer was the greatest exemplar of integrity and loving patient care I have ever known. Joseph Torg is perhaps the wisest counselor on matters of life and orthopedics on earth.

Steven Burkhart taught me how to view a shoulder in mechanical terms, while Felix “Buddy” Savoie continues to instruct me in the most revolutionary shoulder arthroscopic techniques.

I have had the “gift” of a tried and true friend and colleague, Brian Sennett, who has been a continual supportive force in my career, in addition to a superlative source of shoulder knowledge.

My chairman, L. Scott Levin, has supported my academic endeavors without question and has proven time and time again that leadership is all about “walking the talk.”

Finally, I wish to acknowledge my editor, Jenn Schneider, who demonstrated the “patience of Job” in seeing this work to completion.

Philadelphia, PA John D. Kelly IV, MD

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Part I

Overhead Athlete

Pathophysiology of Throwing Injuries

1

Stephen J. Thomas, W. Ben Kibler, and Aaron Sciascia

Introduction

The throwing motion is one of the most unique motions the human body can produce. It incorporates both extreme velocities and impeccable accuracies into one fluid motion [1, 2]. The ability to generate velocity and maintain accuracy is dependent on the synergistic motion of multiple linked body segments. This synergistic motion can be related to the physics that describes waves. Wave mechanics states that if timed correctly, two waves can sum together or completely cancel each other out [3]. The generation of energy with throwing can be thought as waves of energy, which when timed correctly can continually build throughout each body segment. However, if the motion is not synergistic or coordinated, the waves of energy may cancel each other out (Fig. 1.1). When this occurs, distal segments are required to make up for the energy lost at the proximal segments [4]. The driving force in this system is the muscle. Muscles are the actuators of our body that create both motion and force production at the joint segments. The neural activation of muscle is a key component of the ability to not only throw with high velocities but also have pinpoint accuracy. As stated previously, during throwing, waves of energy are created starting with the lower extremity and moving through the core and upper extremity and finally to the ball [5]. Two main components of neural activation can be modulated to throw harder and more accurate. First, the timing of neural impulses is of paramount importance in throwing. If the sequenced activation of muscles is not conducted properly, then waves of energy will cancel out and the resulting kinematics will suffer [6]. Second, the amplitude of neural impulses will dictate the amount of force that is generated at each segment and, therefore, if timed properly, will sum together and be placed on the ball to create maximal velocity [6, 7]. Since throwing is a repetitive act, with major league pitchers averaging 80–100 pitches per game, muscles do undergo fatigue. Fatigue generally has two components that occur simultaneously: neural and mechanical [8]. Neural fatigue will cause nonoptimal firing patterns and reduced amplitudes of neural impulses. Instead of having very complex firing patterns that lead to optimal activation of muscles, the activation becomes less complex with large groups of motor units within muscles firing simultaneously [9, 10]. This is an attempt to make up for the reduced neural amplitude. This compensation pattern results in uncoordinated kinematics that leads to waves of energy being canceled.

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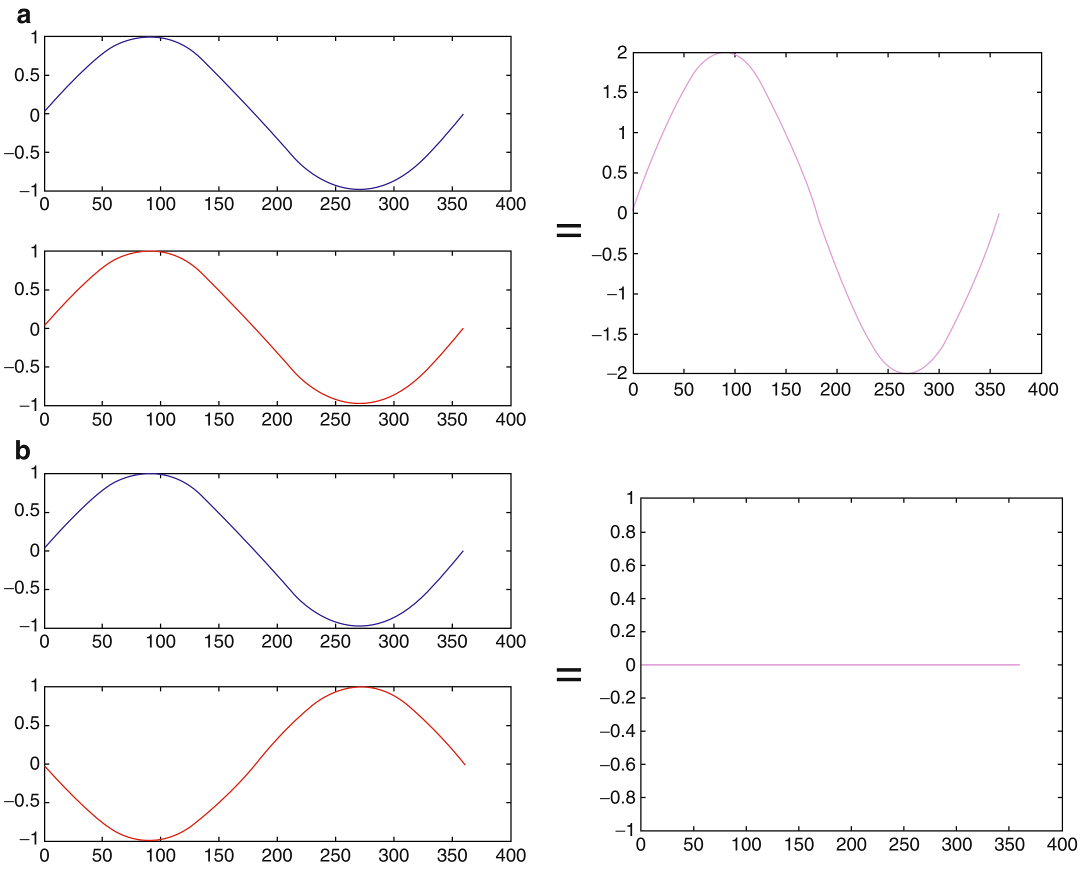

Fig. 1.1 (**a**) An illustration of two individual waves that are in phase. When summed together, the resulting wave is doubled. (**b**) An illustration of two individual waves that are 180° out of phase. When summed together, the resulting wave is completely canceled out

Mechanical fatigue is typically caused by the microdamage of myosin and actin bonds during eccentric muscular contractions [11]. As the amount of damaged myosin and actin increases, the ability to mechanically generate force is reduced. This will also cause a negative feedback loop into the neural component, thereby creating nonoptimal neural firing [10]. It is therefore clear that throwing is a high-velocity act that requires intricate neuromuscular control and timing to achieve optimal performance. In addition, the repetitive nature of throwing can easily lead to fatigue that will disrupt both the kinematics and kinetics. These components are the basis for understanding the pathophysiology of throwing injuries and will be discussed in more detail throughout this chapter.

Due to the complexity of the topic, we will incorporate both basic science and clinical principles to represent the full spectrum of understanding. The role of proper mechanics is very important and often difficult to master; therefore, both normal and abnormal throwing biomechanics will be covered in detail. In addition, the stress of throwing, even with proper kinematics, will cause structural adaptations to both the bone and soft tissues. These adaptations are often the key in both preventing and treating throwing athletes. Therefore, upper extremity structural adaptations will be discussed. Lastly, we will tie all of this information together to gain a more complex understanding of the clinical presentation of several common injuries that occur in throwing athletes.

Mechanics of the Overhead Motion: What Makes the Ball Go?

The overhead throwing motion is developed and regulated through a sequentially coordinated and task-specific kinetic chain of force development and a sequentially activated kinematic chain of body positions and motions [12]. The kinematics of the baseball throw have been well described and may be broken down into phases [13–15]. The most widely accepted descriptions of the phases of throwing include the wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through [15]. These descriptions portray how muscles can move the individual segments, demonstrate the temporal sequence of the motions, and describe the joint angles achieved. The shoulder has been shown to obtain between 160 and 185° of maximal external rotation and 14° of maximal horizontal adduction during the cocking phase, while humeral abduction reaches 90–95° at ball release during arm acceleration [14].

The kinetics have also been described. Moderate anterior shear (380 N) and compressive forces (660 N) occur during arm cocking with internal rotation and horizontal adduction torque reaching up to 90 and 110 Nm, respectively [14]. The forces and torques enable the high internal rotation velocity of approximately 7000° per second to occur during the arm acceleration phase. Consequentially, high posterior shear, inferior shear, and compressive forces occur (310–1090 N) as the body attempts to decelerate the arm [14]. These forces and motions are applied to all of the body segments to allow their summation, regulation, and transfer throughout the segments to result in the performance of the task of throwing. The muscle activation sequencing to produce these kinematics and kinetics demonstrates a proximal-to-distal activation to optimize efficiency [5, 16–19]. In the early phases of throwing (wind-up and stride phases), scapular muscle activity (serratus anterior and upper trapezius) commences prior to larger global shoulder muscle activity (deltoid and pectoralis major) [17, 20]. As the throwing motion progresses from the stride phase to the arm cocking phase, the rotator cuff muscles, specifically the supraspinatus and infraspinatus, have a large amount of activity primarily to align the humeral head with the glenoid [20]. The high activity expands to the remaining rotator cuff muscles during the cocking phase in order to maintain concavity compression and to resist distraction [21, 22]. The cocking phase is also characterized by moderate to high concentric and eccentric activity in larger muscles such as the anterior deltoid, pectoralis major, latissimus dorsi, teres major, biceps brachii, and triceps brachii activity [22]. All of these muscles continue to work both concentrically and eccentrically throughout the remainder of the throwing phases in order to resist unnecessary translations, maintain proper positioning, and direct the ball to its target. The term "kinetic chain" is used collectively to describe the mechanical linkages. Using these definitions and terminology allows a unifying concept to understand the overall mechanics.

An effective athletic kinetic chain is characterized by three components [23]: (1) optimized anatomy in all segments, (2) optimized physiology (muscle flexibility and strength and well-developed, efficient, task-specific, motor patterns for muscle activation), and (3) optimized mechanics (sequential generation of forces appropriately distributed across motions that result in the desired athletic function).

The kinetic chain has several functions: (1) It uses integrated programs of muscle activation to temporarily link multiple body segments into one functional segment (e.g., the back leg in cocking stance and push-off, the arm in long-axis rotation prior to ball release or ball impact) to decrease the degrees of freedom in the entire motion [13, 24, 25], (2) it provides a stable proximal base for distal arm mobility, (3) it maximizes force development in the large muscles of the core and transferring it to the hand [13, 26, 27], (4) it produces interactive moments at distal joints that develop more force and energy than the joint itself could develop and decrease the magnitude of the applied loads at the distal joint [5, 14–17, 28], and (5) it generates torques that decrease deceleration forces [14–16, 29, 30].

Multiple studies have clearly established the basic roles of the kinetic chain, both in baseball and tennis [5, 15, 17, 26, 28, 31–35]. Each body part has specific roles in the entire motion [13]. The feet are contact points with the ground and allow maximum ground reaction force for proximal stability and force generation. The legs and core are the mass for the stable base and the engine for the largest amount of force generation. The scapula must move in specific motions to provide a stable base for muscle activation and congruent ball and socket kinematics. During the initiation of throwing, the scapula is positioned in 40° of internal rotation in the plane of the scapula with slight anterior tilt [36]. As the phases progress, posterior tilt occurs until peaking at maximal humeral external rotation which then transitions to anterior tilt at ball release. Scapular external rotation occurs with maximal horizontal abduction which is likely why the highest serratus anterior activity is seen during the cocking phase [20, 36]. At ball release, the scapula begins in slight upward rotation but reaches a maximum of 40° upward rotation at humeral external rotation [36]. The high amount of lower trapezius activity coincides not as a prime mover of upward rotation but instead as a control for deceleration [22]. The shoulder is the funnel for force regulation and transmission and the fulcrum for stability during the rapid motion of the arm. The arm and hand is the rapidly moving delivery mechanism of the force to the ball or racquet.

To achieve its role in kinetic chain function, the shoulder must develop precise ball and socket kinematics to create maximum concavity compression [21] that optimizes functional stability throughout the entire range of rapid motion. Static restraints include the ligaments (at end ranges of motion) and the limited ball and socket anatomy of the humerus and glenoid. These static constraints must be limited to allow for the wide range of motions. Most of the constraints are dynamic, allowing wide ranges of motion but still conferring functional stability throughout the motions. Requirements for functional stability include optimum alignment of the humerus and glenoid within ±30° angulation [30], co-contraction and compression force couples of the rotator cuff and shoulder muscles [20, 37], a stable scapular base [38], adequate balanced rotational range of motion [39–41], and labral integrity to act as a washer, allowing "best fit" of the humerus into the glenoid [42].

Tasks performed in baseball and tennis occur as a result of the summation of speed principle which states that in order to maximize the speed at the distal end of a linked system, the movement should start with the proximal segments (the hips and core) and progress to the distal segments (shoulder, elbow, wrist) [16]. Each segment in this linked system can influence motions of its adjacent segments. For example, during a baseball pitch, stability of the back and stride legs allow rotation of the trunk which in turn allows for maximal throwing arm external rotation. The stable lower extremity serves as a platform for trunk and upper extremity motion where the amount of trunk rotation is proportionate to the amount of arm motion which can occur. Variations in motor control and physical fitness components such as strength, flexibility, or muscle endurance can affect the efficiency and effectiveness of all segments of the linked system [24, 25, 43].

Efficient mechanics can be improved by decreasing the possible degrees of freedom (DOF) throughout the entire motion [24, 25, 44, 45]. There are 244 possible DOF in the body from the foot to the hand [24]. Most models of maximum efficiency in body motions find that limiting DOF to about 6–8 maximizes the total force output and minimizes effort and load [45]. The DOF can be limited by coordinated muscle activation coupling, called integrative complexes, that constrain and couple positions and motions so that several segments move as one [44]. Examples include the back leg stance position in baseball cocking, where the body is stabilized over the planted leg [13], and the long axis rotation motion in baseball or tennis, where shoulder internal rotation, a minimally moving elbow, and forearm pronation allow the hand to rotate around the long axis from shoulder to wrist [34].

The limited number of independent DOF are called nodes and represent key positions and motions in the overhead tasks [13]. These key positions have been correlated with optimum force development and minimal applied loads and can be considered the most efficient methods of coor-

Table 1.1 Baseball nodes and possible consequences

	Node	Normal mechanics	Pathomechanics	Result	To be evaluated
1	Foot position	Directly toward home plate	Open or closed	Increased load on the trunk or shoulder	Hip and/or trunk flexibility and strength
2	Knee motion	Stand tall	Increased knee flexion	Decreased force to arm	Hip and knee strength
3	Hip motion	Facing home plate	Rotation away from home plate	Increased load on shoulder and elbow	Hip and trunk strength
4	Trunk motion	Controlled lordosis	Hyperlordosis and back extension	Increased load on abdominals and “slow arm”	Hip and trunk strength
5	Scapular position	Retraction	Scapular dyskinesis	Increased internal and external impingement with increased load on rotator cuff muscles	Scapular strength and mobility
6	Shoulder/scapular motion	Scapulohumeral rhythm with arm motion (scapular retraction/humeral horizontal abduction/humeral external rotation)	Hyperangulation of the humerus in relation to the glenoid	Increased load on the anterior shoulder with potential internal impingement	Scapular and shoulder flexibility and strength
7	Elbow position	High elbow (above 90° abduction)	Dropped elbow (below 90° abduction)	Increased valgus load on elbow	Scapular position and strength, trunk and hip flexibility and strength
8	Hand position	On top of the ball	Under or on side of the ball	Increased valgus load on the elbow	Shoulder and elbow position

dinating kinetic chain activation. There may be multiple individual variations in other parts of the kinetic chain, but these are the most basic and the ones required to be present in all motions. The baseball pitching motion can be evaluated by analyzing a set of eight progressive positions and motions (Table 1.1) [32]. These include trunk control over the back leg, hand in pronation “on top of the ball” in cocking, front leg directly toward home plate, control of lumbar lordosis in acceleration, hips facing home plate, arm cocking (scapular retraction/arm horizontal abduction/shoulder external rotation to maintain cocked arm in the scapular plane, “high” elbow above shoulder, and long axis rotation) coupled shoulder internal rotation/forearm pronation, at ball release [5, 13, 15, 17, 28, 31, 46]. The tennis serve motion can be evaluated by analyzing a set of eight “nodes” or positions and motions that are correlated with optimum biomechanics (Table 1.2) [13]. These include optimum foot placement, adequate knee flexion in cocking progressing to knee extension at ball impact, hip/trunk counter rotation away from the court in cocking, back hip tilt downward in cocking, hip/trunk rotation with a separation around 30°, coupled scapular retraction/arm rotation to achieve cocking in the scapular plane, back leg to front leg motion to create a “shoulder over shoulder” motion at ball impact, and long axis rotation into ball impact and follow-through [13, 23, 48]. These nodes can be evaluated by visual observation or by video recording and analysis. Tennis-specific pathomechanics with detailed descriptions of the deleterious motions are listed in Table 1.2.

Adequate performance of the kinetic chain requires optimum anatomy and physiology. Optimum anatomy must be present in all of the joints in the kinetic chain. Joint injury (such as sprained ankles, unresolved knee injury or stiffness, hip tightness, or back injury) can have deleterious effects for core stability, force production, interactive moment production, and arm position [23, 43]. Optimum physiology requires adequate

Table 1.2 Tennis nodes and possible consequences

	Node	Normal mechanics	Pathomechanics	Result	To be evaluated
1	Foot position	In line, foot back	Foot forward	Increased load on trunk or shoulder	Hip and/or trunk flexibility and strength
2	Knee motion	Knee flexion greater than 15°	Decreased knee flexion less than 15°	Increased load on the anterior shoulder and medial elbow	Hip and knee strength
3	Hip motion	Counterrotation with posterior hip tilt	No hip rotation or tilt	Increased load on shoulder and trunk; inability to push through increasing load on abdominals	Hip and trunk flexion flexibility and strength
4	Trunk motion	Controlled lordosis; X-angle ~30°	Hyperlordosis and back extension; X-angle <30° (hypo), X-angle >30° (hyper)	Increased load on abdominals and "slow arm"; Increased load on the anterior shoulder	Hip, trunk, and shoulder flexibility
5	Scapular position	Retraction	Scapular dyskinesis	Increased internal and external impingement with increased load on rotator cuff muscles	Scapular strength and mobility
6	Shoulder/ scapular motion	Scapulohumeral rhythm with arm motion (scapular retraction/ humeral horizontal abduction/humeral external rotation)	Hyperangulation of the humerus in relation to the glenoid	Increase load on the anterior shoulder with potential internal impingement	Scapular and shoulder strength and flexibility
7	Shoulder over shoulder	Back shoulder moving up and through the ball at impact and then down into follow-through	Back shoulder staying level	Increased load on abdominals	Front hip strength and flexibility, back hip weakness
8	Long-axis rotation	Shoulder internal rotation/forearm pronation	Decreased shoulder internal rotation	Increased load on medial elbow	Glenohumeral rotation

X-angle = measurement of hip/trunk separation angle, the angle between a horizontal line between the anterior aspect of both acromions and the horizontal line between both ASIS when viewed from above first described by McLean and Andrisani [151]

Note: Numbers 1–6 occur prior to the acceleration phase of the service motion, while numbers 7–8 occur after ball impact

muscle strength, flexibility, and endurance throughout the kinetic chain. It also requires proper muscle activation patterns for core stability, force development, integrative complexes, joint stabilization, and segment deceleration [23]. The optimized anatomy can then be acted upon by the optimized physiology to create task-specific mechanics to achieve the kinematics and kinetics that produce the desired result of optimal performance in throwing or hitting the ball and create the lowest possible risk of injury.

Abnormal Biomechanics Caused by Structural and Neuromuscular Adaptations

Due to the large repetitive stress of throwing that was described previously, several tissues go through structural and neuromuscular adaptations. These adaptations are different for each tissue type, location, and function. Ultimately, these adaptations cause abnormal pitching biomechanics, which will increase the stress on tissues. This will cause a downward spiral effect, which leads to further tissue adaptations and additional alterations in pitching biomechanics. The combination and continual progression will ultimately lead to shoulder or elbow injuries, which commonly require surgical intervention. In this section, we will cover each of the adaptations that occur due to throwing and the effect they have on pitching biomechanics.

Range of Motion

The most common adaptation that is seen clinically in throwers is a shift in the arc of shoulder motion bilaterally. Throwers often present with a decrease in glenohumeral internal rotation (IR) and a concurrent increase in glenohumeral external rotation (ER) on the throwing arm compared to the nonthrowing arm [49–58] (Fig. 1.2). Wilk et al. [41] has developed the total motion concept which adds IR and ER together to calculate the total arc range on each side. Wilk et al. [41] states that if the *total* motion is equal bilaterally regardless of the shift in motion pattern, then the clinician should not be concerned. When total motion is equal bilaterally, it has been suggested that the shift in the arc of motion is only caused by a bony adaptation called humeral retroversion. However, if there is a loss of total motion on the throwing side, there is usually a soft tissue tightness present which may be reversible with treatment. Recently, this has been supported demonstrating that baseball players with a loss of total motion of 5° or more had a higher rate of shoulder injury [59, 60]. In addition to the total motion concept, there has been much research investigating glenohumeral internal rotation deficits (GIRD). This is a term that has been developed to describe the loss of IR on the throwing arm [52]. There are several hypotheses for the cause of GIRD; however, evidence is still lacking to fully understand the specific tissue adaptations. The three main hypotheses are humeral retroversion, posterior rotator cuff tightness, and posterior capsule tightness/thickness. Each of these tissue adaptations will be discussed in detail in upcoming sections. Regardless of the source of GIRD, it was demonstrated that baseball players with a GIRD of 20° or more were two times more likely to be injured [59].

Bone

The bone is a tissue that is known to have adaptable properties to mechanical load [61]. As such, throwing causes several bony adaptations that are important in understanding the throwing athlete. First, humeral retroversion is described as the bony rotation between the proximal and distal ends of the humerus [62] (Fig. 1.3). Traditionally, it is measured with CT or MRI; however, ultrasound has been demonstrated to be as accurate and have much more accessibility [63, 64]. To understand humeral retroversion in throwers, we first need to discuss the developmental process in normal individuals. At birth, the humerus is in an excessively retroverted position [65]. Clinically this equates to increased glenohumeral ER and decreased glenohumeral IR [66]. Throughout normal development, the humerus undergoes a rotation process that decreases the amount of humeral retroversion. It has been shown that 80 % of the normal developmental rotation process is completed by 8 years old and the remaining 20 % extends to 18 years old [65]. Throwing prior to the completion of this normal developmental rotation process seems to diminish or halt the process, thereby creating side to side differences in humeral retroversion. Most throwers will have more humeral retroversion on the throwing side compared to the nonthrowing side. The association between humeral retroversion and injury is still being heavily researched. Initially, it was suggested to be a positive adaptation. Early researchers reasoned that increase retroversion would afford ER without stretching the anterior capsule and would theoretically inhibit tuberosity/glenoid contact in ER (internal impingement) [47]. However, some recent research suggests that baseball players with greater humeral retroversion have a history of elbow injury [67]. Others have found that baseball players with greater humeral retroversion

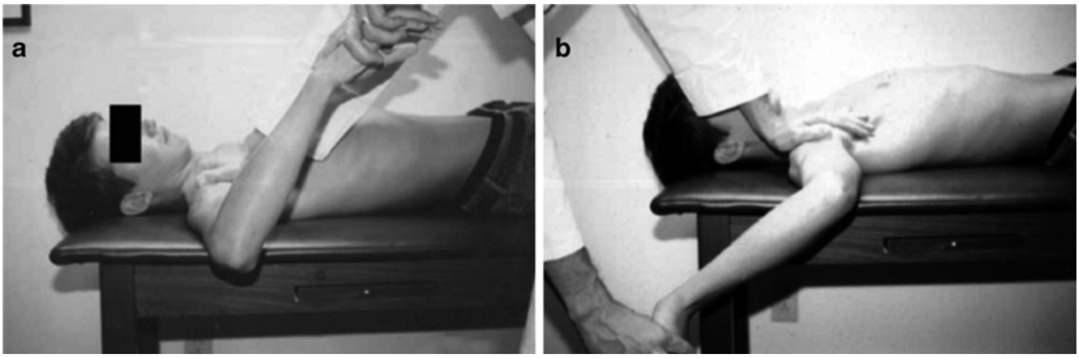

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Fig. 1.2 (**a**) Internal rotation is measured with the patient's shoulder in 90° abduction and the elbow in 90° flexion while the examiner stabilizes the scapula. The end point of internal rotation is taken as the point at which the scapula begins to rotate posteriorly. (**b**) External rotation is also measured while stabilizing the scapula. Note that the neutral position (0°) is that in which the forearm is perpendicular to the patient's body (12 o'clock position in the supine patient) (Reprinted from Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. Arthroscopy. 2003 Apr;19(4):404–20, with permission from Elsevier)

Fig. 1.3 Humeral retroversion (HRT). HRT can be measured as the angle formed by a *line* drawn through the center of the longitudinal axis of the humeral head and neck meeting a *line* drawn along the transverse axis of the condyles, when looking proximal to distal along the humerus (Reprinted from Kinsella SD, Thomas SJ, Huffman GR, Kelly JD 4th. The thrower's shoulder. Orthop Clin North Am. 2014 Jul;45(3):387–401, with permission from Elsevier)

have a thicker posterior capsule of the shoulder [68], which has been implicated in causing shoulder and elbow injuries [52]. Currently, the evidence suggesting that humeral retroversion is either helpful or deleterious to long-term performance is inconclusive.

Next, bone mineral density has been examined bilaterally in baseball players. The results of these studies suggest that the proximal and mid shaft of the humerus on the throwing arm has increased bone mineral density [69, 70]. This finding would be hypothesized based on Wolf's law [61] and the rotational stress of throwing. These results suggest that throughout development, the humerus will adapt in a manner equal to the mechanical loads that are placed on it. This information is important in adolescent throwers due to the open epiphyseal plate at the proximal humerus and the increased propensity for little leaguer's shoulder. Adolescent throwers need to progress in throwing at a much slower pace and also limit the amount of pitches per game and season to allow the bone to adapt at a healthy rate.

The last bony adaptation that can occur in throwers is morphological changes to the bicipital groove. The bicipital groove can develop stenosis from bone ingrowth or spurs [71] (Fig. 1.4). The increased growth of bone within the groove will cause mechanical irritation to the synovial sheath of the biceps tendon and over time cause significant injury. Although bicipital grove stenosis hasn't been documented much in the literature, it likely occurs more frequently in throwing athletes than has previous been suspected.

Soft Tissue

There are many different types of soft tissues in the shoulder that can adapt due to the stress of throwing. Each tissue is different in terms of its

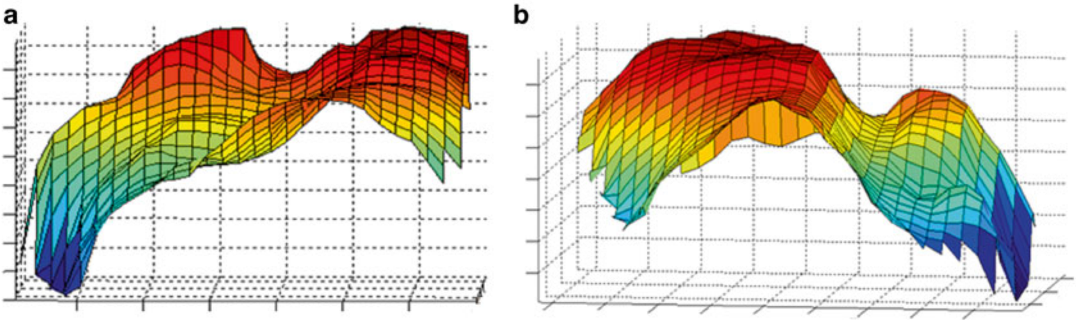

Fig. 1.4 A three-dimensional reconstruction of a bicipital groove viewed from distal to proximal through the bicipital groove. (**a**) This demonstrates the development of bicipital groove stenosis. (**b**) This demonstrates a normal bicipital groove area

composition, structure, and function. In this section, we will discuss all of the different types of soft tissue that are important when treating throwing athletes.

The first category is the joint capsule. The capsule is composed of an inner and outer layer. The inner layer is known as the synovial layer and is responsible for secreting synovial fluid to maintain joint health. The outer layer is composed of dense irregular connective tissue [72]. This layer provides the strength and stabilizing component to the capsule. Throwers can develop adaptations in both the anterior and posterior locations of the joint capsule [68, 73]. During the late cocking and acceleration phase of throwing, large anterior forces occur [14]. Due to these repetitively large forces, it is often thought that the connective tissue of the capsule plastically deforms and is left in a lengthened position. Structurally, the anterior capsule will be unable to center the humeral head on the glenoid at the end ranges of motion. This will allow increased joint translations in the anterior direction, which has been thought to cause secondary impingement or labral injury [74]. During throwing, the athlete will have excessive ER and pain during the late cocking phase of the throw. However, a detailed examination is necessary to discern whether the ER seen during throwing is caused by a combination of glenohumeral, scapular, thoracic, and lumbar motion. It is important to note that anterior capsular laxity does not occur to every throwing athlete. It is often used as a generic diagnosis due to the player having excessive ER and shoulder pain. For example, a recent study by Borsa et al. [75] demonstrated that healthy college throwers did not have side to side differences in anterior translation. This suggests that when this increased anterior humeral translation does occur, it is likely pathologic and may require surgical intervention.

Next, the posterior capsule also undergoes structural adaptations; however, these adaptations are much different than the anterior capsule. When examining pitching kinetics, research has shown that during the deceleration phase, the distraction force is on average 1.5 times body weight [14]. Typically, during the deceleration and follow-through phase, the posterior rotator cuff muscles and scapular stabilizers can absorb the energy [76]. However, throughout a game, these muscles will likely fatigue, thereby reducing the amount of energy that can be absorbed [77]. In this situation, the shoulder will continue to internally rotate to the end range, which will place the remaining force on the posterior capsule. According to Wolf's law [61], the posterior capsule may adapt to the increased stress by hypertrophying. It has been hypothesized that the posterior capsule will ultimately become thick and fibrotic with repetitive throwing, which will create noncompliant tissue and limit glenohumeral IR. Thomas et al. [68] has measured this thickness with ultrasound and found that the throwing shoulder's posterior capsule is thicker compared to the nonthrowing shoulder and the thickness correlates with the loss of glenohumeral IR. In addition, several cadaver studies have shown that a tight posterior capsule will shift the center of the humeral head in a posterior-superior direction during the late cocking phase of the throw [78, 79]. A posterior-superior shift of the humeral head has been demonstrated to cause internal impingement and place increased stress at the insertion of the long head of the biceps tendon at the superior labrum [52] (Fig. 1.5). It is expected that the posterior capsule thickens due to throwing; however, it is currently unknown when this adaptation becomes excessive and problematic.

The next category of soft tissue that is a concern with throwers is muscle/tendon units. There are several muscle/tendon units that develop similar adaptations at the shoulder girdle. The muscles that will be discussed include the posterior rotator cuff (infraspinatus and teres minor), pectoralis minor, triceps brachii, latissimus dorsi, and the teres major.

First, the infraspinatus and teres minor are the two muscles that comprise the posterior rotator cuff. As stated previously, these two small muscles attempt to repetitively absorb a large amount of the 1.5 times body weight force that occurs during the deceleration phase of the throw [14]. To absorb energy, muscles function eccentrically which entails a forceful breaking of the myosin and actin bonds [80]. Several studies have found that repetitive eccentric contractions of the muscle cause significant damage, often called delayed-onset muscle soreness (DOMS) [81–83]. Several studies have also identified that repetitive eccentric contractions cause an increase in passive stiffness and reduced range of motion that peaks at 24 h and typically takes 4–5 days to return to baseline [84, 85]. It is hypothesized that this clinical presentation is caused by damaging of the sarcoplasmic reticulum, which releases excessive calcium [84]. This has been demonstrated in throwers following a simulated game and is characterized by a decrease in glenohumeral IR immediately following the game [86]. Recently, it has been shown that the loss of IR is still present up to 3 days following pitching [87]. This physiologic phenomenon of muscle would not be a concern if throwing did not occur until after the muscle tissue returned to a normal state. However, most throwers initiate throwing before the muscle tissue returns to normal. Over time, the posterior rotator cuff muscles may develop excessive tightness. The hypothesis is that the immediate loss of glenohumeral IR following throwing will still be present before the next bout of throwing, thereby adding to the total loss of motion. This can continue to occur over the season leading to excessive tightness, characterized by a loss of glenohumeral IR. Posterior rotator cuff tightness is thought to be problematic and is hypothesized that it will alter normal throwing biomechanics [52]. During normal throwing, the

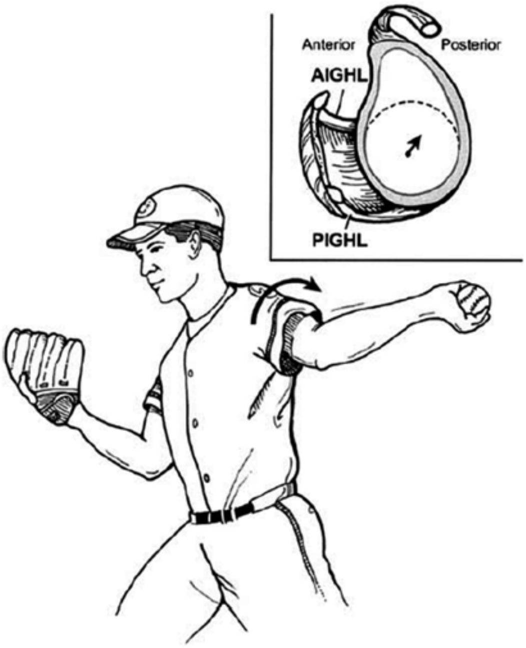

Fig. 1.5 In abduction and external rotation (late cocking), the posterior band of the IGHL is bowstrung beneath the humeral head, causing a posterosuperior shift in the glenohumeral rotation point. Also in late cocking, the biceps vector shifts posteriorly and twists at its base, maximizing peel-back forces. As a result of the tight postero-inferior capsule, this pitcher shows classic derangements of pitching mechanics: hyperexternal rotation, hyperhorizontal abduction (out of the scapular plane), dropped elbow, and premature trunk rotation (Reprinted from Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. Arthroscopy. 2003 Apr;19(4): 404–20, with permission from Elsevier)