4 Why Is the Athlete in Your Office? Making the Right Diagnosis in the Disabled Throwing Shoulder

John M. Tokish and W. Ben Kibler

Introduction

The disabled overhead athlete remains one of the most challenging patient populations for the clinician surgeon to treat. There are many reasons for this. To begin with, presenting symptoms are often varied and may include shoulder pain, mechanical symptoms, a sense of looseness, or loss of speed or control. The patient's history is often one of insidious onset, with complaints that are only reproduced while in the act of throwing, and, as such, very difficult to reproduce in an orthopedist's office setting. In addition, the physical examination can be confusing and challenging. Contributing factors to the clinical presentation are not localized to the shoulder but may be identified in many areas of the kinetic chain. In addition, very few shoulder examination tests are sensitive and specific enough to result in high levels of diagnostic accuracy. While in many patients the clinician can compare the injured to the normal side, the throwing athlete has a number of normal variable adaptations that include increased external rotation, decreased internal rotation, altered scapular position, adaptive laxity, and periscapular muscle atrophy. Unfortunately, imaging is often misleading as well. "Pathologic" findings such as superior labral abnormalities and rotator cuff tendinosis or partial tears are often present in the normal thrower, making it challenging to differentiate between normal adaptation and abnormal pathologic changes. Finally operative decision making remains more art than science. Overtreatment may address the pathology but leave an athlete unable to throw. Any surgical intervention with subsequent rehabilitation will take a toll on the kinetic chain, and significant periods away from training the kinetic chain can, in itself, endanger the thrower. Thus, the clinician must be prepared to invest the time and comprehensive team approach to accurately diagnose these athletes and to understand the individual delicate nature that results in returning them to throw. Once an accurate diagnosis is obtained, it must be applied to the individual athlete to achieve an optimal result.

Value on the Front End

Much effort is currently being made to identify, quantitate, and improve the value associated with the outcomes of treatment of medical conditions. Outcomes are typically defined as how the patient did after an intervention and may be termed "value on the back end" of the treatment process.

J. M. Tokish
Mayo Clinic, Department of Orthopedic Surgery, Phoenix, AZ, USA

W. B. Kibler (✉)
Shoulder Center of Kentucky, Lexington Clinic, Lexington, KY, USA

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There has not been the same amount of effort related to improving the process for making the diagnosis, the "value on the front end" on which the treatment is based.

Most physicians treating symptomatic throwing athletes feel that patients come to their office to get treated for a specific anatomic injury such as a rotator cuff tear, a labral injury, or instability that can be described with an ICD-10 code. The traditional diagnostic process is designed to discover the anatomic injury. When the anatomic diagnosis is established, the content and timing of the treatment can be formulated. This relatively straightforward approach has not been shown to consistently result in comprehensive and accurate diagnoses and effective treatment. Examples can be given for labral injury [1, 2], impingement [3, 4], rotator cuff disease [5, 6], acromioclavicular joint injury [7], clavicle fractures [8], and instability [9]. This has led to efforts to develop a more effective diagnostic process.

The Institute of Medicine (IOM) has recognized the central importance of the diagnosis in health care. In September 2015, the IOM produced the latest report in its highly regarded Quality Chasm Series, titled *Improving Diagnosis in Health Care* [10]. The report documented troubling deficiencies in the effectiveness of developing the diagnosis in all health-care disciplines. Some of the summary findings included the following:

- "Delivery of health care has proceeded for decades with a blind spot – the failure to effectively determine the diagnosis."
- The diagnostic process can be improved, but it will require a re-envisioning of the entire process.

Central to this re-envisioning is a broader definition of the diagnosis and an understanding of the multiple patient factors that may be included in the diagnosis. A more comprehensive definition of diagnosis is "that body of information, collected through the process of evaluating the patient's health problem, that determines the content and timing of the treatment of the health problem" [10]. The patient's health problem frequently consists of more than a discrete anatomic injury. Many clinical problems in overhead athletes result from a process of injury and may involve multiple local and distant deficits. The diagnosis also encompasses the patient's experience with the problem, his or her limitations with the problem, and the expectations of recovery from the problem.

A survey of patients presenting with shoulder pain revealed that 83% related their concern to a problem of lack of function, not a specific injury [11]. Their expectations were that they wished to have this dysfunction returned to function. Function is the outcome that is assessed by most outcome measures. Therefore, function and dysfunction should be the predominant factors in the diagnosis.

Physical function is the ability to complete a specific task. For most overhead athletes, function involves accurately, forcefully, and repetitively placing the arm and hand (and frequently an object in the hand) in a position to optimally throw, hit, support, push, or pull. Physical function has been characterized as anatomy, acted upon by physiology, to produce mechanics. Dysfunction, or the alteration of function, involves pathoanatomy but also frequently involves pathophysiology and pathomechanics. These deficits must be evaluated in the diagnostic process.

It has also been demonstrated that patient-specific factors may play a substantial role in the success of treatment and determination of outcomes. They are individualized, are "brought" to the injury by the patient, and should be included in the evaluation. Multiple factors including depression, catastrophization, and job status/satisfaction have been shown to affect treatment and outcomes [6, 12–18]. Questionnaires have been developed to assess these factors [19–22].

Based on these current thoughts, a model can be developed that guides the diagnostic process and subsequent treatment (Fig. 4.1). The patient's presenting problem consists of clinical symptoms (pain, instability, click/pop, trouble sleeping, decreased motion) and patient dysfunction (inability to throw/serve, inability to push/pull,

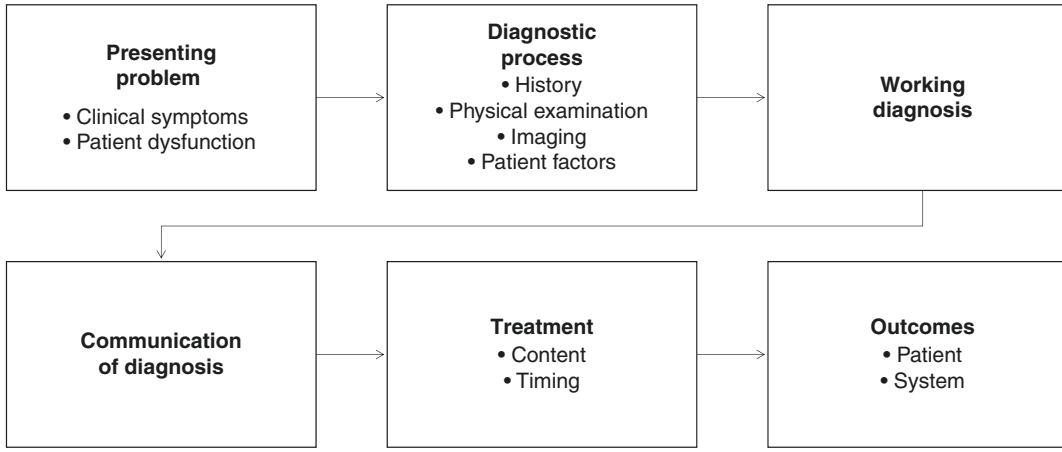

Fig. 4.1 Diagnostic process model

decreased ball velocity/location). The diagnostic process should include the history and the local and distant clinical exam to include anatomical injury (rotator cuff, labral, ligamentous), physiological deficits (muscle flexibility, strength, balance), and biomechanical alterations (joint range of motion, changes in throwing/serving motion). Imaging should be used when indicated and is designed to be confirmative, only infrequently totally diagnostic. Patient-specific factors can be assessed at initial evaluation and help to highlight these issues which may need to be developed.

Several points can be made regarding the applicability of the model to orthopedics and shoulder surgery. First, it is sequential, starting with the patient experiencing some type of alteration of his or her normal functional status. Second, it emphasizes the key role for comprehensive information gathering from multiple sources to develop the diagnosis to be more than an International Classification of Diseases, Tenth Revision code. Third, it emphasizes the involvement of the patient in determining treatment after the diagnosis is made. Fourth, the treatment includes content and timing of the interventions. Finally, the treatment results in outcomes, which the IOM report describes as patient outcomes (observed or measured by clinicians, reported by patients) and system outcomes (quality, cost, safety, efficiency, public confidence in the system). In this model, there is a linear, almost cause-and-effect relation between the diagnosis and the outcome. The implications from this model are, even though much effort and many resources are being expended to determine the outcomes of treatment, the "value on the back end," as much effort should be placed into improving the diagnostic process, to develop the "value on the front end" that can guide more effective treatments.

This model can also demonstrate how diagnostic errors can occur. Diagnostic errors may be defined as "the failure to develop the information required to establish an accurate and timely explanation of the patient's health problem, and failure to meaningfully communicate the information to the patient" [10]. The information must be accurate (not differing from the actual patient problem, imprecise, or incomplete) and timely (not delaying the correct treatment). It also must be communicated to the patient in understandable terms so that the patient can participate in the determination of the treatment plan.

There are demonstrated deficiencies in the diagnostic process and the resulting diagnoses in shoulder surgery. In general, they often result in imprecise and incomplete information. They often fail to identify the actual anatomic lesion and the associated physiological and biomechanical alterations, fail to include patient-reported factors and expectations, do not adequately define what functional loss exists, and are inconsistent

Table 4.1 Information that is important but often not included in diagnoses related to overhead athletes

Diagnosis	Omitted information
Labral injury	Glenohumeral internal rotation deficit (GIRD) Scapular dyskinesis Kinetic chain deficits
Impingement	Rotator cuff disease Labral injury Instability Biceps tendonitis Adhesive capsulitis Patient-specific factors
Rotator cuff injury	Labral injury Altered shoulder rotation Scapular dyskinesis Postural deficits Patient-specific factors
Acromioclavicular (AC) joint injury	Anterior/posterior AC joint laxity Rotary AC joint laxity Scapular dyskinesis
Clavicle fracture	Distal fragment anterior rotation Scapular dyskinesis
Scapular dysfunction	Weakness: Lower trapezius/serratus anterior Tightness: Pectoralis minor/upper trapezius/latissimus dorsi Core weakness and/or instability Patient-specific factors
Medial elbow injury	GIRD Scapular dyskinesis Kinetic chain deficits
Lateral elbow injury	Posterior shoulder weakness

in guiding treatment, and they only infrequently are associated with predictability of outcomes. There is also anecdotal but widely believed evidence of overuse of imaging in the diagnostic process and overdiagnosis of many shoulder problems [23]. Most frequently for overhead athletes, the error will result in an imprecise or incomplete diagnosis (Table 4.1). This can alter or delay the treatment.

In summary, the overhead athlete is in your office because he or she is concerned about an alteration of function, a dysfunction, and they wish to have the function restored. The dysfunction has components of pathoanatomy, pathophysiology, and pathomechanics and can be affected by individualized patient-specific factors. The complete and accurate diagnosis includes pertinent information from all of these areas and will be communicated to the athlete to create a treatment protocol.

Information can be organized as the 5 As [24]:

- Accuracy: All anatomic, physiological, and biomechanical alterations that accompany the health problem should be evaluated and categorized.
- Assessment: The process should include patient-specific factors and expectations and meaningful communication to ascertain patient acceptance and involvement.
- Agreement: The process should result in high interrater reliability for the process and the content of the evaluation.
- Applicability: The process should result in reliable guidance for the content and timing of all the aspects of the comprehensive treatment plan.
- Accountability: The information should be able to reasonably relate to predictions of outcome.

As doctors and clinicians continue to search for methods to improve the quality, safety, efficacy, and value of treatment, devising better surgical techniques or more precise measurements of outcomes will not necessarily be of maximal benefit unless equal attention is placed on improving the diagnosis on which the techniques and subsequent measurements depend.

Understanding the Context of the Disabled Throwing Shoulder

One of the most challenging aspects to treating the disabled throwing shoulder (DTS) is that it is, in many respects, the final common pathway of an intricate series of events beginning in the core, moving through the kinetic chain, and resulting in the release of a ball moving at a tremendous speed. Dysfunction in any one of these events will affect all downstream chain events. If one is to understand the DTS, one must also understand each step that transfers input energy to the shoulder

during throwing and the shoulder's role in transferring output energy to the final parts of the chain. Further, the clinician must understand whether the dysfunctional event is anatomic, physiologic, or biomechanic. If there is anatomic structural damage, it is unlikely that rehabilitation will solve the issue, and if it is physiologic, rehabilitation may be the mainstay of treatment. Therapists, coaches, and surgeons have differing backgrounds and areas of expertise, and are not generally trained in the fine points of recognizing pathology across disciplines. Thus the clinician must learn to speak other disciplines' languages and employ a team of experts from across specialties to address the complexities of the DTS. A basic understanding of the framework of the kinetic chain is a good place to begin.

Role of the Kinetic Chain

The thrown ball is the result of a sequential and coordinated kinetic chain of force development requiring a specific set of body positions and motions [25, 26]. The kinetic chain has several functions [27]: (1) using integrated programs of muscle activation to temporarily link multiple body segments into one functional segment to decrease the degrees of freedom in the entire motion [28, 29]; (2) providing a stable proximal base for distal arm mobility; (3) maximizing force development in the large muscles of the core and transferring it to the hand [30, 31]; (4) producing 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 [26, 32–35]; and (5) producing torques that decrease deceleration forces [26, 36, 37].

While biomechanically technical, these functions have real clinical implications. One mathematical model showed that a 20% reduction in trunk kinetic energy resulted in 70% more mass in the distal segments to maintain the same energy at ball impact [25]. An additional study in tennis players showed that failure to adequately flex the knees in the cocking phase of serving resulted in a 17% increase in shoulder load and a 23% increase in elbow valgus load when velocities were maintained [38]. Other examples correlate decreased hip range of motion associating with shoulder injury and poor throwing mechanics [39].

Thus if one is to understand the disabled throwing shoulder, one must understand the "abled" throwing shoulder, which in turn requires a thorough understanding of the shoulder's proper place within the kinetic chain. While no comprehensive "ideal" evaluation system has been established, advances have been made in this area. Recently, Myers et al. [40] reported a validated method of observational analysis in tennis players. Players with improved flexibility and power demonstrated superior mechanics during the tennis serve, and there was good consistency among raters in their objective evaluation of the serve.

History Considerations in the Disabled Throwing Shoulder

Ultimately, the answer to the question, "why is this athlete in your office," is a simple one: he or she can't throw. A proper understanding of why this is the case is the cornerstone of all treatment and begins with a thorough and individualized history. There is a communication gap that exists between patient and clinician and even between clinicians of different specialties. A patient may seek an understanding of why "it hurts when I throw." The surgeon may speak of a partial thickness tear of the supraspinatus, the therapist may diagnose tightness of the posterior capsule, and the pitching coach may address this as failure to correctly get to the top of the slot. All may have a portion of the truth, but the effective clinician must be able to understand all of these perspectives and their languages and ultimately communicate back to the patient the answer of why they are in your office.

The Chief Complaint

The patient with a chief complaint of "I can't throw" should first be asked, "why not?" The answer to this question is the first critical step in

Table 4.2 Pain-related DTS: questions and considerations

History question	Clinician consideration
Did the pain start with one single event or insidious?	Single: suggests anatomic structural damage Insidious: suggests overuse
Where exactly is the pain when you get it?	Top of shoulder: acromioclavicular joint Greater tuberosity: rotator cuff In the back: internal impingement, labral pathology, posterior shoulder tightness In the front: biceps pathology, scapular dyskinesis
When do you get it?	Acceleration: internal impingement, cuff Follow-through: biceps, posterior shoulder tightness
Onset: Is it immediate or only with prolonged use?	Immediate: structural abnormality Prolonged use: overuse, physiologic overload, chain issues
What helps it?	Stretching: posterior shoulder tightness Strengthening/thorough warmup: dyskinesis, muscle imbalance

formulating the ultimate diagnosis, as it can create an early differential diagnosis to guide the rest of the history and physical examination. It is patient centered, meaning that the answer to this first question individualizes the remainder of the clinical encounter, workup, and ultimate treatment plan. It is also efficient, as it focuses specifically on the patient's complaint, and avoids the pitfalls of a generalized "one size fits all" approach. It, however, can be quite varied and complex. Answers such as pain, clicking, a loss of velocity, a loss of ball control, a sense of fatigue, numbness or deadness, or even the sense that they can't "get into the right slot" are all common patient perspectives to explain their inability to effectively throw. The history can then be guided to specifically address the original source, progression, and response to treatments of this complaint. If pain is the athlete's perception for why he or she can't throw, the history should focus on finding the source of this pain. Table 4.2 provides guidance on historical questions when an athlete's DTS is related to pain.

Clicking or popping is a common complaint by a disabled thrower. It is important to differentiate between clicking that is symptomatic and that which is just present, but not painful or mechanical. In the former, mechanical clicking generally represents a structural abnormality, and one's suspicion should gravitate toward labral pathology, loose bodies, or chondral defects. Painless and nonmechanical clicking is common and is often due to subacromial crepitance. This is often temporary and can be treated with rehabilitation and reassurance.

Numbness or deadness often leads the clinician to consider neurologic or vascular sources. This is an important part of the workup of these patients, as thoracic outlet syndrome is a well-recognized source of disability in throwers [41–43]. This suspicion may take a clinician down a different algorithm toward unique physical examination findings, imaging workup, and even specialist consultation and thus is an excellent example of why the original question of the patients' perspective on "why" they can't throw is so critical. It is important to note, however, that a chief complaint of numbness or loss of control can be due to abnormalities within the kinetic chain and shoulder. Shoulder instability, labral tears, and muscle weakness are also common sources of this complaint, and thus a complaint by the athlete of numbness or deadness is not an automatic referral to a thoracic outlet or spine specialist.

Finally, athletes who can't throw due to loss of velocity or control can be some of the most difficult to sort out. This sensation can be due to defects in the kinetic chain, structural abnormalities, or biomechanical alterations in form. This set of complaints often requires the sports medicine physician to rule out structural or anatomic abnormalities, a therapist to rule out kinetic chain weaknesses, and the pitching coach to rule out biomechanical maladaptations.

Clinical Course and Progression of Care

Once the chief complaint is understood, and the clinician has an initial differential in mind, the clinical course of the complaint from its incep-

tion to the present is obtained. Responses to treatment, such as periods of rest, anti-inflammatories, or steroid injections, even if temporary, are important for diagnostic as well as therapeutic considerations. Time courses are also critical. With the pressure to perform, even at the youth and high school levels, there is often an urgency to treat the disabled throwing shoulder. Thus patients and their parents often will present for a surgical evaluation after "failing physical therapy" over the course of a few weeks. It is incumbent upon the clinician to trace the history of present illness thoroughly to ensure that conservative treatments that have been prescribed have been appropriately applied.

Current Status and "Degree of Disability"

It is important to understand the current status of the patient. An in-season condition that is being played through will likely be managed differently than an off-season injury that results in complete disability. This requires an understanding of the patient's competitive goals and where they are in their season or career. It is also important to understand their access to resources, such as physical therapy, coaching, and medical care.

The final aspect to the current status of the problem is the *degree of disability* incurred by the athlete from their condition. This can vary from minimal annoyance with high-level sports to complete disability with activities of daily living. Understanding where the patient is on this spectrum greatly aids in guiding how aggressive the diagnostic workup is and how invasive the treatment plan should be. It is important to note that an accurate assessment of the degree of disability may require communication with the athletic trainer or physical therapist, because some athletes may attempt to "play through" injuries that render them ineffective and put themselves in danger of further injury. These are sometimes difficult decisions for an athlete to make, and often a trainer's input is valuable in defining the degree of disability.

Past Medical History and Review of Systems

Although athletes are among the healthiest patients in our population, questions about past medical history should not be neglected. These include questions about medications, allergies, and congenital or other medical problems. Finding out that a swimmer with shoulder pain has Ehlers-Danlos syndrome might not only point to multidirectional instability (MDI) as a diagnosis but will undoubtedly influence the treatment of such a shoulder. Although often negative, a review of systems and queries regarding past medical history can avoid missing key aspects affecting the diagnosis and eventual treatment of the overhead athlete.

At the completion of a well-structured history, the clinician should have a fairly strong initial clinical suspicion of "why the patient is in your office." With this in mind, the physical examination can be guided to strengthen or refute these suspicions on the way to an accurate clinical diagnosis.

Physical Examination Considerations in the Disabled Throwing Shoulder

A comprehensive evaluation program is necessary to evaluate the thrower, both in terms of injury potential and understanding the patterns of alteration in injury. Just as the throw itself begins with the lower extremities and the core, so too should the examination of the disabled throwing shoulder. This will be covered in more depth in Chap. 5, but a brief discussion can illustrate some common and key principles in the evaluation.

A proper functioning core is critical to successful throwing. Deficiencies in the core often result in overloading of the shoulder and can lead to injury. This is especially true in adolescent and preadolescent athletes who often have underdeveloped posterior chain musculature (gluteals, hamstrings, erector spinae). This aspect of the core can be evaluated with a single leg squat (Fig. 4.2) and has been shown to be deficient in a

Fig. 4.2 Single leg squat. This image shows the importance of a stable squat, with no collapse or lean. (**a**) Performance in front of a mirror can provide biofeedback to the patient to improve performance. (**b**) As the athlete progresses, perturbations can be added to add an additional challenge to core stability during the maneuver

high percentage of adolescent athletes [44]. Other defects of the proximal kinetic chain can have detrimental effects on the shoulder [45]. One study of NCAA athletes has demonstrated that poor performance on functional movement screening and Y-balance tests (assessments of core stability) correlated with shoulder injury and shoulder surgery [46]. Thus an evaluation of core strength and functional stability should be a part of the evaluation of every patient with a disabled throwing shoulder.

Scapular Considerations

The upper extremity evaluation of the disabled throwing shoulder must begin with the scapula. The scapula forms the stable fulcrum from which the arm can achieve the key positions necessary to successfully throw a ball with velocity and control, and deficits or dyskinesis of the scapula may result in altered performance and increased injury risk. The normal mechanics of scapular motion in the throwing shoulder are scapular retraction, upward rotation, posterior tilt, and balanced rotation [27]. The dysfunctional scapula often demonstrates deviations from this even in the resting position, but the changes can be subtle. In an effort to aid the clinician in an accurate and comprehensive evaluation for scapular dyskinesis, a consensus meeting was established [47], and a standardized approach to clinical observation was developed [48, 49]. The testing protocol begins with an evaluation of inflexibilities (pectoralis minor and humeral rotation deficits), and the resting position of the scapula is noted [50, 51]. Tightness of the pectoralis minor can be estimated by asking the patient to stand with their back against the wall and measuring the distance from the wall to the coracoid on each side. A difference greater than 3 cm is considered positive for pec minor tightness [27]. The dynamic motion of the scapula is evaluated with the arms moved into forward flexion and descent. Medial scapular prominence is noted as dyskinesis. If positive and provocative, the examiner performs corrective maneuvers to determine if these maneuvers alter the symptoms. One test is the scapular assistance test**.** This test is performed while the patient attempts to raise their arm overhead. The examiner depresses the upper medial border of the scapula while he or she pushes the inferior border laterally to assist in upward rotation and posterior tilt. This test can decrease external impingement symptoms [52]. The scapular retraction test depresses the medial border of the scapula along its course and can increase rotator

cuff strength and decrease internal impingement symptoms in the setting of labral injury [53, 54].

The role of the scapula in the disabled throwing shoulder was originally defined by Burkhart et al. [55] and refined by Kibler [27], 10 years later. Originally referred to as a SICK (*S*capular malposition, *I*nferior medial border prominence, *C*oracoid pain and malposition, and dys*K*inesis of scapular movement) scapula, much has been learned about adaptation and pathologic changes of scapular mechanics. The principles of tightness of the pectoralis minor and weakness of the lower trapezius and serratus anterior have stood the test of time and remain cornerstones in the treatment of the scapular component of the disabled throwing shoulder. Adaptations do exist, however, and scapular dyskinesis can be found in normal asymptomatic athletes [56, 57]. Thus the scapular examination must be taken in context of the total picture. Correction of symptoms with assistive maneuvers is suggestive of the clinical relevance of the dyskinesis to the clinical symptoms.

GH Rotation Deficits

In 2003, Burkhart et al. introduced the concept of GIRD (glenohumeral internal rotation deficits) as a key component of the disabled throwing shoulder [58]. In that paper, the authors described "symptomatic GIRD" as a side-to-side difference >25° and proposed that the underlying posterior capsular tightness that caused it was the source of the disabled throwing shoulder. This work did call attention to the alterations, both adaptive and pathologic, that are seen in the disabled throwing shoulder, and much work has been done to refine these initial observations. Tokish et al. reported that up to 40% of asymptomatic professional pitchers displayed GIRD by any of the common definitions and cautioned against using GIRD in a vacuum to diagnose pathology [59]. Several authors have shown that GIRD is, in part, due to adaptive humeral bony retroversion [60, 61], and Kibler has shown that GIRD increases both acutely and over several days after a throwing workout [62]. This "thixotropy" is postulated to result from acute or chronic sarcomere strain leading to stiffness, which can be addressed with stretching. Thus, GIRD should be approached with caution as it can be a normal adaptation but should also be understood as a potential source of disability in the throwing shoulder. A more recent description of pertinent motions in the throwing shoulder includes total rotational range of motion (TROM). This measurement takes into account adaptations in both external and internal rotation and may give early evidence of potentially deleterious alterations in rotation. Most studies show that TROM is symmetric in throwers and servers but should not exceed 186° as an absolute number. A 5° asymmetry in TROM has been shown to be predictive of increased injury risk [63]. In order to consistently measure these motions, a disciplined approach should be employed. The patient should be laid supine with the scapula supported. A goniometer should be used, and the arm should be rotated only until the scapula demonstrates initial movement. Players demonstrate changes in their measured motions over the course of a game and season [64, 65], and the "curve of change" or the ability to return to baseline may be the most important measurement. Changes that do not resolve with posterior capsule and horizontal adduction stretching and are associated with pain should be carefully watched and treated.

Shoulder-Specific Examination

Once the kinetic chain and appropriate ranges of motion have been considered, the shoulder itself should be examined. Particular attention should be placed on an attempt to reproduce the patient's actual symptoms. As noted, at this point in the workup, the clinician should have a strong suspicion of the differential diagnosis, and we use the physical examination to confirm or refute these suspicions. Thus we employ the physical examination of the disabled throwing shoulder by beginning with a suspected diagnosis first and then perform the associated provocative tests associated with this pathology, which is the opposite of the method commonly taught in medical school and residency. In our experience, this approach is more efficient and more accurate.

Table 4.3 Provocative physical examination tests in the disabled throwing shoulder

Suspected diagnosis	Physical examination "musts"
Internal impingement	Apprehension test for pain, relocation test
Symptomatic posterior tightness	GIRD, cross body adduction deficit with pain
Cuff pathology	Impingement signs of Neer and Hawkins, Jobe's test, resisted external rotation
Superior labral pathology	Active compression test, modified dynamic labral shear test, internal rotation resisted strength test
Instability	Apprehension for reproduction of symptoms, posterior push-pull test for symptomatic posterior instability, symptomatic sulcus sign for multidirectional instability
Biceps tendonitis/ partial tearing	Active compression test, biceps groove tenderness, speed's test

A list of these diagnoses and their recommended confirmatory tests are included in Table 4.3, which begins with a potential diagnosis and then tests it with physical examination findings.

It should be noted that the purpose of these provocative maneuvers is to reproduce the patient's symptoms as exactly as possible. When tests of a particular differential are positive and the others are negative, this is strong evidence that the diagnosis is correct. Unfortunately, this is often not the case, as there is commonly overlap and coexistent pathologies present in the shoulder. In addition, some throwers only display symptoms during throwing. In such cases, observing the athlete throwing or communication with the athlete's coach or trainer may shed clarity on the exact positions of provocation.

Imaging

While a detailed description of the specific imaging findings in the throwing shoulder is beyond the scope of this chapter, there are a few important concepts that will help the physician to use imaging to enhance their ability to determine why the athlete is in their office.

X-ray evaluation and advanced imaging are critical components of the disabled throwing shoulder. As in most cases, standard radiographic imaging begins with a shoulder X-ray series and in many cases is all that is necessary. It is important to remember that more than 99% of competitive throwers do not get paid to throw and are often young and playing multiple sports. Standard X-ray evaluation may show the hallmarks of Little Leaguer's Shoulder which includes proximal humeral physeal widening or metaphyseal bony changes. This finding is often confirmatory in an adolescent or preadolescent, and no further study may be required. Even when the X-rays are negative, the clinical examination is often sufficient for treatment, and should not prompt an automatic MRI.

Nevertheless, the MRI has become the cornerstone in the evaluation of the throwing shoulder, and while it can be an incredibly helpful tool in confirming a diagnosis [66], there are some important points to discuss in this regard. The first is that the MRI should be used primarily as a confirmatory and supportive tool, not as the cornerstone of diagnosis. Miniaci et al. [67] demonstrated that 79% of asymptomatic professional baseball players demonstrate abnormal signal in their cuff and labrum. This has been confirmed in little league players as well, where over half of asymptomatic players demonstrate abnormalities on MRI [68]. Overreliance on an MRI can be detrimental to a correct diagnosis, resulting in the overtreatment of adaptive change interpreted to be pathologic. It is therefore critical that clinicians who care for the throwing athlete be proficient in reading the MRI themselves as it is best used in combination with knowledge obtained in the history and physical examination. Advanced imaging can be helpful in confirming the diagnosis and as a preoperative planning tool. The conventional axial view allows good tangential visualization of the posterior inferior labrum, while the oblique axial view allows better tangential visualization of the posterior labrum.

Providing Value on the Back End to the Disabled Throwing Shoulder

One area that has been deficient, especially in the treatment of the throwing shoulder, is measurement of specific and accurate outcomes after treat-

ment. This may be described as a search for "value on the back end" or how well do the treatments return the athlete to their desired level of function? Tibone, for example, reported on the results of acromioplasty in an elite throwing population [69]. Despite excellent improvements in pain relief, only 4 of 18 pitchers returned to throw at their preinjury status. This early report called out the challenges of measuring outcomes in the throwing athlete. Traditional self-reported outcome tools have consistently demonstrated a "ceiling effect" in throwers, which limited the ability to document incremental improvements at the higher end of function [70]. In response, outcome scores specific to throwing populations have been developed. Alberta et al. debuted the Kerlan-Jobe Orthopaedic Clinic overhead athlete's score (KJOC) [71], in a population of throwing athletes. Domb et al. [72] applied it to throwers who underwent ulnar collateral ligament (UCL) reconstruction. In that paper they found that the KJOC score was the most sensitive score for detecting subtle changes in performance in the throwing athlete. Neuman et al. reported similar findings in a population of throwers who underwent shoulder surgery and concluded that the KJOC score provided a more stringent assessment of overhead athletes' function than the ASES score [73].

Sauers et al. have developed the "Functional Arm Scale for Throwers" (FAST). Their approach was to employ a disablement model to more fully evaluate the health-care quality of life of the thrower. The FAST score evaluates the "whole-person" health-care disablement model which takes into account emotional and social factors in addition to limitations in throwing [74]. A subsequent article by the same authors demonstrated that the FAST score is a reliable, valid, and responsive scale for measuring patient-reported health-care outcomes in throwing athletes with injury [75] and has been found to be an effective measure of disability in a population of female softball pitchers.

Thus, just as the throwing shoulder is unique from a diagnostic perspective, the evaluation of outcomes in these patients requires specialized attention to their individual requirements. We would recommend the KJOC and FAST scores as routine tools in the evaluation of outcomes in this specialized population.

Conclusions

The disabled throwing shoulder is a complex diagnostic dilemma. Keys to ultimate success include understanding the athlete's chief complaint, formulating an early differential diagnosis, and using the physical examination and imaging to confirm the correct source of the patient's disability. The evaluation of treatment outcomes requires special attention to the specific specialized activities and scores required of this population. Thus the disabled throwing shoulder requires meticulous attention from presentation, through diagnosis and treatment, with an in-depth evaluation of outcomes. The patient is in our office for a reason. It is incumbent upon the clinician to determine that reason and to assist in returning them to throw.

References

1. Kibler WB, Sciascia A. Current practice for the diagnosis of a Superior Labral Anterior to Posterior (SLAP) lesion: systematic review and physician survey. Arthroscopy. 2015;31(12):2456–69.
2. Hegedus EJ, Goode AP, Cook CE, Michener L, Myer CA, Myer DM, et al. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta-analysis of individual tests. Br J Sports Med. 2012;46:964–78.
3. Ketola S, Lehtinen J, Rousi T, Nissinen M, Huhtala H, Konttinen YT, et al. No evidence of long-term benefits of arthroscopic acromioplasty in the treatment of shoulder impingement syndrome: five-year results of a randomised controlled trial. Bone Joint Res. 2013;2(7):132–9.
4. Alqunaee M, Galvin R, Fahey T. Diagnostic accuracy of clinical tests for subacromial impingement syndrome: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2012;93:229–36.
5. Unruh KP, Kuhn JE, Sanders R, An Q, Baumgarten KM, Bishop JY, et al. The duration of symptoms does not correlate with rotator cuff tear severity or other patient-related features: a cross-sectional study of patients with atraumatic, full-thickness rotator cuff tears. J Shoulder Elb Surg. 2014;23(7):1052–8.
6. Wylie JD, Suter T, Potter MQ, Granger EK, Tashjian RZ. Mental health has a stronger association with patient-reported shoulder pain and function than tear size in patients with full-thickness rotator cuff tears. J Bone Joint Surg Am. 2016;98:251–6.
7. Cho CH, Hwang I, Seo JS, Choi CH, Ko SH, Park HB, et al. Reliability of the classification and treatment of dislocations of the acromioclavicular joint. J Shoulder Elb Surg. 2014;23:665–70.

8. Jones GL, Bishop JY, Lewis B, Pedroza AD, MOON Shoulder Group. Intraobserver and interobserver agreement in the classification and treatment of midshaft clavicle fractures. Am J Sports Med. 2014;42(5):1176–81.
9. Kuhn JE. A new classification system for shoulder instability. Br J Sports Med. 2010;44:341–6.
10. Balogh EP, Miller BT, Ball JR. Improving diagnosis in healthcare. Washington: National Academies Press; 2015.
11. Smith-Forbes EV, Moore-Reed SD, Westgate PM, Kibler WB, Uhl TL. Descriptive analysis of common functional limitations identified by patients with shoulder pain. J Sport Rehabil. 2015;24:179–88.
12. Pavlin JD, Sullivan MJL, Freund P, Roesen K. Catastrophizing: a risk factor for postsurgical pain. Clin J Pain. 2005;21(1):83–90.
13. Quartana PJ, Campbell CM, Edwards RR. Pain catastrophizing: a critical review. Expert Rev Neurother. 2009;9(5):745–58.
14. Das De S, Vranceanu AM, Ring DC. Contribution of kinesophobia and catastrophic thinking to upper-extremity-specific disability. J Bone Joint Surg Am. 2013;95(1):76–81.
15. Moradi A, Mellema JJ, Oflazoglu K, Isakov A, Ring D, Vranceanu AM. The relationship between catastrophic thinking and hand diagram areas. J Hand Surg Am. 2015;40(12):2440–6.
16. Baranoff J, Hanrahan SJ, Connor JP. The roles of acceptance and catastrophizing in rehabilitation following anterior cruciate ligament reconstruction. J Sci Med Sport. 2015;18:250–4.
17. Menendez ME, Baker DK, Oladeji LO, Fryberger CT, McGwin G, Ponce BA. Psychological distress is associated with greater perceived disability and pain in patients presenting to a shoulder clinic. J Bone Joint Surg Am. 2015;97:1999–2003.
18. Cho CH, Jung SW, Park JY, Song KS, Yu KI. Is shoulder pain for three months or longer correlated with depression, anxiety, and sleep disturbance? J Shoulder Elb Surg. 2013;22:222–8.
19. Sullivan MJL, Bishop S, Pivik J. The pain catastrophizing scale: development and validation. Psychol Assess. 1995;7:524–32.
20. Walton DM, Wideman TH, Sullivan MJL. A Rasch analysis of the pain catastrophizing scale supports its use as an interval-level measure. Clin J Pain. 2013;29:499–506.
21. Ivarsson A, Tranaeus U, Johnson U, Stenling A. Negative psychological responses of injury and rehabilitation adherence effects on return to play in competitive athletes: a systematic review and meta-analysis. Open Access J Sports Med. 2017;8:27–32.
22. Freynhagen R, Baron R, Gockel U, Tolle TR. painDETECT: a new screening questionnaire to identify neuropathic components in patients with back pain. Curr Med Res Opin. 2006;22(10):1911–20.
23. Weber SC, Martin DF, Seiler JG III, Harrast JJ. Incidence rates, complications, and outcomes as reported by American Board of Orthopedic Surgery part II candidates. Am J Sports Med. 2012;40:1538.
24. Kibler WB. Value on the front end: making the effective diagnosis for optimal treatment. Arthroscopy. 2017;33(2):493–5.
25. Kibler WB. Biomechanical analysis of the shoulder during tennis activities. Clin Sports Med. 1995;14:79–85.
26. Putnam CA. Sequential motions of body segments in striking and throwing skills: description and explanations. J Biomech. 1993;26:125–35.
27. Kibler WB, Kuhn JE, Wilk KE, Sciascia AD, Moore SD, Laudner KG, et al. The disabled throwing shoulder - Spectrum of pathology: 10 year update. Arthroscopy. 2013;29(1):141–61.
28. Davids K, Glazier PS, Araujo D, Bartlett R. Movement systems as dynamical systems: the functional role of variability and its implications for sports medicine. Sports Med. 2003;33(4):245–60.
29. Linter DM, Noonan T, Kibler WB. Injury patterns and biomechanics of the athlete's shoulder. Clin Sports Med. 2008;27(4):527–51.
30. Toyoshima S, Miyashita M. Force-velocity relation in throwing. Res Q. 1973;44(1):86–95.
31. Toyoshima S, Hoshikawa T, Miyashita M. Contributions of body parts to throwing performance. In: Nelson RC, Morehouse CA, editors. Biomechanics IV. Baltimore: University Park Press; 1974. p. 169–74.
32. Hirashima M, Kadota H, Sakurai S, Kudo K, Ohtsuki T. Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. J Sports Sci. 2002;20:301–10.
33. Hirashima M, Kudo K, Watarai K, Ohtsuki T. Control of 3D limb dynamics in unconstrained overarm throws of different speeds performed by skilled baseball players. J Neurophysiol. 2007;97(1):680–91.
34. Hirashima M, Yamane K, Nakamura Y, Ohtsuki T. Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. J Biomech. 2008;41:2874–83.
35. Hirashima M, Ohtsuki T. Exploring the mechanism of skilled overarm throwing. Exerc Sport Sci Rev. 2008;36(4):205–11.
36. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med. 1995;23(2):233–9.
37. Fleisig GS, Barrentine SW, Escamilla RF, Andrews JR. Biomechanics of overhand throwing with implications for injuries. Sports Med. 1996;21:421–37.
38. Elliott B, Fleisig G, Nicholls R, Escamillia R. Technique effects on upper limb loading in the tennis serve. J Sci Med Sport. 2003;6(1):76–87.
39. Robb AJ, Fleisig GS, Wilk KE, Macrina L, Bolt B, Pajaczkowski J. Passive ranges of motion of the hips and their relationship with pitching biomechanics and ball velocity in professional baseball pitchers. Am J Sports Med. 2010;38(12):2487–93.

40. Myers NL, Kibler WB, Lamborn L, Smith BJ, English T, Jacobs C, et al. Reliability and validity of a biomechanically based analysis method for the tennis serve. Int J Sports Phys Ther. Jun. 2017;12(3):437–49.
41. Bottros MM, AuBuchon JD, McLaughlin LN, Altchek DW, Illig KA, Thompson RW. Exercise-enhanced, ultrasound-guided anterior scalene muscle/pectoralis minor muscle blocks can facilitate the diagnosis of neurogenic thoracic outlet syndrome in the high-performance overhead athlete. Am J Sports Med. 2017;45(1):189–94.
42. Ciampi P, Agnoletto M, Scotti C, Ballis R, Gerevini S, Peretti GM, et al. Thoracic outlet syndrome in the overhead athlete: a report of 2 cases of subclavius posticus muscle. Clin J Sports Med. 2017;27(3):e29–31.
43. Shutze W, Richardson B, Shutze R, Tran K, Dao A, Ogola GO, et al. Midterm and long-term follow-up in competitive athletes undergoing thoracic outlet decompression for neurogenic thoracic outlet syndrome. J Vasc Surg. 2017;66(6):1798–805.
44. Beckett M, Hannon M, Ropiak C, Gerona C, Mohr K, Limpisvasti O. Clinical assessment of scapula and hip joint function in preadolescent and adolescent baseball players. Am J Sports Med. 2014;42(10):2502–9.
45. Laudner K, Wong R, Onuki T, Lynall R, Meister K. The relationship between clinically measured hip rotational motion and shoulder biomechanics during the pitching motion. J Sci Med Sport. 2015;18(5):581–4.
46. Chimera NJ, Smith CA, Warren M. Injury history, sex, and performance on the functional movement screen and Y balance test. J Ath Train. 2015;50(5):475–85.
47. Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the "scapula summit". Br J Sports Med. 2013;47:877–85.
48. McClure PW, Tate AR, Kareha S, Irwin D, Zlupko E. A clinical method for identifying scapular dyskinesis: Part 1: Reliability. J Athl Train. 2009;44(2):160–4.
49. Tate AR, McClure PW, Kareha S, Irwin D, Barbe MF. A clinical method for identifying scapular dyskinesis: Part 2: Validity. J Athl Train. 2009;44(2):165–73.
50. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther. 2005;35(4):227–38.
51. Kibler WB, Sciascia AD, Thomas SJ. Glenohumeral internal rotation deficit: pathogenesis and response to acute throwing. Sports Med Arthrosc Rev. 2012;20(1):34–8.
52. Kibler WB. The role of the scapula in athletic function. Am J Sports Med. 1998;26:325–37.
53. Kibler WB, Sciascia AD, Dome DC. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. Am J Sports Med. 2006;34(10):1643–7.
54. Tate AR, McClure P, Kareha S, Irwin D. Effect of the scapula reposition test on shoulder impingement symptoms and elevation strength in overhead athletes. J Orthop Sports Phys Ther. 2008;38(1):4–11.
55. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. Arthroscopy. 2003;19(6):641–61.
56. Madsen PH, Bak K, Jensen S, Welters U. Training induces scapular dyskinesis in pain-free competitive swimmers: a reliability and observational study. Clin J Sport Med. 2011;21(2):109–13.
57. Plummer HA, Sum JC, Pozzi F, Varghese R, Michener LA. Observational scapular dyskinesis: known-groups validity in patients with and without shoulder pain. J Orthop Sports Phys Ther. 2017;47(8):530–7.
58. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: Pathoanatomy and biomechanics. Arthroscopy. 2003;19(4):404–20.
59. Tokish JM, Curtin MS, Kim YK, Hawkins RJ, Torry MR. Glenohumeral internal rotation deficit in the asymptomatic professional pitcher and its relationship to humeral retroversion. J Sports Sci Med. 2008;7(1):78–83.
60. Osbahr DC, Cannon DL, Speer KP. Retroversion of the humerus in the throwing shoulder of college baseball pitchers. Am J Sports Med. 2002;30:347–53.
61. Reagan KM, Meister K, Horodyski M, Werner DW, Carruthers C, Wilk KE. Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. Am J Sports Med. 2002;30(3):354–60.
62. Kibler WB, Sciascia AD, Moore SD. An acute throwing episode decreases shoulder internal rotation. Clin Orthop Relat Res. 2012;470:1545–51.
63. Wilk KE, Macrina LC, Fleisig GS, Aune KT, Porterfield RA, Harker P, et al. Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: a prospective study. Am J Sports Med. 2015;43(10):2379–85.
64. Freehill MT, Ebel BG, Archer KR, Bancells RL, Wilckens JH, McFarland EG, et al. Glenohumeral range of motion in major league pitchers: changes over the playing season. Sports Health. 2011;3(1):97–104.
65. Thomas SJ, Swanik KA, Swanik CB, Huxel KC. Glenohumeral rotation and scapular position adaptations after a single high school female sports season. J Athl Train. 2009;44(3):230–7.
66. Lin DJ, Wong TT, Kazam JK. Shoulder injuries in the overhead-throwing athlete: epidemiology, mechanisms of injury, and imaging findings. Radiology. 2018;286(2):370–87.
67. Miniaci A, Mascia AT, Salonen DC, Becker EJ. Magnetic resonance imaging of the shoulder in asymptomatic professional baseball players. Am J Sports Med. 2002;30(1):66–73.
68. Pennock AT, Dwek J, Levy E, Stearns P, Manning J, Dennis MM, et al. Shoulder MRI abnormalities in asymptomatic little league baseball players. Orthop J Sports Med. 2018;6(2):232596711875682.

69. Tibone J, Jobe FW, Kerlan RK, Carter VS, Shields CL, Lombardo SJ, et al. Shoulder impingement syndrome in athletes treated by an anterior acromioplasty. Clin Orthop Relat Res. 1985;198:134–40.
70. Franz JO, McCulloch PC, Kneip CJ, Noble PC, Linter DM. The utility of the KJOC score in professional baseball in the United States. Am J Sports Med. 2013;41(9):2167–73.
71. Alberta FG, ElAttrache NS, Bissell S, Mohr K, Browdy J, Yocum LA, et al. The development and validation of a functional assessment tool for the upper extremity in the overhead athlete. Am J Sports Med. 2010;38(5):903–11.
72. Domb BG, Davis JT, Alberta FG, Mohr KJ, Brooks AG, ElAttrache NS, et al. Clinical follow-up of professional baseball players undergoing ulnar collateral ligament reconstruction using the new Kerlan-Jobe Orthopaedic Clinic overhead athlete shoulder and elbow score (KJOC Score). Am J Sports Med. 2010;38(8):1558–63.
73. Neuman BJ, Boisvert CB, Reiter B, Lawson K, Ciccotti MG, Cohen SB. Results of arthroscopic repair of type II superior labral anterior posterior lesions in overhead athletes: assessment of return to preinjury playing level and satisfaction. Am J Sports Med. 2011;39(9):1883–8.
74. Sauers EL, Bay RC, Snyder Valier AR, Ellery T, Huxel Bliven KC. The Functional Arm Scale for Throwers (FAST)-Part I: The design and development of an upper extremity region-specific and population-specific patient-reported outcome scale for throwing athletes. Orthop J Sports Med. 2017;5(3):2325967117698455.
75. Huxel Bliven KC, Snyder Valier AR, Bay RC, Sauers EL. The functional arm scale for throwers (FAST)-part II: reliability and validity of an upper extremity region-specific and population-specific patient-reported outcome scale for throwing athletes. Orthop J Sports Med. 2017;5(4):232596711770001.