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INJURIES IN OVERHEAD ATHLETES (J DINES AND C CAMP, SECTION EDITORS)

Glenohumeral Internal Rotation Deficit: Prime Suspect or Innocent Bystander?

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Abstract

Purpose of Review Glenohumeral internal rotation deficit (GIRD) is a term used in the literature to describe the physiological adaptation that occurs in the dominant arm of the overhead-throwing athlete. The meaning of this term and the clinical significance and the rationale for its treatment have all been described with some ambiguity within the literature. GIRD as a measurement is multivariate. There is an adaptive bony component in humeral retroversion (HR) and muscular contributions in the form of thixotropy which can confound the capsular component of GIRD. Emerging diagnostic tools such as ultrasound can help differentiate between the bony and soft tissue contributions as well as provide a dynamic assessment in the throwing shoulder. The purpose of this review is to describe and differentiate between anatomical GIRD (aGIRD) and pathological GIRD (pGIRD), discuss the clinical significance of pGIRD and values reported within the literature, and describe its measurement and clinical treatment.

Recent Findings Recent literature has demonstrated that GIRD alone is not associated with injury risk of the upper extremity in the overhead athlete. Although past literature has demonstrated pGIRD as increasing injury risk, other variables such as external rotation (ER) deficit, horizontal adduction deficit, and shoulder flexion deficit have been associated with injury of the upper extremity while GIRD did not. Further, an appreciation for the difference between adaptive GIRD and pathologic GIRD has recently been emphasized to ensure optimal treatment addresses the pathologic portion of GIRD. The recent focus on early treatment approaches to pGIRD may play a role in its diminished risk association.

Summary This review offers the term humeral retroversion (HR) Corrected GIRD as a more clinically sensitive value that may provide the clinician a more precise rationale for the treatment of pGIRD. Currently, diagnostic ultrasound is a reliable and valid method for measuring HR in the overhead-throwing athlete. Future research that validates clinical methods for assessing HR could provide utility for clinical decision-making in the absence of diagnostic ultrasound.

Keywords GIRD · Humeral retroversion · Range of motion · Overhead athlete · Sleeper stretch · Cross-body stretch

Introduction

Literature describing the shoulder characteristics unique to overhead athletes has existed as far back as 1969 [1]. Chandler and Kibler reported a group of elite junior tennis players who demonstrated decreased shoulder internal rotation (IR) and a subsequent increased external rotation (ER) on their dominant (D) side compared to their non-dominant (ND) side (2). In addition, although reported but not described, the total range of motion (TROM =ER + IR) was relatively equal when comparing D side versus ND sides [2]. Overhead throwers, specifically baseball players, have also been described in the literature as having similar shoulder characteristics described above [3–6]. Later on, in the 1990s and early 2000s, others have described these characteristics in baseball, softball, tennis players and swimmers [7–10]. The term glenohumeral internal rotation deficit (GIRD) has been defined as a loss of shoulder IR of the dominant shoulder compared with the non-dominant shoulder in overhead athletes [5, 9]. Others, however, use the term GIRD to describe an internal rotation measurement that describes an association

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with injury or injury risk [11]. The purpose of this review is to identify up to date definition(s) of the term GIRD, describe how it is measured, characterize its meaning in the context in which it is measured, offer a historical perspective in its treatment and provide recent findings in the literature that may influence GIRD's impact on overhead athletes.

How to Measure GIRD

Shoulder range of motion is typically assessed passively in the supine position with the humerus abducted to 90° and elbow flexed to 90°. A bolster is placed under the humerus to prevent movement posterior to the frontal plane (see Fig. 1). Previous studies utilized a bolster to maintain the humerus in the plane of the scapula or more specifically described as 10–12° anterior to the coronal plane [11, 12]. Passive range of motion (PROM) has been measured using standard range of motion procedures using a Jamar goniometer. A leveling bubble attached to the goniometer can be used to maintain a perpendicular stationary arm in relationship to the table [12, 13]. The axis of rotation of the goniometer is placed at the olecranon process, the stationary arm perpendicular to the table and the moving arm along the ulnar shaft in line with the ulnar styloid process at the wrist. Typically, 2 clinicians assess PROM, one that will assess the PROM with the goniometer and the other moving the shoulder into internal rotation (IR) and external rotation (ER). The clinician moving the arm into either ER or IR stabilizes the shoulder manually. Originally stabilization was performed with a downward pressure by the one clinician against the anterior aspect of the humerus [9]. Later research demonstrated that a "C-shaped" hand position in which the clinician's thumb contacts the coracoid process and the fingers wrap around the posterior aspect of the scapula is a more reliable stabilization technique compared with anterior humeral pressure and no stabilization [14]. Subsequent research used similar techniques in range of motion set-up and stabilization techniques [15, 16••]. Measurements are performed on the dominant and non-dominant shoulders. TROM can be calculated for the D and ND sides by adding ER + IR together **(**Fig. 2 **and** Table 1**).**

The goniometric measurement technique described above has consistently shown good intra-observer reliability and modest inter-observer reliability with accuracy up to 5° [18, 19]. In addition, the measurements on overhead-throwing athletes were reported as reliable with intra-tester reliability intraclass correlation coefficients as .81 and .87 [20]. Another study by Kibler reported a high degree of reproducibility with a test-retest reliability of .96 and sensitivity to detection of chance of 3° [21]. Recent studies have used a digital inclinometer to measure range of motion in lieu of the standard goniometric technique described above [22•, 23••]. Comparisons in reliability have been made between the use of a standard Jamar Goniometer and a digital level. Relative reliability was assessed using Intra-tester ICCs and ranged from .91 to .99 with measurements made with a goniometer and the digital level and Inter-tester ICCs ranged from .31 to .95. For comparing a goniometer to a digital inclinometer the Inter-tester ICCs ranged from .71 to .98, but it should be highlighted that ER and IR measurements were 3–5° greater for the digital level compared to the goniometer [24]. A recent 2018 study reported a HALO digital goniometer as a valid and reliable tool for measuring shoulder range of motion in healthy individuals [17••]. The previous two referenced studies indicate that a digital device and a standard goniometer should not be interchanged when measuring one individual's change of motion over time. The authors of this study point out that measurement reliability is improved when range of motion is performed by the same two clinicians throughout the data collection on an individual subject. In addition, the authors of this study advocate 2 clinicians, Jamar goniometer use with bubble level attachment and C-shaped scapular stabilization as the most reliable measuring techniques.

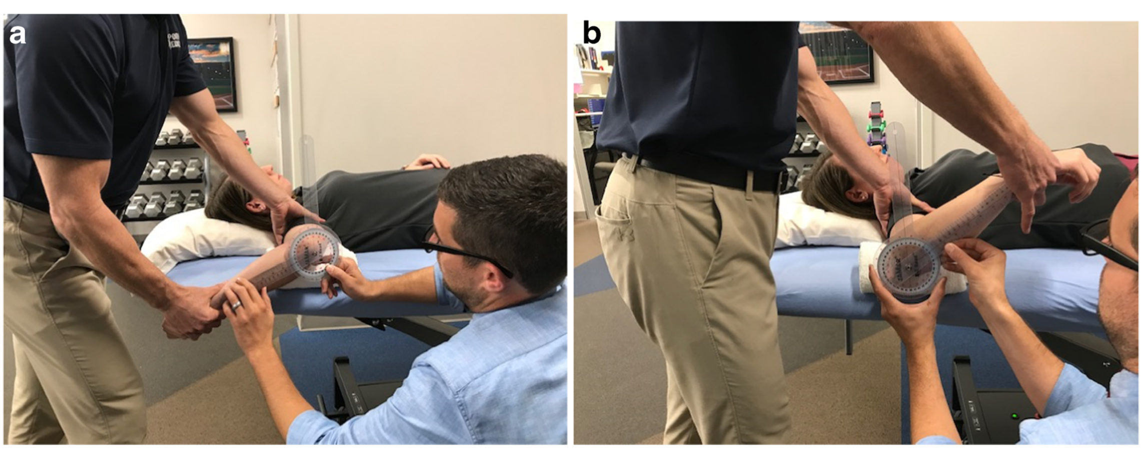

Fig. 1 **a** Shoulder passive external rotation goniometric measurement. **b** Shoulder passive internal rotation goniometric measurement

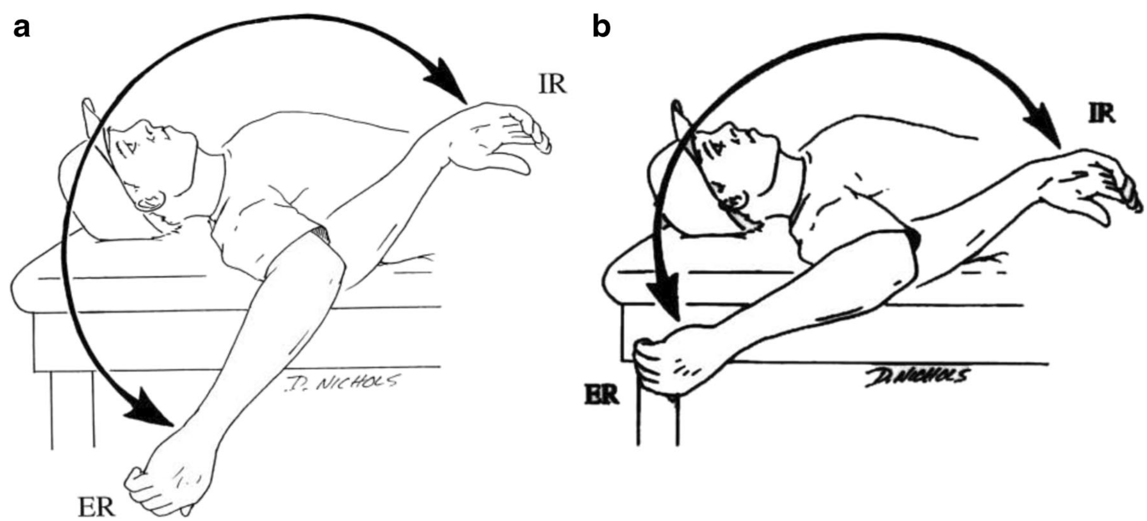

Fig. 2 **a** Dominant side TROM compared to **b** [17]

What Does GIRD Actually Mean?

As previously described above, overhead athletes exhibit a loss of IR and an increase in ER on their D side compared to their ND side as a normal adaptation to the sport that they perform with equal TROM in a side to side comparison [12]. In a study on 372 professional baseball players, ER was an average 7° greater and IR was an average of 7° less in D shoulder versus ND shoulder [25]. Of importance is the fact that this study reported findings on asymptomatic players which underscores the idea that GIRD is a unique characteristic to overhead athletes and not necessarily diagnostic of injury. Myers et al. reported that the D shoulder has 10–15° more ER and 10–15° less IR compared to the ND shoulder which further illustrates symmetry between asymptomatic shoulders [26]. This type of GIRD has been considered a normal adaptation specific for the overhead athletic population and has been referred to as anatomical GIRD (aGIRD) [15]. Pathological GIRD (pGIRD) has been reported as a shoulder deficient in ER to make up for the loss IR on the dominant side ultimately creating TROM asymmetry between the D and ND shoulders [15].

Table 1 GIRD related calculations: considerations for humeral retroversion creating a humeral retroversion adjusted GIRD measurement

Parameter	Calculation
GIRD	Dominant IR − non-dominant IR
ERG	Dominant ER − non-dominant ER
TROM	IR + ER
TROM difference	Dominant TROM − non-dominant TROM
HR difference	Dominant HR − non-dominant HR
HR corrected GIRD	GIRD + HR difference
HR corrected ERG	ERG − HR difference

GIRD glenohumeral internal rotation deficit, *ERG* external rotation gain, *TROM* total range of motion, *HR* humeral retroversion, *IR* internal rotation, *ER* external rotation

Reuther KE, Sheridan S, Thomas SJ (2018) Differentiation of bony and soft-tissue adaptations of the shoulder in professional baseball pitchers. Journal of Shoulder and Elbow Surgery 27:1491–1496 (Table on page 1493 with nomenclature modifications for paper consistency)

In 1991 Verna first described GIRD as pathological in relation to shoulder dysfunction [27]. The numerical value of pGIRD has been inconsistent and evolved throughout the literature. Pathological GIRD has been defined in the literature as (1) GIRD > 25° (2) GIRD > 20° (3) 10% loss of TROM when comparing D side to ND side (4) IR loss that exceeds ER gain on the D side (5) IR loss with a loss of TROM loss and later (6) side to side asymmetry of IR loss greater than 18° [11, 15, 26, 28, 29]. Later studies also reported injuries associated with a pGIRD of 11 and 18° [26, 30]. Specifically in a study by Wilk et al., 18° of GIRD was related to a 1.9 increase in risk for injury. In addition, a 5-degree asymmetry in TROM was reported as being predictive of injury [31]. In 2013, the consensus for pGIRD changed to GIRD > 18° and a TROM > 5° both of which had been reported as predictive of injury but not causative [28]. Due to these inconsistencies, we would not recommend using a single range of motion measurement to signify that GIRD is pathologic. Rather, we recommend that the deficit be placed in the greater context of the overall examination and history of motion measurements.

Reasons for Loss of Internal Rotation

The contributing factors for the loss of IR in overhead athletes have been reported as 1) osseous changes due to humeral retroversion (HR) 2) posterior capsular thickening and 3) muscular adaptations, or thixotropy [12, 28, 29, 32]. Thixotropy has been defined as an increase in muscle stiffness as a result of repetitive strain that can affect joint motion (not related to neurological changes). (37) Osseous changes are the result of humeral retroversion seen in the overhead-throwing athlete. Humeral retroversion (HR) has been reported as a normal variance in overhead throwers and viewed as a contributing component of aGIRD. A 10–12° difference in IR loss and ER gain was reported as non-pathological as long as the TROM of the D and ND sides were equal [11]. A group of healthy baseball players were reported as having greater HR on their D side versus ND side and compared to both control groups' shoulders and once HR accounted for there was no difference in shoulder IR measurements between D and ND sides [33]. Another study reported a positive relationship between HR and shoulder ER and a negative relationship between IR on the dominant arm of a group of college baseball players' D side. In addition, they reported an overall increase of 16° in HR of the D side versus the ND side [34]. A recent 2018 study also reported increased HR on the D side versus ND side in a group of professional baseball pitchers [23••].

Posterior capsular thickening in shoulders of overhead athletes has been purported as being the result of capsular remodeling in response to the dominant side increase in ER [35, 36]. This may result in a loss of D side IR. Burkhart et al. originally stated that the loss of IR in symptomatic shoulders demonstrating pGIRD was the result of posterior-inferior capsular contractures which then resulted in an increase in D side ER [9]. The previous authors also reported the arthroscopic findings of baseball players with Type II SLAP lesions as having significant thickening and scarring of posterior/inferior capsules. Studies using diagnostic ultrasound have provided evidence of posterior capsular thickening of the D side of baseball players [23••, 34]. Both studies reported a positive relationship between HR and posterior capsular thickening.

Muscular adaptations in overhead throwers have been reported as being the result of repetitive eccentric forces applied to the posterior rotator cuff during the follow-through phase of the pitching motion [20]. In particular the acute response to these forces after a bout of throwing results in muscle shortening and subsequent short-term loss of IR ROM peaking between 4 and 18 h [11]. Chronic muscular eccentric loads to the posterior rotator cuff can lead to an overall increased stiffness in the muscles which can affect shoulder IR. This phenomenon has been referred to as thixotropy and it is intimately related to the muscle's exposure history to the eccentric loads during the deceleration phase of throwing [37].

Treatment of GIRD

The clinical treatment of GIRD has involved targeting the effects of either capsular or muscular adaptations or a combination of both. Osseous changes should be identified and understood in terms of their contribution to the overall numerical value of GIRD. Treatment strategies can be more appropriately adjusted knowing the percentage of GIRD associated to bony components. Studies that utilize diagnostic US to measure HR offer an HR corrected GIRD which may provide more sensitive utility when assessing the need to target the treatment of posterior capsule thickness or muscular adaptions [29, 36, 38, 23••.]. Noonan et al. utilized diagnostic US to assess HR and found no differences between baseball players that were injured (shoulder and elbow) and uninjured although there were joint-specific injury differences. Pitchers that sustained a shoulder injury displayed 4° less HR (D Side) compared to uninjured pitchers and pitchers that sustained elbow injuries displayed 5° more HR (D side). Those pitchers with elbow injuries that required UCL reconstruction displayed 4° more HR on the D side [39•]. Thus HR may be protective of the shoulder, but detrimental to the elbow. Future research that establishes the reliability and validity of clinical testing for HR could have a significant impact on the future of appropriate treatment of pGIRD as diagnostic US is not readily available in most clinical settings. To date there are no known published studies (see Fig. 2 and Table 1).

Much of the research on the treatment for GIRD involves targeting posterior capsular thickening and the posterior rotator cuff muscular adaptations in the form of "sleeper stretches" and "cross-body stretches". Early research reported an increase in D side IR and TROM with daily posterior-inferior capsular stretching of a group of high-level tennis players and a decrease in shoulder injuries. Burkhardt et al. also reported the use of daily stretching programs for Major League baseball pitchers as a preventive intervention to maintain GIRD below a 20-degree threshold [28]. The stretches described from this 2003 article include a side-lying "sleeper stretch" (arm at 90° shoulder flexion) and a standing self "cross-body" stretch (no scapular stabilization). Others have described the side-lying sleeper stretch as being modified and performed in varying° of flexion [40, 41]. In 2013, Wilk et al. offered modifications to the sleeper stretch and the cross-body stretch in order to avoid some clinical pitfalls and improve the effects on the targeted tissues. The Sleeper stretch was modified by having the athlete roll posteriorly 20–30° keeping the treated extremity in the scapular plane, providing better scapular stabilization and avoiding any subacromial impingement. In addition, a bolster can be placed underneath the elbow to further increase the stretch in the posterior shoulder (see Fig. 3a). the cross-body stretch was modified by having the patient stabilize their scapula in the side-lying position and bring their own arm into horizontal adduction while their unaffected arm maintains a neutral rotation of the affected arm [12, 42, 43] (see Fig. 3b). These modified stretches have been utilized in a more recent study reporting a significant gain in IR and HA ROM after a 4-week intervention program [22•]. Other evidence suggests scapular stabilization is a superior method for stretching the posterior shoulder structures than without.

Other forms of treatment targeting the posterior capsule and the posterior rotator cuff muscles include stretching of

Fig. 3 **a** Self-modified sleeper stretch. **b** Self cross-body stretch

the patient by way of the clinician. Internal Rotation can be performed with the patient in supine with the arm abducted to 90° and the scapula manually stabilized by the clinician [41]. The clinician can also provide a passive stretch with the addition of contract-relax techniques [12]. The cross-body stretch can also be performed by the clinician with the client in supine where the clinician can manually stabilize the scapula and horizontally adduct the arm while the client maintains neutral rotation with their contralateral arm [12, 43, 44] (see Fig. 4a, b). Other literature depicts alternative (indirect) treatment methods for gaining shoulder IR. These treatment methods include myofascial release, Instrument assisted soft tissue massage (Graston), contralateral SI joint stretching, postural restoration breathing techniques, and alternative methods of posterior shoulder stretching [45••, 46••, 47••, 48••, 49••]. Future research is needed to determine the effectiveness of indirect treatment techniques that affect shoulder ROM. Direct treatments on the joint potentially create more motion in a joint with either anterior or posterior instability. GIRD has been associated with posterior-superior labral tear, partial articular sided rotator cuff tears, and SLAP tears presenting as either anterior or posterior instability or a combination of both [50••]. The challenge with the above-described stretches is that it is unclear whether they are targeting capsular thickening (joint) or muscular adaptations (muscle) or both. The addition of joint mobilization (capsular effects) to the cross-body stretches was reported as clinically relevant compared to cross-body stretching alone and controls but not statistically significant [51]. Multiple studies provide evidence that a formal stretching program targeting the posterior shoulder results in increases in shoulder IR, and either HA or TROM [6, 22•, 41, 52]. The question remains: at what point does GIRD as a measurement require the above mentioned interventions or more simply stated what value is significant enough to treat?

When Does GIRD Require an Intervention?

It is our opinion that that GIRD is best assessed and treated in the context in which the patient is seen. GIRD treated based on an isolated measurement in time presents an incomplete picture of the patient profile. GIRD assessment that is made (1) in the presence of injury, (2) in response to acute loss of IR, (3) throughout a given sports season, and (4) in the context of the player's age and years of throwing provides the context in which to monitor and treat GIRD. Multiple studies report a higher incidence in shoulder and/or elbow injuries in the presence of GIRD [30, 53–56]. In contrast, other studies found no statistically significant correlation between GIRD and shoulder and/or elbow injuries [57, 58, 59•, 60••]. One possible explanation for no correlation between GIRD and injury in more recent studies is the plethora of literature describing the treatment of GIRD in the form of the previously described sleeper and cross-body stretches. Much of the literature aforementioned on GIRD reported as an injury predictor were with organized teams that more than likely have instituted preventive stretching programs to minimize GIRD to below

Fig. 4 Clinician assisted cross body stretch. **a** The clinician Stabilizes the scapula and the patient horizontally adducts and maintains neutral rotation. **b** Clinician maintains scapular stabilization and neutral rotations and performs the passive stretch into horizontal adduction

pathological values. In a recent Meta-Analysis by Keller et al., there was no statistically significant correlation between shoulder range of motion and shoulder or elbow injury in the studies that they pooled. However, results did favor injury in an overhead athlete with GIRD [61••]. Again, the question remains as to whether there is a critical value for pathological GIRD? As described earlier the critical values of pGIRD have evolved over the years from 25 to 20° to a more commonly accepted value of 18°. Another recent meta-analysis attempted to clarify the definition of GIRD in adolescent and adult overhead athlete's assessment and whether there was an increased risk for injury associated with its value. The results indicated that the average GIRD values were greater in injured adult athletes compared to non-injured adult overhead athletes. The value was less between injured and non-injured groups when looking at adolescent overhead athletes [62••]. The authors also suggested a critical value (pGIRD) of 13.8° when combining adults and adolescents. This value is significantly less than the widely accepted value of 18° established in 2013 by Kibler et al. [11] establishing the need for further research to determine more sensitive values of pGIRD with the possible need for age-specific values. Thus, it must be emphasized that a single number is insufficient and should be considered after accounting for HR and thixotropy.

An acute loss of IR ROM in response to bouts of high-intensity throwing has been reported in the literature as previously described by Kibler et al. [11]. A group of professional baseball pitchers demonstrated a loss of 8° IR immediately after pitching and a TROM loss of 9°. In contrast, there was no significant change in ER. The authors also suggested the cause as being an increase in passive muscle tension in response to the eccentric forces imposed on the posterior shoulder during the follow-through phase of pitching [20]. Another recent study reported a reduction in D side IR and an increase in ER and TROM on the dominant side of a group of professional tennis players [63••]. The authors of this article suggest that an intervention facilitating the return to individualized baseline IR values in baseball players is critical in the return to competition. Repeated bouts of unchecked eccentric throwing could contribute to progressive chronic posterior shoulder stiffness in the form of thixotropy potentially creating pathology. The timing of peak loss of IR previously described as between 4 and 18 h is critical in regard to a pitcher's next outing. In professional baseball, starting baseball pitchers typically have a bullpen session 2 days after pitching in a game while relievers may be asked to pitch on successive days and multiple times during a 7-day period. Return to baseline IR values may serve as one of the contributing variables on the player's readiness for return to competition.

Evidence suggests that shoulder IR ROM can be maintained over the course of a professional baseball season. In addition, evidence suggests that previously described treatments offer a means to improve or maintain IR within non-pathological ranges. Over the course of a season, a regular stretching program can be used to maintain IR ROM. Reinold et al. described unpublished 2008 data on a group of 20 professional baseball pitchers who performed a daily stretching program to maintain their ROM. The pitchers performed 3–5 repetitions of stretches with 10-s holds in the directions of shoulder flexion, ER and IR at 90° abduction and horizontal adduction resulting in no change in IR passive ROM over the course of a baseball season [64]. A 2017 study reported no change in GIRD measurements over the course of an entire major league baseball season with the implementation of an in-season ROM maintenance program. The maintenance program included stretching, soft tissue mobilization, joint mobilizations and was individualized based on individualized assessments [16••] GIRD measurements throughout the season may be beneficial by providing a means for monitoring a cumulative increase in GIRD possibly due to increased posterior shoulder stiffness. In the skeletally mature adult baseball player, any changes throughout the season could be correlated to posterior shoulder tightness with HR remaining constant.

Age and number of years of throwing/pitching should be considered when looking at GIRD. A 2014 study by Hibberd et al. reported an increase in both GIRD and HR in healthy overhead athletes when comparing high school athletes (16–18 years old) to younger athletes (< 13 years old). Once HR was accounted for TROM and GIRD remained unchanged across all groups [65]. Consequently, an increase in GIRD seen in a player from youth to high school could be attributed to the progressive bony adaptation of HR seen in overhead athletes and not necessarily from posterior soft tissue tightness. The Johnson Meta-analysis mentioned previously reported lower levels of GIRD when comparing adolescents to adults [62••]. Changes between these age groups may be related to normal physiological adaptations based and age and should be considered when assessing a player's ROM from adolescence to adulthood. Unpublished data from one professional baseball organization was collected over a 7-year period (2011–2018). Individual pitchers measured throughout their career within the organization demonstrated a decrease in shoulder IR (GIRD) and TROM with an increase in horizontal adduction ROM. This organization assessed the ROM at the beginning, middle and end of seasons and performed individualized treatment programs. Further research looking at ROM trends over the course of individual player's careers could help establish possible norms of ROM in pitchers over the course of their careers.

Conclusions

Much of the literature supports the concept of pathological GIRD as being a contributing factor to shoulder or elbow injuries. Treatment strategies within the literature describe effective techniques that improve IR range of motion (reduction in GIRD). The degree in which GIRD becomes pathological remains less clear as values within in the literature provide variability. The extensive treatment strategies within the literature have provided the clinician the ability to reduce pathological GIRD or maintain acceptable levels for an overhead-throwing athlete during a season. Consequently, recent literature has reported GIRD as being less of a predictor of injury than other variables such as ER deficit, TROM deficit, shoulder flexion deficit or horizontal adduction deficit [30, 55, 57, 58, 59•, 60••, 61••]. Future research assessing treatment strategies of other injury-related variables may benefit the clinical care of overhead athletes. The literature also describes the use of diagnostic ultrasound as a method to measure humeral retroversion and its relationship to GIRD in the overhead athlete. Future research looking at methods to assess humeral retroversion clinically may benefit the clinician's assessment of GIRD when diagnostic ultrasound is not readily available. Finally, a new concept of humeral retroversion (HR) corrected GIRD should be explored as past literature has highlighted the relationship between the two concepts via diagnostic ultrasound. Accounting for HR in healthy overhead athletes could help guide clinical decision in whether treatment interventions are necessary.

Compliance with Ethical Standards

Conflict of Interest John Zajac, DPT, and John M Tokish, MD, declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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•• Of major importance

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