©Journal of Sports Science and Medicine (2008) **7**, 78-83
http://www.jssm.org

Research article

Glenohumeral internal rotation deficit in the asymptomatic professional pitcher and its relationship to humeral retroversion

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Abstract
The purpose of this study was to determine if glenohumeral internal rotation deficits (GIRD) exist in an asymptomatic population of professional pitchers, and to assess whether these changes are primarily a bony or soft tissue adaptation. Twenty three, active, asymptomatic professional (Major League Baseball) pitchers volunteered for the study. Clinical measures of glenohumeral ranges of motion, laxity, GIRD, as well as radiographic measures of humeral retroversion were taken by two independent orthopaedic surgeons. Data comparing side to side differences in range of motion, laxity, and humeral retroversion were analyzed for statistical significance using a paired t-test for continuous data and a Chi-squared test for ordinal data, with a significance set at 0.05. Evaluations of statistical correlations between different measurement parameters were accomplished using a Pearson product moment correlation. We hypothesized GIRD will be positively correlated with humeral retroversion (HR) in the pitching arm. All clinical and radiographic measures were made in the field, at spring training, by physicians of both private and institutional based sports medicine practices. For the entire group, significant differences were exhibited for HR, external rotation at 90° and internal rotation at 90°, for dominant vs. non-dominant arms. GIRD of greater than 25° was noted in 10/23 of pitchers. In this group, HR was significantly increased and correlated to GIRD. No such increase or correlation was noted for the non-GIRD group. GIRD is a common finding in asymptomatic professional pitchers, and is related to humeral retroversion. Thus internal rotation deficits should not be used as the sole screening tool to diagnose the disabled throwing shoulder.

Key words: Glenohumeral internal rotation, humeral retroversion, pitcher ROM.

Introduction

It is a well reported that overhead athletes, and specifically baseball pitchers, undergo an increase in external rotation (ER) and a decrease in internal rotation (IR) of their throwing arms (Crockett et al., 2002; King et al., 1969; Meister, 2001; Osbahr et al., 2002; Pieper, 1998; Reagan et al., 2002). Explanations of these changes have included both bony and soft tissue adaptations (Crockett et al., 2002; Kawamura, 1998; Mackiuchi, 1998; Meister, 2001; Osbahr et al., 2002; Pieper, 1998; Reagan et al., 2002). Initially, investigators attributed the change in arc of motion to soft tissue adaptations, including stretching of the anterior capsular structures, with a corresponding tightening of the posterior capsule (Burkhart et al., 2003c; Burkhart et al., 2003a; Myers et al., 2006; Verna, 1991). These observations led many to develop rehabilitation programs that stressed stretching of the posterior capsule and strengthening of the dynamic anterior stabilizers of the throwing shoulder (Burkhart et al., 2003b; Kibler, 1998).

It has also been suggested that bony adaptations may take place in the throwing athlete(Mackiuchi, 1998; Pieper, 1998, Soderlund et al., 1989). In professional team handball players, Pieper (1998) noted that these players demonstrated an increase in humeral retroversion of their throwing arm compared to the non-throwing arm. This finding has been corroborated by several studies in baseball players (Mackiuchi, 1998; Meister, 2001; Myers et al., 2006; Pieper, 1998; Soderlund et al., 1989) and suggests that the pitching arm is subject to mechanical stress that may conscript these bony adaptations (Sabick et al., 2004; 2005). Furthermore, several of these studies have sought to determine if the adaptations in retroversion were related to the changes in glenohumeral range of motion experienced by these athletes. The answer to this question has been controversial, with some authors reporting a statistical correlation (Osbahr et al., 2002; Reagan et al., 2002) while others have shown no relationship (Kawamura S, 1998).

Range of motion changes have also been reported in painful throwing shoulders (Kibler, 1998; Myers et al., 2006; Verna, 1991). One recent theory suggests a primary posterior-inferior capsular contracture as a potential source of the disabled throwing shoulder and that it can be measured by a glenohumeral internal rotation deficit (GIRD) (Burkhart et al., 2003b). Given that changes in internal rotation exist as normal adaptations, however, it is unclear how much GIRD the clinician should accept as normally adaptive vs. what represents clinically significant GIRD. This threshold of clinical significance has been described as: (1) GIRD greater than 25° between dominant and non-dominant arms, (2) IR loss that exceeds ER gain, and (3) IR loss with an overall loss in total arc of motion. These definitions, however, have not been evaluated in a population of active, asymptomatic pitchers.

The purpose of this study, then, was to examine a population of active, asymptomatic professional baseball pitchers for GIRD and determine the relationship between GIRD, and its bony versus soft tissue determinants.

Methods

Institutional Review Board for Human Subjects participation in medical research was granted by the corresponding author's institution. Access to Major League Baseball (MLB) team players was granted by the team's owner, team manager, team head trainer and/or supervising physician(s). All MLB pitchers were then solicited individually for voluntary participation and Informed Consent was obtained on each enrolled pitcher. All measurements took place about half way through the team's official spring training. All pitchers were currently participating in their regular training program, which included posterior capsu-

Received: 10 August 2007 / Accepted: 21 November 2007 / Published (online): 01 March 2008

lar stretching and core strengthening. All pitchers were actively competing and none had any symptoms of soreness or disability that had kept them from participating in spring training.

Range of motion and laxity measurements

All pitchers underwent independent examination of each arm by two independent orthopaedic surgeons (RJH and MSC). Results were recorded as the average between the two measurements. Measurements were discarded for angular discrepancies greater than 10°, ruler differences greater than 10%, or laxity differences exceeding one grade. Glenohumeral range of motion measurements were made using a 360° goniometer according to established techniques (Surgeons, 1965). Specific measurements were made for IR and ER at 0° abduction, IR and ER at 90° abduction, forward elevation, and cross-body adduction measured as the linear distance (centimeters) between the antecubital fossa and the contralateral coracoid process with the arm maximally passively horizontally adducted. Internal rotation measurements at 0° were recorded as the corresponding thoracic vertebral level. In addition to these measurements, glenohumeral laxity with the arm at the side was documented in an anterior, posterior, and inferior direction. For the anterior and posterior directions, laxity was graded in the following way: The patient was placed supine with the scapula stabilized by an assistant. The two physicians (RJH and MSC) performed all independent measurements and results were averaged. The grading system used was grade (1) up the face but short of the glenoid rim; grade (2) up the face to the glenoid rim, partially over the rim (perched); or grade (3) complete dislocation. For inferior laxity testing, the arm was maximally distracted in an inferior direction while the scapula was stabilized by an assistant. A ruler was used to measure the distance in millimeters between the top of the humeral head and the inferior aspect of the acromion.

GIRD Definitions and Measurement

Several definitions of GIRD exist. According to Burkhart et al. (Burkhart et al., 2003b),GIRD is “the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder”. Other definitions include: (1) an internal rotation loss that exceeds the external rotation gain in the dominant arm; (2) a loss of internal rotation with a loss of total arc of motion in the pitching arm; and, (3) a loss of greater than 25° of internal rotation (Burkhart et al., 2003b). While we chose the 3rd definition for our statistical comparisons between groups, as it is the definition that exists in the literature, we did calculate the number of GIRD(s) based on the first two definitions as well. This enabled us to establish the percentage of pitchers who exhibited GIRD under each definition, and using the 3rd definition, allowed us to separate our overall cohort into a GIRD and non-GIRD group for comparisons between groups.

Humeral retroversion radiographic measurement

Humeral retroversion (HR) was measured using the method of Soderlund et. al. (1989). This was accomplished by obtaining a modified axillary radiograph of the dominant (D) and non-dominant (ND) arm of each pitcher in the study. Plain radiography was available on site and exposure was set at 63 kv and 32-40mAs. The patient was placed supine and the shoulder was placed in 90° of flexion and 10° of abduction. A stand was used for arm support, with the forearm horizontal and parallel to the long axis of the body. The X-ray beam was centered over the humeral head through the biceps musculature. The positioning was supervised by one of the authors (JMT) and the quality of the radiograph was also evaluated to ensure that landmarks necessary for retroversion measurement could be identified. Each pitcher underwent this technique for both throwing and non-throwing arms. Three pitchers required a repeat radiograph secondary to improper penetration of the beam. The second radiograph was adequate in all three pitchers. All radiographs were accomplished before the range of motion measurements were obtained for all subjects.

Once the radiographic examinations were completed, the left and right radiographic markers and names of players were covered so that it was not possible to determine identity of a subject or a left from a right arm. Moreover, all radiographic data was obtained by a physician blinded (JMT) to the range of motion data. Each radiograph was then measured by a single author (JMT) for humeral retroversion (HR) using an established and validated technique (Soderlund et al., 1989). Values were recorded, and markings were removed. All radiographs were then shuffled and re-measured on a second occasion (approximately 1 month later) by the same author. Measurements were thrown out if variability exceeded 5°. Once all of the measurements were taken, the range of motion data and radiographic measurements were sent to a single author (MRT) who was blinded to the participants name and limb dominance for tabulation and statistical processing.

Statistical analysis

Data comparing side to side differences in range of motion, laxity, and humeral retroversion were analyzed for statistical significance using a paired t-test for continuous data and a Chi-squared test for ordinal data, with a significance set at 0.05. Evaluations of statistical correlations between different measurement parameters were accomplished using a Pearson product moment correlation. All statistical analyses were accomplished utilizing the SPSS statistical package (SPSS Vers.12, SPSS Inc, Chicago, IL).

We utilized the Cohen’s Kappa (K) statistic as described by Landis and Koch (1977) to determine the inter-rater reliability of the IR and ER measures. Since there are several, our method to calculate the Cohen’s Kappa was to first calculate the *Observed Concordance* (agreement) which equals the matrix diagonal sum divided by n; we then calculated the *Expected Concordance of chance* which equals the diagonal row*column totals divided by n, summed, divided by the total n. We then calculated Cohen’s Kappa by (Observed Concordance - Expected Concordance)/(1-Expected Concordance). Within the scope and limitation of our purpose and according to criteria proposed by Landis and Koch, 1977; a K = 0.40 to 0.59 range was considered moderate inter-rater reliability,

Table 1. Range of motion, laxity, and HR measures between D and ND arms for entire group. Data are means (±1 SD).

Measurement	Dominant	Non-Dominant	Difference	p value
ER at 0 (degrees)	69.8 (27.8)	74.2 (12.3)	-4.4	.49
ER at 90 (degrees)	123.7 (12.8)	10.0 (9.6)	18.7	<.0001*
IR at 0 (degrees)	6.9 (2.5)	5.6 (1.9)	1.3	.07
IR at 90 (degrees)	47.4 (16.7)	65.9 (17.0)	-18.5	.0006*
Elevation (degrees)	164.7 (8.7)	167.9 (7.3)	-3.2	.1882
Cross-body adduction (cm)	10.6 (4.6)	8.7 (4.7)	1.9	.1811
Ant. Laxity (mm)	2.3 (.7)	2.3 (.7)	0	1
Post. Laxity (mm)	2.1 (.65)	2.1 (.75)	0	.8355
Inf. Laxity (mm)	10.9 (2.8)	11.0 (2.2)	-0.1	.9068
Total arc of motion (degrees)	171.6 (16.0)	171.1 (17.0)	0.5	.922
Humeral Retroversion (degrees)	29.7(11.0)	18.5 (9.3)	11.2	.0008*

* Denotes statistical significance at $p < 0.05$.

0.60 to 0.79 substantial, and 0.80 outstanding ({Landis, 1977 #52}).

Results

A complete data set from 23 MLB pitchers (mean age 26.3 ± 4.1 yrs; height 1.88 ± .03 meters, weight 94.3 ± 7.5 kg, 15 right handed pitchers, 8 left handed pitchers) was obtained.

Results of measurements comparing D vs. ND arms for the entire group are summarized in Table 1. There were no significant differences detected between total arc of motion, laxity, ER at 0°, IR at 0°, elevation, or cross body adduction between the D and ND arms. Significant differences were observed for HR, ER and IR at 90°, when comparing D and ND arms. When comparing the entire group, we noted an average increase of 19° in ER at 90° in D vs. ND arms. In addition, there was an average decrease in abducted IR of the D arm by an average of 19°. Measurements of HR revealed that D arms demonstrated an 11° average increase over ND arms.

The presence of GIRD was then determined by the 3 separate and defined methods. Defining significant GIRD as a loss in IR that was greater than the gain in ER, we found GIRD in 10/23 pitchers. Defining significant GIRD as a loss in IR with a loss in total arc of motion, we found it in 8/23 pitchers. Finally, when we defined significant GIRD as a loss of IR of at least 25°, 10/23 pitchers met the criteria.

A comparison of the GIRD and non-GIRD groups can be found in Table 2. Of note, GIRD pitchers showed a significant average increase in HR (15.50 vs. 6.60, p = 0.0297), a 7° elevation increase, an 18° loss in total arc of motion change, and a significant average increase in D arm anterior laxity. No differences were found for HR in ND arms, or any other measure of laxity between groups.

Pearson correlation coefficients are listed for IR and possible bony and soft tissue contributing parameters in Table 3. Of note, there was a significant correlation between HR and IR in the D arm in GIRD pitchers (r^2 = 0.48). No such correlation existed in non-GIRD pitchers (r^2 = 0.03) or in ND arms of either GIRD ($r^2 < 0.001$) or non-GIRD (r^2 = 0.03) pitchers. No strong correlations existed between IR and either of the two methods we used to measure posterior capsular tightness (posterior laxity and cross-body adduction).

Table 3. Selected Pearson's correlations for IR deficits in GIRD and non-GIRD pitchers.

Correlation	GIRD (r^2)	Non-GIRD (r^2)
D IR and D HR	.48*	.03
ND IR and ND HR	<.01	.03
D IR and D post laxity	.04	.05
ND IR and ND post laxity	.03	.13
D IR and D cross-body adduction	.10	<.01
ND IR and ND cross-body adduction	.24	.11

* Denotes statistical significance at $p < 0.05$.

The computed Kappa statistics for IR and ER measures were between 0.74 and 0.63 respectively, offering substantial inter-rater reliability as defined by Landis & Koch (1977).

Discussion

The disabled throwing shoulder continues to be one of the more challenging conditions the shoulder surgeon faces. Recently, it has been suggested that this condition is the result of a primary posterior-inferior capsular contracture (Burkhart et al., 2003a). Diagnosis of this condition has been made by noting a significant difference between IR

Table 2. Comparisons between GIRD and non-GIRD pitchers. Data are means (±1 SD).

Measurement	GIRD	Non-GIRD	Difference	p value
D HR (degrees)	33.6 (8.6)	25.6 (12.9)	8	.08
ND HR (degrees)	18.1 (8.9)	19.0 (10.1)	.9	.36
Difference HR (degrees)	15.5 (11.2)	6.6 (8.6)	8.9	.029*
D cross body adduction (cm)	12.30 (3.3)	8.75 (5.2)	3.6	.07
ND cross body adduction (cm)	8.7 (4.8)	7.5 (4.6)	.9	.38
Difference cross body adduction (cm)	3.60 (4.2)	1.25 (2.9)	2.40	.07
D posterior laxity (mm)	2.1 (.5)	2.0 (.7)	.1	.47
ND posterior laxity (mm)	2.20 (.8)	2.17 (.6)	.03	.46
Difference posterior laxity (mm)	.10 (.4)	.03 (.5)	.07	.55

* Denotes statistical significance at $p < 0.05$.

in D vs. ND arms or GIRD. Unfortunately, little data exists on what constitutes significant GIRD, whether it exists in a normal population of throwers, and whether it is the result of pathologic capsular contracture, or simply coexistent to it. Such information will help determine if this measurement is a valid tool for evaluating the shoulder at risk for disability. The purpose of this study was to determine if GIRD exists in asymptomatic professional baseball pitchers, and if present, to determine whether it is explained by bony or soft tissue adaptations.

One of the difficulties with any discussion on GIRD is settling on an exact definition. Strictly speaking GIRD is the measured difference of IR between D and ND arms. This difference, however, is present to some degree in most throwers, and isn't sufficient to mark the clinical importance of the loss in IR seen in the disabled throwing shoulder. Burkhart et al. (2003a) when they described the term, dealt with this issue by defining "symptomatic" GIRD as an IR loss of greater than 25° in D vs. ND arms, and was the first definition for clinically significant GIRD. These same authors noted that range of motion alterations can become problematic when IR loss exceeds ER gain in pitchers, a second definition of GIRD. Finally, GIRD has been defined as a loss in IR in the presence of a loss in total arc of motion between arms. We evaluated 23 asymptomatic professional baseball pitchers by each of these definitions. Regardless of the method we used for defining GIRD, we found it to be a common finding in asymptomatic baseball pitchers (35-43%). In addition these normal pitchers demonstrated a large range (-45 to 5°) and a large standard deviation (±16°) suggesting that GIRD is quite variable in this normal population. This finding complicates the use of a single GIRD measurement to define a pathologic state.

Burkhart et al. (2003a) cited a series where preoperative GIRD was noted all pitchers in a series of type II SLAP tears confirmed arthroscopically. The review, however, did not include any asymptomatic athletes, data on the pre-pathologic state of these patients, or the numbers of patients with GIRD who did not have type II SLAP tears. Thus it is difficult to determine what degree of IR loss heralded the pathology vs. what may have been merely co-existent to it. Given that 43% of our asymptomatic actively pitching subjects displayed GIRD by this same definition, one must question whether a single measurement of GIRD (the measure of internal rotation difference on clinical exam) is a valid method to measure the posterior-inferior tightness responsible for the disabled throwing shoulder.

In another study, Verna et al. (1991) reported that 60% of pitchers with pre-season GIRD went onto have shoulder problems that required them to stop pitching. This same data, however, would suggest that nearly half of pitchers with GIRD did *not* develop shoulder pathology. Thus, while GIRD was noted on physical examination, it is possible that its presence was unrelated or may have been a normal finding in the group that did not develop symptoms.

One study has looked at this question in both symptomatic and asymptomatic pitchers. Myers et al. (2006) compared 11 pitchers with symptomatic internal impingement with 11 normal throwers for GIRD. The average GIRD for symptomatic pitchers was 19.7° +/- 12.8°, while the GIRD for asymptomatic pitchers was 11.1° +/-9.4°. The authors did not comment on whether any pitcher had an IR loss that exceeded an ER gain, or an IR loss with a loss of total arc of motion, and while the difference was significant, GIRD in symptomatic pitchers was below the 25 degree threshold reported by Burkhart et al. (2003c), and only 4° higher than what the authors themselves note as the normal value of 10-15° (Myers et al., 2006). In our asymptomatic population, the average GIRD was 17°, and around 40% of all pitchers met any definition of clinically significant GIRD. Given this data, and the relatively large standard deviations and range in GIRD measurements present in both our data and that of Myers et al. (2006), we would conclude that GIRD is a variable measure in the asymptomatic population, and therefore should not be used as sole proof for the disabled throwing shoulder. A better use of measuring GIRD may be in a longitudinal fashion, to note progress with stretching programs as has been reported by Kibler et al. (1998) or progression of a pathologic state from baseline.

One explanation for the variability of GIRD may lie in adaptive HR. Humeral retroversion has been shown to coincide with the arc of motion changes seen in D arms of pitchers by several authors (Crockett et al., 2002; Kawamura, 1998; Mackiuchi, 1998; Meister, 2001; Osbahr et al., 2002; Pieper, 1998; Reagan et al., 2002). The data of the present study underscores this, with D arms showing an 11° increase in humeral retroversion versus ND arms. To determine how much HR influenced IR changes, we analyzed the data with a Pearson coefficient, and noted a strong ($r^2 = 0.48$) correlation between the two, suggesting that humeral retroversion may play an important role in IR deficits seen in the D arms of throwers. This data is in agreement with that of Reagan et al. (2002) and Osbahr et al. (2002), who also found statistically significant correlations between retroversion and range of motion changes.

In contrast, we found no statistically significant relationship between GIRD and measures of soft tissue contributions in this asymptomatic population. Posterior capsular laxity was not different between GIRD and non-GIRD groups, and we found no significant correlation between posterior capsular laxity and IR changes. Likewise cross-body adduction, our other measure for posterior capsular tightness, did not significantly differ between GIRD and non-GIRD groups, nor was it correlated to changes in IR for either group. These findings are in agreement with those of Borsa et al. (2005) who found no side to side differences in shoulder laxity in pitchers, nor any correlations between shoulder laxity and range of motion adaptations. Myers et al. (2006) also noted no relationship between GIRD and measures of posterior capsular tightness in asymptomatic pitchers. It should be noted, however, that Myers et al. did demonstrate such a difference in symptomatic pitchers, and should this finding be borne out in subsequent studies, it may establish this measurement as a tool for the diagnosis of the disabled throwing shoulder.

There are several limitations to this study. First, we evaluated a relatively small group of pitchers, and while our numbers are comparable to those of other published studies (Meister, 2001; Osbahr et al., 2002; Reagan et al., 2002). Thus, while our data exhibited accepted Kappa scores, the data set may lack the necessary power to have detected meaningful associations beyond those reported herein. Second, a static measurement of range of motion was used in our analysis, and may not reflect the true limits of range of motion during the pitch (Sabick et al., 2004). Third, while orthopedic surgeons performing measurements on range of motion and laxity were blinded to HR data, identities of the pitchers were not withheld. Surgeons may have been biased by knowing the pitcher, his arm dominance, and therefore an expectation of which side should have adaptive changes. Finally, it should be stressed that this was a group of asymptomatic pitchers, and thus one should be cautious in generalizing these findings to pitchers with disabled throwing shoulders. Nevertheless, given that GIRD exists as a common and variable finding in the normal pitching population, and that normal adaptive retroversion appears to be a significant contributor to it, we conclude that it should not be used as confirmation of the diagnosis of the disabled throwing shoulder. Whether it may be used in an individual over time to track progress or deterioration remains to be seen. A different measure of posterior capsular contracture such as cross-body adduction may be a better screening tool for the disabled throwing shoulder or the shoulder at risk and certainly deserves further study.

Conclusion

Gird appears more prevalent in pitchers then previously thought. Large ranges of GIRD make using this as the sole clinical diagnosis of the disabled shoulder speculative at best. In contrast to previous published papers, we found no statistically significant relationship between GIRD and measures of soft tissue contributions in this asymptomatic population.

References

Borsa, P.A., Wilk, K.E., Jacobson, J.A., Scibek, J.S., Dover, G.C., Reinold, M.M. and Andrews, J.R. (2005) Correlation of range of motion and glenohumeral translation in professional baseball pitchers. *American Journal Sports Medicine* **33,** 1392-1399.

Burkhart, S.S., Morgan, C.D. and Kibler, W.B. (2003a) The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. *Arthroscopy* **19,** 404-420.

Burkhart, S.S., Morgan, C.D. and Kibler, W.B. (2003b) The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* **19,** 641-461.

Burkhart, S.S., Morgan, C.D. and Kibler, W.B. (2003c) The disabled throwing shoulder: spectrum of pathology. Part II: evaluation and treatment of SLAP lesions in throwers. *Arthroscopy* **19,** 531-539.

Crockett, H.C., Gross, L.B., Wilk, K.E., Schwartz, M.L., Reed, J., O'mara, J., Reilly, M.T., Dugas, J.R., Meister, K., Lyman, S. and Andrews, J.R. (2002) Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *American Journal Sports Medicine,* **30,** 20-26.

Kawamura, S.K. and Yoshimoto, H. (1998) Ultrasonographic evaluation of the humeral retroversion in baseball players: A correlation between range of motion and the humeral retroversion. *Twenty-Fifth Annual Meeting of the Japan Shoulder Society, Oct 29-30th, Tokyo, Japan.*. Book of Abstracts: 1.

Kibler, W.B. (1998) The relationship of glenohumeral internal rotation deficit to shoulder and elbow injuries in tennis players: a prospective evaluation of posterior capsular stretching. *Annual closed meeting of the American Shoulder and Elbow Surgeons, Oct 3,* New York, USA. Book of Abstract: 21.

King, J., Brelsford, H.J. and Tullos, H.S. (1969) Analysis of the pitching arm of the professional baseball pitcher. *Clinical Orthopaedics and Related Research,* **67,** 116-123.

Landis, J.R. and Koch, G.G. (1977) An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics* **33(2),** 363-374.

Mackiuchi, D.T.H., Mihara, T., Hokari, S., Uesto, H., Suzuki, K., Uchikawa, T., Kan, N., Ohta, K., Makino, Y., Matsuhisa, T. and Minami, K. (1998) The glenoid and humeral head torsion in baseball players. *Twenty-Fifth Annual Meeting of the Japan Shoulder Society, Oct 29-30t , Tokyo, Japan*. Book of Abstract: 2.

Meister, K. (2001) Humeral retroversion and its relationship to rotational motion in the shoulder of the collegiate baseball player. *American Academy of Orthopedic Surgeons Annual Meeting. March 1-6, San Francisco, USA*. Book of Abstract: 38.

Myers, J.B., Laudner, K.G., Pasquale, M.R., Bradley, J.P. and Lephart, S.M. (2006) Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *American Journal Sports Medicine* **34,** 385-391.

Osbahr, D.C., Cannon, D.L. and Speer, K.P. (2002) Retroversion of the humerus in the throwing shoulder of college baseball pitchers. *American Journal Sports Medicine* **30,** 347-353.

Pieper, H.G. (1998) Humeral torsion in the throwing arm of handball players. *American Journal Sports Medicine* **26,** 247-253.

Reagan, K.M., Meister, K., Horodyski, M.B., Werner, D.W., Carruthers, C. and Wilk, K. (2002) Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *American Journal Sports Medicine* **30,** 354-360.

Sabick, M.B., Kim, Y.K., Torry, M.R., Keirns, M.A. and Hawkins, R.J. (2005) Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal humeral epiphysiolysis and humeral retrotorsion. *American Journal Sports Medicine* **33,** 1716-1722.

Sabick, M.B., Torry, M.R., Kim, Y.K. and Hawkins, R.J. (2004) Humeral torque in professional baseball pitchers. *American Journal Sports Medicine* **32,** 892-898.

Soderlund, V., Kronberg, M. and Brostrom, L.A. (1989) Radiologic assessment of humeral head retroversion. Description of a new method. *Acta Radiologica* **30,** 501-505.

Surgeons, American Academy of Orthopaedic Surgeons (1965) *Joint motion: method of measuring and recording.* Chicago, IL: American Academy of Orthopaedic Surgeons. 1-150.

Verna, C. (1991) Shoulder flexibility to reduce impingement. *3rd PBATS (Professional Baseball Athletic Trainer Society), January 20-22, Mesa, Arizona, USA.* Book of Abstarct: 18.

Key points

- GIRD is relatively common in asymptomatic baseball pitchers (35-43%).
- Large ranges (-45 to 5°) and a large standard deviation (±16°) were noted suggesting that GIRD is quite variable in this population.
- GIRD is a variable measure in the asymptomatic population, and therefore should not be used as sole proof for the disabled throwing shoulder.

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