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Glenohumeral Internal Rotation Deficit and Risk of Upper Extremity Injury in Overhead Athletes: A Meta-Analysis and Systematic Review

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Context: Current perception dictates that glenohumeral internal rotation deficit (GIRD) is a chronic adaptation that leads to an increased risk of pathologic conditions in the dominant shoulder or elbow of overhead athletes.

Objective: To determine whether adaptations in glenohumeral range of motion in overhead athletes lead to injuries of the upper extremity, specifically in the shoulder or elbow.

Data Sources: An electronic database search was performed using Medline, Embase, and SportDiscus from 1950 to 2016. The following keywords were used: *GIRD, glenohumeral internal rotation deficit, glenohumeral deficit, shoulder, sport, injury, shoulder joint, baseball, football, racquet sports, volleyball, javelin, cricket, athletic injuries, handball, lacrosse, water polo, hammer throw*, and *throwing injury*.

Study Selection: Seventeen studies met the inclusion criteria for this systematic review. Of those 17 studies, 10 included specific range of motion measurements required for inclusion in the meta-analysis.

Study Design: Systematic review and meta-analysis.

Level of Evidence: Level 4.

Data Extraction: Data on demographics and methodology as well as shoulder range of motion in various planes were collected when possible. The primary outcome of interest was upper extremity injury, specifically shoulder or elbow injury.

Results: The systematic review included 2195 athletes (1889 males, 306 females) with a mean age of 20.8 years. Shoulders with GIRD favored an upper extremity injury, with a mean difference of 3.11° (95% CI, –0.13° to 6.36°; $P = 0.06$). Shoulder total range of motion suggested increased motion (mean difference, 2.97°) correlated with no injury ($P = 0.11$), and less total motion (mean difference, 1.95°) favored injury ($P = 0.14$). External rotational gain also favored injury, with a mean difference of 1.93° ($P = 0.07$).

Conclusion: The pooled results of this systematic review and meta-analysis did not reach statistical significance for any shoulder motion measurement and its correlation to shoulder or elbow injury. Results, though not reaching significance, favored injury in overhead athletes with GIRD, as well as rotational loss and external rotational gain.

Keywords: GIRD; shoulder; motion; injury; throwing; overhead athlete

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Upper extremity injuries are prevalent among overhead and throwing athletes. Athletes from racquet sports participants to Major League Baseball (MLB) pitchers place a substantial amount of repetitive stress on their dominant upper extremity. This repetitive overhead motion in skeletally immature athletes leads to osseous adaptations initially, but with skeletal maturity, the torque and force experienced through the shoulder leads to changes in range of motion, specifically increased external rotation and decreased internal rotation, which could lead to glenohumeral internal rotation deficit. With this in mind, biomechanical studies suggest that pitchers can generate close to 7000 deg/s of internal rotation angular velocity, while tennis serves and handball volleys can generate 5580 and 4700 deg/s of velocity, respectively.[4,23] These high angular velocities may be a contributing factor to upper extremity injuries. Previous literature suggests that nearly 75% of time lost from competition for baseball pitchers is due to injury of the upper extremity.[11] A recent study by Conte et al[3] indicated that 25% of all MLB pitchers have undergone ulnar collateral ligament (UCL) reconstruction.

The literature supports that overhead and throwing athletes develop adaptations to their dominant shoulders that affect their passive range of motion (ROM). Multiple studies demonstrate that the athlete's dominant shoulder, when compared with the nondominant shoulder, develops decreased internal rotation (IR), known as *glenohumeral internal rotation deficit* (GIRD).[2,6,25] In 2011, Wilk et al[26] defined GIRD as a 20° or greater loss of IR in the throwing shoulder compared with the nonthrowing shoulder. In that study, the authors demonstrated that pitchers with GIRD are almost twice as likely to be injured than those without GIRD. Additionally, they showed that pitchers with total rotational motion deficit of more than 5° had an increased injury rate.[26] Many believe that GIRD may be a maladaptive anatomic change that causes altered glenohumeral kinematics and throwing motions.[2] Furthermore, a variety of studies document deleterious outcomes in athletes with GIRD.[5,7,21]

The current perception is that GIRD is a chronic adaptation that leads to an increased risk of pathologic conditions in the dominant extremity, specifically shoulder or elbow injuries. The hypothesis of this study is that the current literature will support that GIRD leads to an increased risk for pathologic conditions of the shoulder and elbow in overhead athletes.

METHODS

A systematic review of peer-reviewed English-language literature evaluating the impact of GIRD in overhead athletes was performed using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and checklists. The search was completed on May 18, 2016, using an explicit search algorithm in the following databases: Medline (1950-May 18, 2016), Embase (1960-May 18, 2016), and SportDiscus (1975-May 18, 2016). Search terms included: *GIRD, glenohumeral internal rotation deficit, glenohumeral deficit, shoulder, sport, injury, shoulder joint, baseball, football, racquet sports, volleyball, javelin, cricket, athletic injuries, handball, lacrosse, water polo, hammer throw*, and *throwing injury*.

Eligibility Criteria

All studies that reported on GIRD along with an upper extremity injury were considered for inclusion in the study. The search included levels 1 through 4 evidence (per the Oxford Centre for Evidence-Based Medicine). Both electronic and print journal articles were eligible for inclusion. Expert opinions, case reports, editorial reports, and medical conference abstracts were excluded. Age and level of competition were not exclusion criteria.

All studies that followed a cohort of athletes to determine risk of GIRD were eligible for inclusion. Studies that did not report upper extremity injuries were excluded. The primary outcome was any upper extremity injury, including shoulder pain or injury and elbow pain. The authors also opted to specifically include elbow UCL injury due to the common association between GIRD and UCL injury. GIRD was assessed for an association with the aforementioned upper extremity injuries. Additional parameters of upper extremity motion were assessed, including total range of motion (TROM), TROM loss, total external rotation (ER), and ER gain. Specifically, TROM was defined as the sum of total ER and total IR. TROM of the dominant shoulder should be within 5° of the nondominant shoulder. TROM loss was defined as the difference in TROM between the dominant extremity and the nondominant extremity within the same athlete, while ER gain was defined as the difference between total ER in the dominant extremity and total ER in the nondominant extremity in a single overhead athlete.

Two authors selected pertinent studies for full review by assessing titles and abstracts. The same 2 authors analyzed full manuscript texts using the aforementioned criteria. Of the articles meeting inclusion for the systematic review, all reference lists were appraised to assure thorough literature analysis (Figure 1). There was no blinding of authorship, institution, or journal publication by the reviewers. Disagreement was resolved by consensus or additional review from a third author.

Extracted study data included author(s), title, publication year, study type, and level of evidence. Demographics evaluated included patient age, sex, height, weight, body mass index, and type of sport. When available, data on shoulder ROM (total IR, GIRD, total ER, ER gain, TROM, and TROM loss) were collected. The primary outcome of interest was upper extremity injury, more specifically, shoulder or elbow injury.

Two independent reviewers assessed the methodological quality of the studies included. The GRADE checklist (GRADE Profiler version 3.2.2; Grading of Recommendations Assessment, Development, and Evaluation [GRADE] Working Group) was used to determine the quality of the selected studies.

Statistical analysis of the data was performed using RevMan software (RevMan 5.0.23; The Nordic Cochrane Centre/The Cochrane Collaboration). Continuous data were reported as standardized mean differences. Individual studies with a

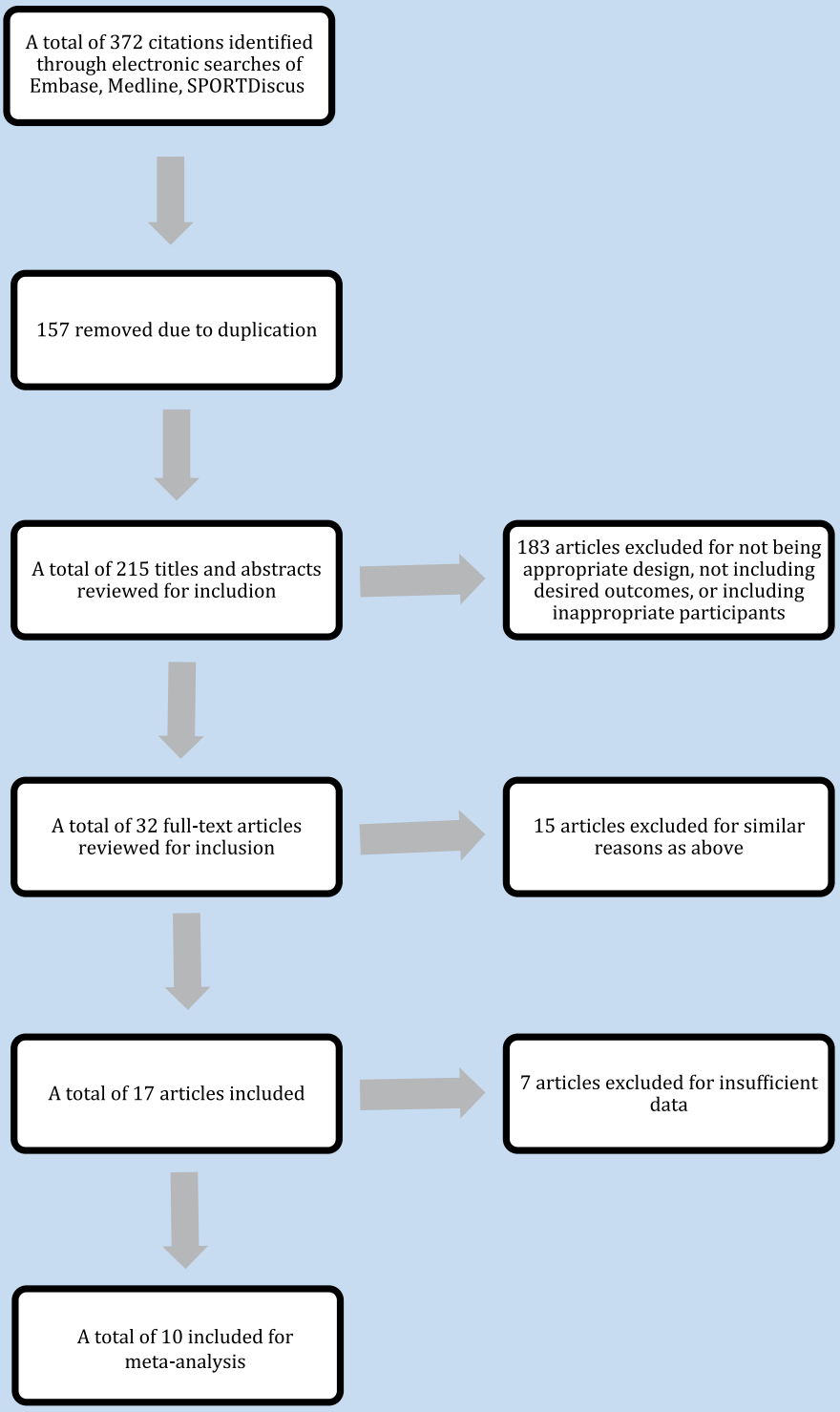

Figure 1. Flow diagram of selection of publications for meta-analysis.

discrepancy in reporting of outcomes or method of performing measurements were excluded from the pooled analysis of the primary and/or secondary outcomes. The cutoff for homogeneity of data was set as an I^2 of less than 60% to justify data pooling.

RESULTS

The initial electronic search resulted in 372 hits of full-text articles. After reviewing the titles, abstracts, and associated reference lists, 17 studies were eligible for inclusion in this

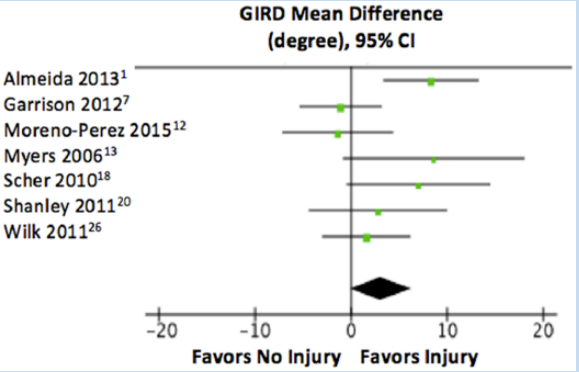

Figure 2. Forest plot showing mean difference in glenohumeral internal rotation deficit (GIRD) of injured versus uninjured overhead throwing athletes.

systematic review. Figure 1 summarizes the results of the literature search, while Appendix Table A1 (available in the online version of this article) summarizes the characteristics of each of the 17 included studies. A total of 2195 participants (1889 males, 306 females) were included in this study, with a mean age of 20.8 years.

Specific outcome measures reported from each of the included studies are provided in Appendix Table A2 (available online).

From the 17 studies evaluated, GIRD measurement comparisons between injured and uninjured athletes were available in 7 studies.[1,7,12,13,18,20,26] Measurements from bilateral extremities as well as between injured and uninjured athletes were provided for TROM in 7 studies[1,7,12,13,18,20,26] and TROM loss in 6 studies.[1,7,10,12,13,20] Measurements for total ER were available in 8 studies,[1,5,7,10,12,13,20,21] and ER gain was provided in 6 studies.[1,5,7,10,12,13] The GRADE criteria were used to evaluate the quality of each of the included studies, as summarized in Appendix Table A3 (available online).

A summary of the individual studies included in this systematic review is provided in Appendix 1 (available online).

Synthesis of Results

Shoulders with GIRD showed a nonstatistically significant correlation for both shoulder and elbow injury, with a mean difference of 3.11° (95% CI, –0.13° to 6.36°; $P = 0.06$) (Figure 2). The I^2 was 54%, which validates the pooling of data from the studies included (Table 1 and Appendix Table A4, the latter available online). The mean differences for GIRD between injured and uninjured athletes from each included individual study are displayed in Table 1.

Results for shoulder TROM showed that more motion correlated with no injury of the upper extremity. A mean difference of –2.97° (95% CI, –6.64° to –0.70°; $P = 0.11$) was noted for shoulder TROM, in favor of no injury. The pooling of

Table 1. Mean differences of glenohumeral internal rotation deficit between injured and uninjured athletes

Study	Injury		No Injury		Weight, %	Mean Difference, deg [95% CI]	I^2 (%)	*P*
	Mean, deg	Total, n	Mean, deg	Total, n				
Almeida et al (2013)[1]	15	30	6.7	27	16.9	8.30 [3.40, 13.20]		
Garrison et al (2012)[7]	12.53	30	13.63	19	18.8	–1.10 [–5.30, 3.10]		
Moreno-Perez et al (2015)[12]	11.9	19	13.3	28	14.9	–1.40 [–7.10, 4.30]		
Myers et al (2006)[13]	19.7	11	11.1	11	8.3	8.60 [–0.78, 17.98]		
Scher et al (2010)[18]	10.1	11	3.1	18	11.3	7.00 [–0.42, 14.42]		
Shanley et al (2011)[20]	9.9	27	7.1	9	11.8	2.80 [–4.33, 9.93]		
Wilk et al (2011)[26]	12.9	33	11.3	137	18.0	1.60 [–2.91, 6.11]		
Total		161		249	100.0	3.11 [–0.13, 6.36]	54	0.06

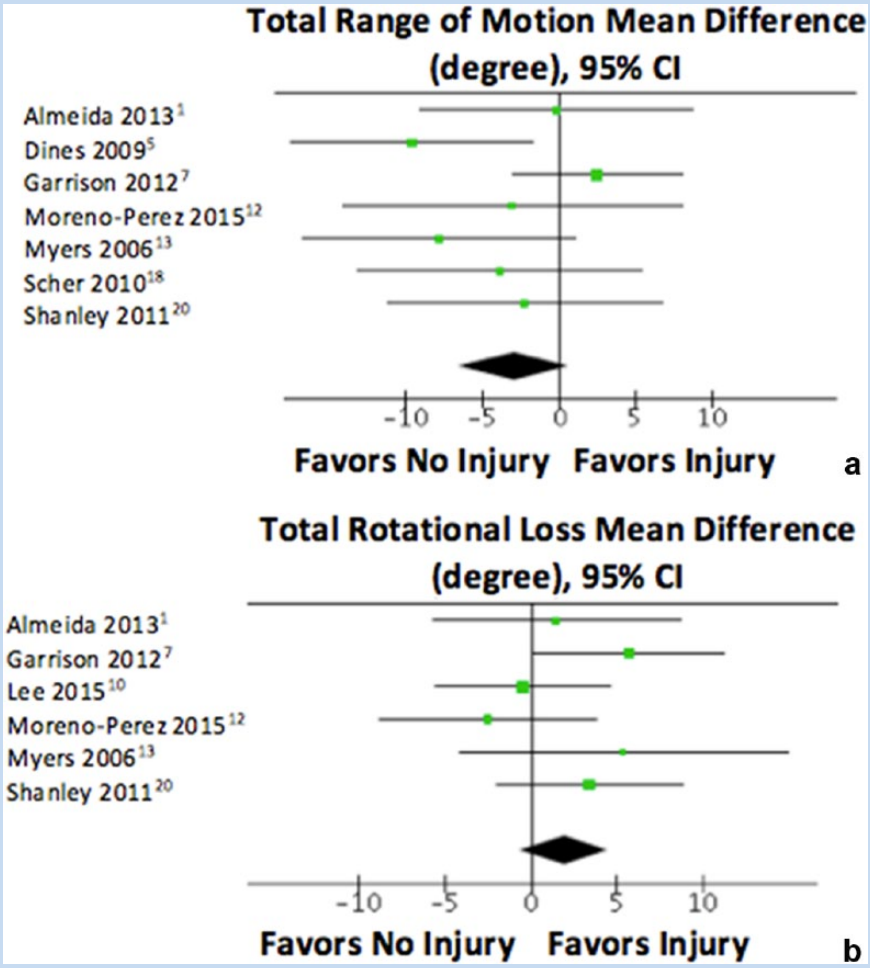

Figure 3. (a) Forest plot showing mean difference in total range of motion in the dominant arm of injured versus uninjured overhead throwing athletes. (b) Forest plot showing mean difference in total range of motion between throwing and nonthrowing extremity in injured versus uninjured overhead throwing athletes.

data for TROM was validated by an I^2 of 26%. In accordance, results for TROM loss favored injury, with a mean difference of 1.95° (95% CI, –0.65° to 4.55°; $P = 0.14$) (Figure 3). Likewise, pooling of data for TROM loss was validated by an I^2 of 8%.

Total shoulder ER was not in favor of either injury or no injury among overhead athletes. The mean difference for total ER was –1.15° (95% CI, –4.59° to 2.29°; $P = 0.51$). The I^2 for pooling data for total ER was 57%. On the other hand, ER gain favored injury among throwing athletes. The mean difference for ER gain was 1.93° (95% CI, –0.12° to 3.99°; $P = 0.07$) (Figure 4). The I^2 for pooling data for ER gain was 0%. Overall, pooling of data was validated by an I^2 of less than 60% for both the primary and secondary outcomes in ROM. Mean differences for TROM, TROM loss, total ER, and ER gain are displayed in Appendix Table A4 (available online).

Additionally, this investigation compared studies that included patients younger than 18 years[10,20] with complete data available to those studies that included patients older than 18 years.[1,5,7,12,13,21] There were no differences found for ROM between studies with participants younger than or older than 18 years of age. When comparing athletes by age and limiting to the dominant throwing extremity, the following ROM analyses were completed: GIRD ($P = 0.47$), TROM ($P = 0.21$), total rotational loss ($P = 0.25$), total ER ($P = 0.68$), and ER gain ($P = 0.96$).

DISCUSSION

Shoulder ROM adaptations have long been implicated in pathology of the upper extremity in the overhead athlete. After review and synthesis of data from 17 publications, findings, though not significant, suggest that GIRD may be a deleterious adaptation to the shoulder. Evidence also suggests an increased TROM may have a protective effect from injury, while loss of TROM may be detrimental to the overhead athlete. In like manner, in this study, total ER did not seem to be beneficial or

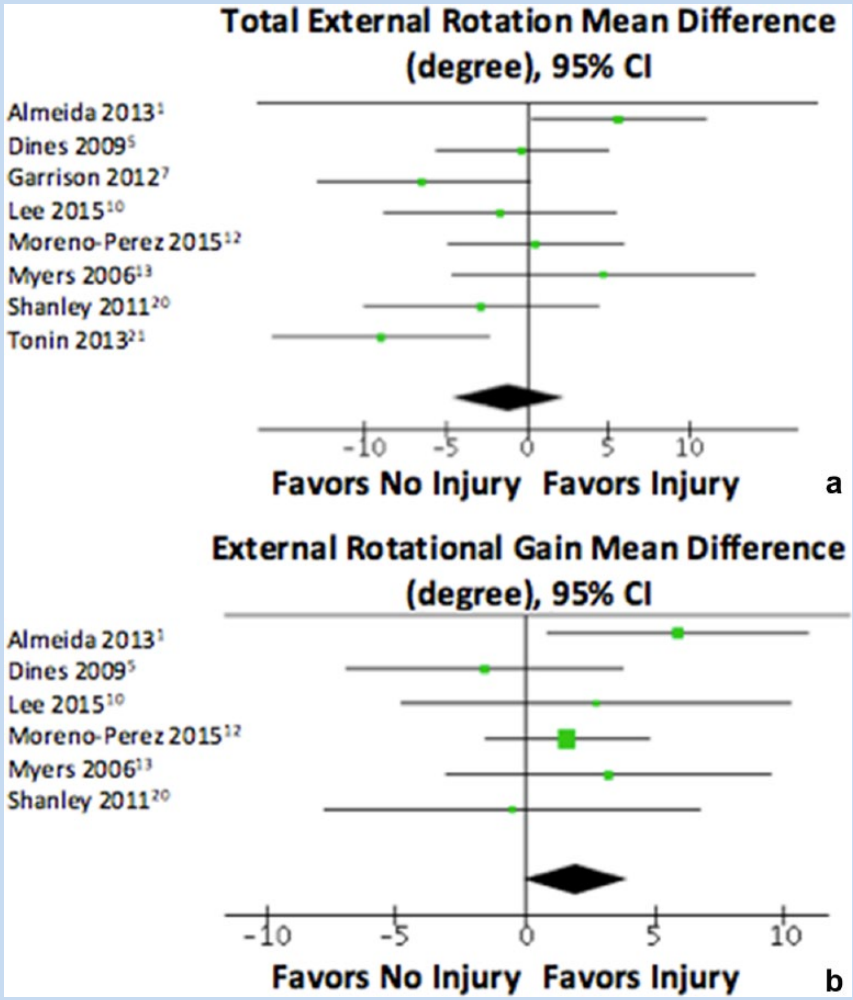

Figure 4. (a) Forest plot showing mean difference in total external rotation in the dominant arm of injured versus uninjured overhead throwing athletes. (b) Forest plot showing mean difference in external rotational gain between throwing and nonthrowing extremity in injured versus uninjured overhead throwing athletes.

deleterious to the throwing athlete; rather, excessive ER, in comparison with the contralateral extremity, may increase the risk of an upper extremity injury in overhead athletes.

GIRD was intricately detailed in 2003 by Burkhart et al,[2] who suggested that rotation adaptations could initiate a pathophysiologic cascade to the throwing shoulder. Later, Dines et al[5] investigated the idea that elbow pathology may also be related to GIRD by altering the biomechanics of the thrower, acting not only proximally at the shoulder but also more distal on the extremity. Yet, there has been some discrepancy in the relationship of GIRD with injury. For example, Dines et al[5] compared baseball players who had undergone UCL reconstruction with asymptomatic matched controls, and results showed significantly more GIRD in those who had UCL injury. Similarly, Shanley et al[20] conducted a prospective cohort study on high school baseball and softball players and found that those who were injured had significantly higher GIRD measurements. Moreover, they found that those who had GIRD of >25° in the dominant shoulder had approximately 4 times the risk of upper extremity injury.[20] By contrast, Wilk et al[24,25] described prospective results from a cohort of 296 MLB pitchers, evaluating the role of shoulder ROM differences and shoulder and elbow injuries. Their results found no significant correlation with GIRD and shoulder or elbow injury. This current review and meta-analysis of the available data in the published literature found an association, but no significant correlation, between GIRD and upper extremity injury in the overhead athlete.

Besides GIRD, others have implicated lack of TROM of the dominant arm, compared with the nondominant arm, as a potential contributor to upper extremity injury. Wilk et al[26] prospectively evaluated a cohort of 119 MLB pitchers and 170 pitcher seasons and found a significant relationship between TROM deficits and shoulder injury. They found that pitchers

who had TROM deficits greater than 10° of their contralateral arm were at 2.5 times greater risk for shoulder injury.[26] The same group evaluated the associations of TROM deficits and elbow injuries from a similar prospective cohort and found similar results with regard to elbow injuries as with the shoulder, that those with deficits in dominant-arm TROM are at increased risk of injury.[24] They added that if a player exhibited a TROM deficit, he or she was 2.4 times more likely to be placed on the disabled list for an elbow injury. The results from our analysis help to corroborate the aforementioned results, with TROM deficit showing a nonsignificant association with risk of injury; the data also support the reverse, that those players with increased TROM on their dominant extremity may be protected from injury.

While much attention has been placed on the glenohumeral IR measurements, little focus has been placed on the effect of ER on injury in overhead athletes. Fleisig et al[6] previously reported that the maximum elbow varus torque is produced near the moment of maximum shoulder ER. An externally rotated shoulder position places a significant amount of tension on the UCL and compression to the radiocapitellar joint. One would then expect more ER should place increased force on the structures about the shoulder and elbow with overhead activity and increase the risk for injury. Wilk et al[25] found the opposite of this in their prospective evaluation of 296 MLB pitchers. They found that pitchers with ER insufficiency were more likely to undergo surgery, 2.2 times more likely be placed on the disabled list for a shoulder injury, and 4 times more likely to undergo shoulder surgery.[25] Results from this analysis of the literature indicate that there are no conclusive data implicating ER differences and injury. However, data from this study do suggest that ER gain may place an individual at risk for upper extremity injury to both the shoulder and the elbow.

Although out of the scope of this study, the effect of humeral retrotorsion on the development of GIRD and upper extremity injuries must be mentioned. In 2015, Noonan et al[15] demonstrated that increased humeral retrotorsion may put more stress on the posterior shoulder of pitchers, which may result in ROM deficits. They also demonstrated that pitchers with GIRD had greater side-to-side differences in humeral retrotorsion when compared with pitchers without GIRD.[15] In 2014, Hibberd et al[9] performed a study on youth and adolescent baseball players and ultimately concluded that an age-related increase in GIRD is primarily due to humeral retrotorsion instead of soft tissue tightness. In 2013, Polster et al[16] studied 25 MLB pitchers and found a strong correlation between lower degrees of dominant arm humeral torsion and more severe injuries of the upper extremity. One of the major limitations of this study is that the effect of humeral retrotorsion on the development of GIRD and upper extremity injuries was not considered.

Most importantly, with regard to glenohumeral ROM measurements, differences between sides were also small and may be within the error of measurement. There are a number of other limitations with this review and meta-analysis. As a comprehensive review, the strength of the meta-analysis depends on the strength of the individual studies. With this in mind, there are no studies of high level of evidence, which incorporates randomization of athletes. Consequently, many studies could not be used in the pooled analysis. Nevertheless, several studies provided baseline measurements that allowed the calculation of differences in motion. Another limitation is the difference in follow-up time among studies, which could influence the identification of injuries. The design of the included studies, both prospective and retrospective, undoubtedly affected follow-up. Despite the differences in study design and follow-up time, all studies meeting inclusion criteria were included to allocate a larger sample size. This large inclusion of studies helped to address another limitation of small study populations within studies of GIRD. Given this was a review of previously published literature, we had no way to ensure glenohumeral ROM measurements were uniformly and appropriately performed.

CONCLUSION

The pooled results of this systematic review and meta-analysis did not reach statistical significance for any shoulder motion measurement and its correlation to shoulder or elbow injury. Results, though not reaching significance, favored injury in overhead athletes with GIRD as well as rotational loss and external rotational gain.

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