Glenohumeral Internal Rotation Deficit and Injuries

A Systematic Review and Meta-analysis

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Background: There is an association between throwing activity and glenohumeral internal rotation deficit (GIRD). An 18° to 20° deficit has been adopted as the standard definition of pathological GIRD, but specific findings as to how GIRD relates to an injury are inconsistent.

Purpose: To systematically review the literature to clarify the definition of GIRD diagnosis for adolescent and adult overhead athletes and to examine the association between GIRD and an increased risk of injuries in these athletes.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review of the literature was performed. Observational studies comparing glenohumeral internal rotation range of motion (ROM) in injured and uninjured overhead athletes were included for the meta-analysis. Studies of adolescent and adult athletes were analyzed separately. ROM was compared for the injured and uninjured groups, and a weighted mean GIRD was estimated. To account for potential heterogeneity across studies, both fixed- and random-effects models were used to calculate a standardized mean difference (SMD).

Results: Nine studies of level 3 or 4 evidence were included. From these, 12 study groups (4 adolescent, 8 adult) comprising 819 overhead athletes (226 injured, 593 uninjured) were included in the meta-analysis. The estimated SMD in GIRD between the injured and uninjured groups was 0.46 (95% CI, 0.15-0.77; $P < .01$) for the overall sample. The between-group effect was larger for adults (SMD, 0.60 [95% CI, 0.18 to 1.02]; $P < .01$) than adolescents (SMD, 0.20 [95% CI, –0.24 to 0.63]; $P = .13$). The weighted mean GIRD for the injured and uninjured groups was 13.8° ± 5.6° and 9.6° ± 3.0°, respectively, which also differed by age group. Moderate study heterogeneity was observed ($I^2 = 69.0\%$).

Conclusion: Based on this systematic review, the current definition of pathological GIRD may be too conservative, and a distinct definition may be required for adolescent and adult athletes. While the results indicate a link between internal rotation deficits and upper extremity injuries in the overhead athlete, higher quality prospective research is needed to clarify the role that GIRD plays in future injuries to overhead athletes of various ages.

Keywords: GIRD; injury; overhead athlete; range of motion; shoulder

Overhead motions of the arm in sports make an athlete susceptible to various forms of injury, including rotator cuff tears, superior labrum from anterior to posterior (SLAP) lesions, and internal impingement. Among the risk factors frequently investigated in association with these injuries is glenohumeral internal rotation deficit (GIRD). The cause of GIRD is currently understood to be tightening of the posterior structures of the shoulder, which causes improper shoulder deceleration, leading to repetitive microtrauma.[7,24,49,51] It has also been found that osseous adaptation results in increased compressive forces to the subacromial and coracoacromial regions, starting in athletes as young as 10 years old who participate in overhead sports.[31,57] Traditionally, pathological GIRD had been defined as a difference of ≥18° in passive internal rotation (IR) range of motion (ROM) between the dominant arm and nondominant arm (Figure 1).[11]

The association between overhead athletes and GIRD has been described,[11,35] but specific findings are inconsistent, and there are various definitions of GIRD in the literature. It is unclear, for example, whether GIRD is a cause of shoulder abnormalities or a physiological response to the

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Figure 1. Right hand–dominant overhead athlete with glenohumeral internal rotation deficit.

pathological shoulder.[18,36,41] Studies on the topic note that up to a 15° difference in IR ROM between dominant and nondominant arms may be indicative of normal GIRD in the overhead athlete.[1,23,55] Pathological GIRD has been defined in previous studies as an IR ROM deficit between arms of as little as 11°[51] and as much as 40°.[50] In addition to the presence of GIRD, other ROM differences have been documented, such as the ratio of IR deficit and external rotation gained in the dominant arm compared with the nondominant arm or assessment of the side-to-side difference of the total arc of motion as opposed to the loss of IR alone.[19,49] Data from Wilk et al[76] showed that the risk of GIRD is 2 times greater when the IR deficit is 18°, which is the deficit that Kibler et al[35] adopted to be considered pathologic at the 2012 Throwing Summit. Although this consensus exists, the variations in published definitions of normal and pathological GIRD require clarification, and few studies have determined a threshold for injuries due to GIRD.

Therefore, this study had 2 primary purposes: (1) to systematically review the literature to clarify the definition of GIRD diagnosis and (2) to perform a meta-analysis to examine the association between GIRD and the risk of injuries in overhead athletes. A better understanding of these factors can facilitate investigation into the importance and methods of prevention, screening, and treatment of GIRD.

METHODS

This review followed the guidelines and checklist of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). It was registered through PROSPERO, the database of the international prospective register of systematic reviews (#CRD42017055613). Three of the authors (J.E.J., J.A.F., C.M.N.) conducted an in-depth literature search (PubMed, CINAHL, Scopus, Ovid MEDLINE, and the Cochrane Library) of published peer-reviewed research. The following search terms and combinations of keywords yielded results: glenohumeral internal rotation deficit; GIRD; GIRD shoulder; GIRD AND injury; glenohumeral internal rotation deficit AND injury; ROM AND articulatory/physiology AND shoulder joint/physiology AND risk factor; shoulder joint/injuries OR shoulder joint/pathology OR shoulder joint/physiopathology AND internal rotation deficit; ROM AND articulatory/physiology AND shoulder joint/physiology AND baseball injuries. After reviewing each title and abstract, the authors reviewed the list of references for citations that might have been missed by the initial search. New titles were then located using Google Scholar.

The inclusion criteria required that each article report the following information: (1) a study population of overhead athletes who participated in the sports of baseball,[3,5,9,74,75] tennis,[17,20,22] volleyball,[28,58-60] handball,[2,25-27,62] cricket,[3,66,67] and swimming[6,12,68,71]; (2) the presence or absence of an injury, symptoms, or both (the definition used for injured or symptomatic athletes included specific injuries such as ulnar collateral ligament [UCL] insufficiency; internal impingement; arthroscopically proven SLAP tears; general shoulder, elbow, or any upper extremity injury; a history of shoulder injuries; or simply shoulder pain that was either reproducible with throwing or limited participation in training or games); and (3) shoulder ROM measurements, which were compared with the outcomes of the athlete who was injured or symptomatic versus uninjured or asymptomatic. Additionally, the articles reviewed were published in English and studied human participants of all ages. Articles not available from our local university library were obtained through an interlibrary loan.

The review process began with an independent abstract review of each article by 3 of the authors (J.E.J., J.A.F., C.M.N.). Data extraction was performed by reviewing the data for study demographics and ROM measurements of injured or symptomatic athletes compared with those of uninjured or asymptomatic athletes. If the mean GIRD was not calculated in the original publication, the authors calculated the mean GIRD of injured versus uninjured athletes using the difference of the means reported for ROM measurements. Only articles that compared ROM in injured or symptomatic versus uninjured or asymptomatic populations were included. The review process is outlined in Figure 2.

Statistical Analysis

Statistical analysis was completed in Stata 14.2 (StataCorp) using the METAN program.[10] Because of the potential for

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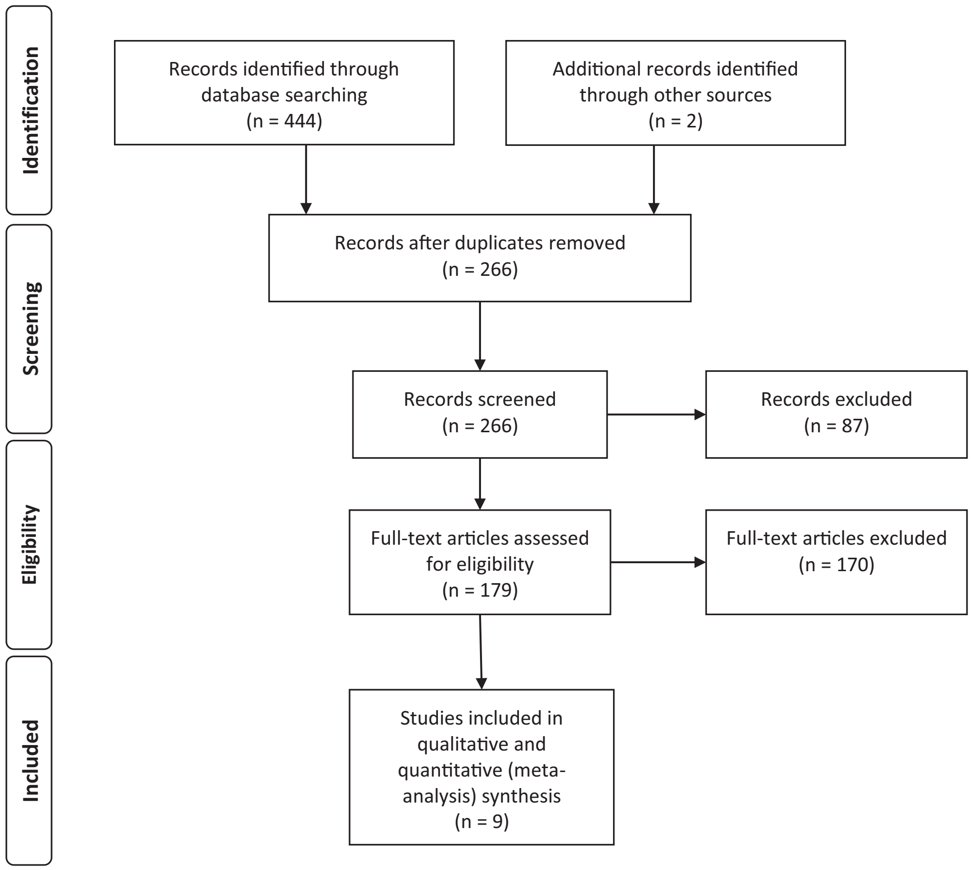

Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of study selection.

heterogeneity across studies, both fixed- and random-effects models were used to estimate the standardized mean difference (SMD) in GIRD between injured and uninjured athletes. The pooled SMD, estimated via the Cohen method[16] and weighted using an inverse variance method, was calculated separately for studies including youth/adolescent or adult athletes. A study that restricted the ages of the athletes included in its study sample to ≤18 years was included in the youth/adolescent group. Studies that did not restrict their sample's age to ≤18 years were included in the adult group. Weighted means were pooled to estimate a mean value of GIRD for both injured and uninjured athletes in both age groups. A forest plot was used to summarize these data.

Study heterogeneity was assessed using the I^2 statistic, calculated to describe the percentage of total variation across studies caused by heterogeneity rather than chance, and a funnel plot. A high I^2 value is associated with increased heterogeneity and indicates the potential utility of using a random-effects model for analysis to control for this heterogeneity.[32] The funnel plot was assessed for the presence of general small study effects, including reporting bias and true heterogeneity across studies.[65]

RESULTS

Study Characteristics

The search produced 446 articles from the 5 databases; 180 duplicates were removed, leaving 266 unique articles. The original screening removed 87 articles that did not specifically address GIRD, did not involve athletes, or had no reported injuries. The remaining 179 articles were reviewed for actual ROM values for glenohumeral IR and injuries. Articles that compared ROM in injured or symptomatic versus uninjured or asymptomatic populations were included, which left 9 articles with 12 study groups and a total of 819 participants for the meta-analysis (Table 1).

Level of evidence was determined using the Oxford 2011 levels of evidence guide.[14] The level of evidence for the included studies was generally low, between 3 and 4. Of the 819 overhead athletes who were analyzed, 226 were in the injured group and 593 were in the uninjured group.

Differences in Study Methods

Four[2,40,45,61] of the 9 studies included in the meta-analysis used patient-reported history of symptoms and injuries,

TABLE 1
Study Characteristics[a]

Study	LOE	Sample Size	Sport	Age, y, Mean ± SD	No. of Injured	No. of Uninjured	GIRD, deg, Mean ± SD		Injury Type	SMD (95% CI)
							Injured	Uninjured		
Magnusson et al[40] (1994)	4	47	Adult baseball pitchers	23.6 ± 0.4	21	26	11.72 ± 2.75	11.00 ± 2.83	History of shoulder injuries	0.26 (–0.32 to 0.84)
Myers et al[46] (2006)	4	22	Adult baseball	21.7 ± 2.8	11	11	19.7 ± 12.8	11.1 ± 9.4	Pathological internal impingement	0.77 (–0.10 to 1.64)
Dines et al[21] (2009)	4	58	Adult baseball	20.6 ± 4.9	29	29	28.52 ± 10.65	12.69 ± 8.05	UCL insufficiency	1.68 (1.08 to 2.28)
Scher et al[61] (2010)										
Pitchers	4	29	Adult baseball pitchers	26.3 ± 3.8	11	18	10.1 ± 9.0	3.1 ± 11.2	History of shoulder injuries	0.67 (–0.10 to 1.44)
Nonpitchers	4	28	Adult baseball nonpitchers		12	16	13.5 ± 8.8	4.2 ± 13.8	History of shoulder injuries	0.78 (0.00 to 1.56)
Wilk et al[76] (2011)	3	170	Adult baseball pitchers	25.6 ± 4.1	33	137	12.9 ± 12.0	11.3 ± 11.3	Shoulder injuries	0.14 (–0.24 to 0.52)
Almeida et al[2] (2013)	4	57	Adult handball	20.2 ± 2.3	30	27	15.0 ± 12.6	6.7 ± 5.1	Reproducible pain of at least 3/10 on the VAS while throwing for ≥1 month	0.85 (0.30 to 1.39)
Moreno-Perez et al[45] (2015)	4	47	Adult tennis	23.2 ± 4.9	19	28	11.9 ± 10.5	13.3 ± 8.6	Shoulder pain that prevented training, competition, or both	–0.15 (–0.73 to 0.44)
All adults		458			166	292	15.0 ± 13.1	9.9 ± 7.9		
Shanley et al[64] (2011)										
Softball	3	103	Adolescent softball	15.6 ± 1.2	9	94	5.5 ± 8.7	6.6 ± 9.0	Upper extremity injury	–0.12 (–0.81 to 0.56)
Baseball	3	143	Adolescent baseball	15.8 ± 1.3	18	125	12.1 ± 11.8	7.4 ± 8.6	Upper extremity injury	0.52 (0.02 to 1.02)
Shanley et al[63] (2015)										
Youth	3	47	Youth baseball pitchers	9.9 ± 1.2	18	29	8.0 ± 9.0	11.5 ± 13.5	Overuse shoulder or elbow injury	–0.29 (–0.88 to 0.30)
Adolescents	3	68	Adolescent baseball pitchers	14.9 ± 1.2	15	53	18.0 ± 13.0	10.5 ± 13.0	Overuse shoulder or elbow injury	0.58 (–0.01 to 1.16)
All youth/ adolescents		361			60	301	11.4 ± 7.8	9.0 ± 3.5		
Overall		**819**		**19.8 ± 2.5**	**226**	**593**	**13.8 ± 5.6**	**9.6 ± 3.0**		

[a]GIRD, glenohumeral internal rotation deficit; LOE, level of evidence; SMD, standardized mean difference; UCL, ulnar collateral ligament; VAS, visual analog scale.

while the other 5 studies[21,46,63,64,76] used clinical evaluations to determine symptoms and injuries in participants. Three studies[63,64,76] used preseason ROM measurements and followed the athletes throughout the season, monitoring for injuries.

All athletes included in the analysis were playing their sport competitively in leagues ranging from youth to professional. Shanley et al investigated GIRD in youth baseball pitchers and adolescent baseball pitchers[63,64] as well as in adolescent softball players.[64] All other studies included adult athletes only. The mean age was 19.8 ± 2.5 years (range, 8-37 years), and 688 (84%) were male. Table 1 summarizes the sports that the 819 athletes played; there were 612 (75%) baseball players. Of these baseball players, 454 (74%) were pitchers and 158 were field players. Of the other 76 male athletes, 47 played high-level tennis and the other 29 played handball. Of the 131 female athletes, 103 (79%) were softball players, and the other 28 played handball. Among the softball players, 12 athletes were pitchers and 91 were field players.

Moderate I^2 values confirmed important inconsistency across these studies. For the full sample, $I^2 = 69.0\%$, while for studies including only adults, $I^2 = 73.3\%$, and for adolescents, $I^2 = 55.1\%$. Given these values, we report the results of the random-effects model. As described in the discussion, this heterogeneity was not insignificant when trying to standardize the definition of GIRD. The asymmetric distribution shown in the funnel plot (Figure 3) further highlights that effects reported in individual studies are inconsistent because of high study heterogeneity, some level of reporting bias, or a combination of these. In addition, the reported outcomes in some studies, while potentially meaningful, were incompatible to compare statistically with other literature in this field, so these had to be excluded from the meta-analysis.

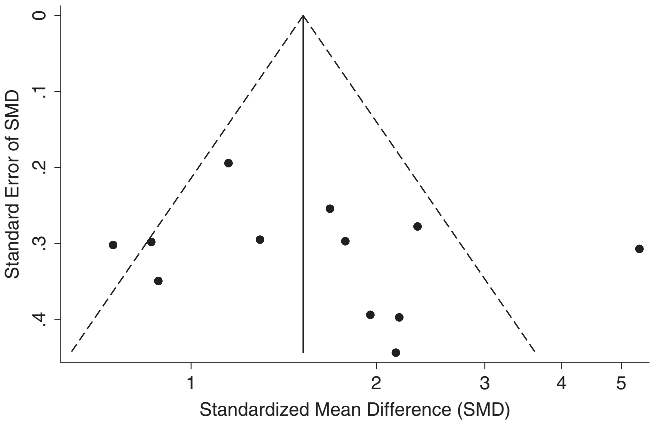

Figure 3. Funnel plot (with pseudo–95% CIs) of the 12 groups contained in the 9 included studies.

Clinical Symptoms and Injuries Reported

The types of injuries and symptoms reported by athletes in each study are summarized in Table 1. Three studies involved any injury to the dominant upper extremity related to sports that caused the athlete to miss ≥1,[63] ≥2,[61] or any number of games.[64] Four of the 9 studies included shoulder injuries only. These included pain or an injury causing the player to be unable to participate in sports,[45,76] a self-reported history of injuries,[40,45] or internal impingement diagnosed by an orthopaedic surgeon.[46] One study specifically investigated UCL insufficiency that required surgery,[21] while another involved reproducible pain of at least 3 of 10 on the visual analog scale at a reported minimum of 2 years for 2 hours per day and 2 days per week for more than 1 month.[2]

GIRD in Injured Versus Uninjured Groups

Considering all studies together, results of the analysis showed a statistically significant ($P < .01$) difference in GIRD between the injured group and uninjured group in both fixed- and random-effects models, as shown in the forest plot (Figure 4). The estimated SMD between the 2 groups was 0.46 (95% CI, 0.15-0.77) for the random-effects model, indicative of a medium effect size.[16] The weighted mean GIRD among all injured athletes was 13.8° ± 5.6°, while the mean among those not injured was 9.6° ± 3.0°. However, the between-group effect size was significant only for adult athletes (SMD, 0.60 [95% CI, 0.18-1.02]; $P < .01$), in whom the weighted mean GIRD was 15.0° ± 13.1° for injured athletes and 9.9° ± 7.9° for uninjured athletes. For adolescents, the SMD was 0.20 (95% CI, –0.24 to 0.63; $P = .13$). The weighted mean GIRD for injured adolescent athletes was 11.4° ± 7.8°, and for uninjured adolescent athletes it was 9.0° ± 3.5°.

DISCUSSION

GIRD is commonly found starting at a young age, even in asymptomatic athletes who participate in overhead sports.[31,59] The overhead throwing motion may result in an adaptive response in the osseous development of young athletes[31,47,57] as well as in the soft tissues of the shoulder as these overhead athletes age, which may contribute biomechanically to the development of abnormalities.[42,43,53] It is uncertain what degree of lost ROM is associated with an injury, or if it truly is associated. Research generally favors the idea that GIRD is associated with elbow and shoulder injuries in overhead athletes,[38] such as those to the UCL[13,21,57] and rotator cuff,[2,54] internal impingement,[7,24,51] superior labral tears,[7,24,51,54,56] biceps tendinosis,[56] and Little League shoulder.[30] A variety of other studies, however, have failed to show compelling data that support the role of GIRD in upper extremity injuries.[58,61,74,75] For this study, we systematically reviewed the literature to determine the mean IR deficit in injured overhead athletes to clarify the diagnosis of GIRD. We further sought to determine, through a meta-analysis, if GIRD is linked to injuries in overhead athletes.

This review found 9 studies that compared the mean difference in glenohumeral IR ROM deficits in injured and uninjured athletes. The results indicate that GIRD in injured adult athletes is indeed greater than that of uninjured adult athletes. This effect is less clear for adolescent athletes. Among studies, a large overlap in GIRD measurements existed between injured and uninjured athletes, especially in the youth/adolescent groups, in which the mean difference was only 2.4°. There was only a 5.1° difference between the injured and uninjured adult athletes as well. These small differences suggest a significant overlap between the injured and uninjured groups, which indicates that there should be a lower threshold for intervention in these athletes if the goal is to prevent injuries. The mean deficit for all injured athletes (13.8°), regardless of age, was not only in the low end of the range of values reported in the literature (11°[51] to 40°[50]), but it is also lower than the 18° threshold established at the 2012 Throwing Summit.[35] The findings of the current study suggest that this adopted definition of pathological GIRD may be more applicable to adults than to adolescents but also that a lower threshold may need to be considered for both groups.

Clinical Implications

Determining who is at risk of injuries based on ROM deficits is worthwhile because there is evidence that such deficits can be corrected.[1,48] This review shows that ROM deficits are more common in overhead athletes who are injured. When a potential risk factor such as this ROM deficit is identified, it is reasonable to initiate measures to correct the deficit in an attempt to prevent injuries in this population.[73]

Conservative treatment with stretching has been the primary treatment for GIRD.[48] Other suggestions for conservative treatment include mobilization techniques[15,78] as well as strengthening and conditioning programs targeting shoulder girdle stability.[29,51] Another consideration might be the use of muscle energy techniques (a common technique in physical therapy and osteopathic manual therapy).[44] Although there is limited evidence available to

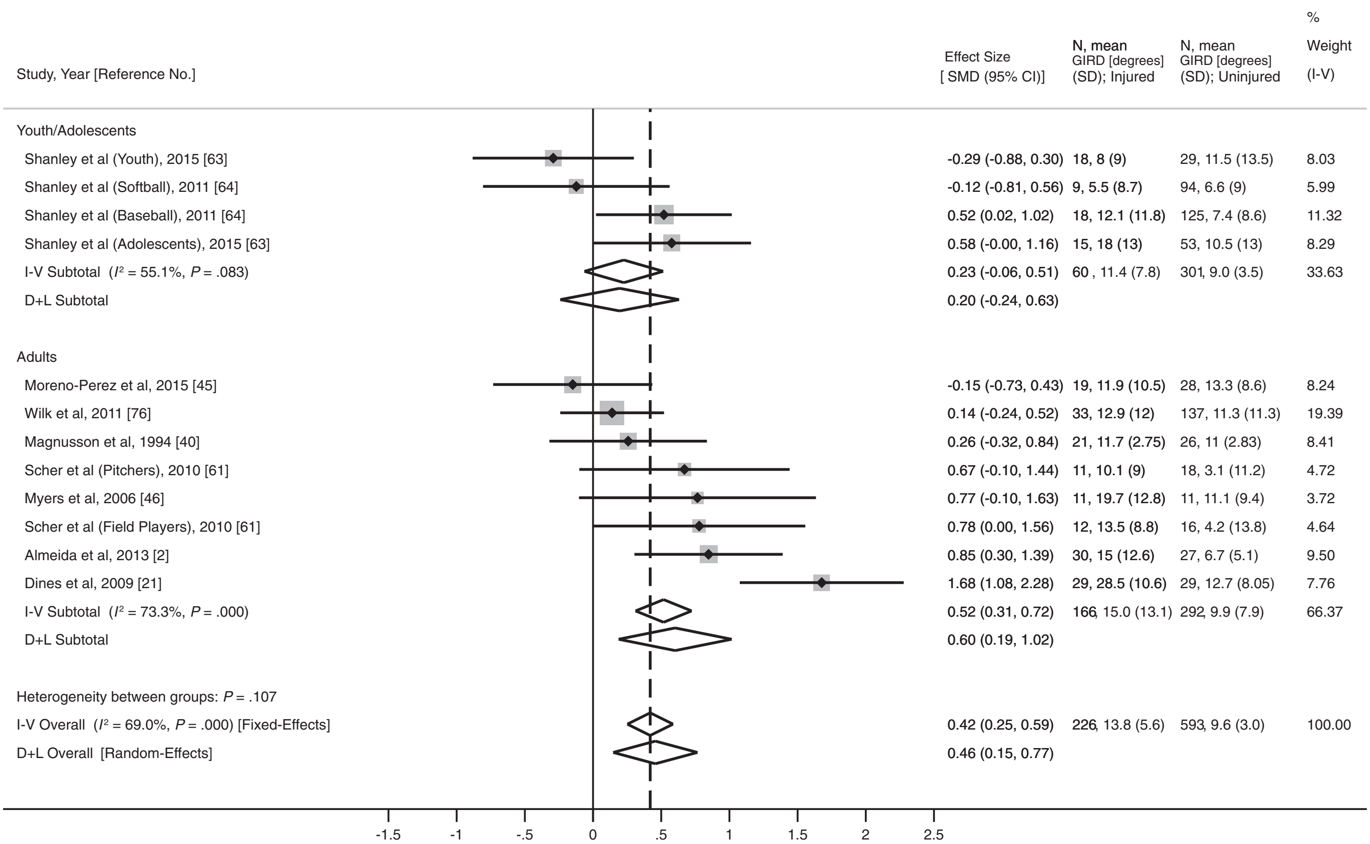

Figure 4. Forest plot (sorted by age group, ascending for standardized mean difference [SMD]) comparing injured versus uninjured shoulders for the presence of glenohumeral internal rotation deficit (GIRD).

show the effect that the treatment and correction of GIRD have on its associated conditions, there is reasonable evidence to suggest that treating ROM deficits could reduce future injury risk and improve associated conditions. For example, the use of early treatment may lead to fewer games lost in overhead athletes identified quickly as having GIRD,[4-6] suggesting that early conservative treatment could be the best response when athletes with GIRD are identified in preseason screening examinations.

Additionally, GIRD has been associated with posterior capsule thickening and stiffness as well as internal impingement.[53] When physical therapy for patients with internal impingement successfully resolves symptoms, there is an accompanying decrease in posterior shoulder stiffness,[72] and it is possible that this is related to decreased GIRD and the risk of injuries. The application of muscle energy techniques to posterior shoulder soft tissues immediately after a throwing session increased ROM in IR and horizontal adduction (horizontal flexion) compared with previous measurements.[44]

Because conservative treatment through stretching is safe, easy, and affordable, it is worth considering the implementation of IR stretching programs for all overhead athletes, regardless of measured ROM. This may be especially true considering that the mean difference in GIRD found in uninjured and injured groups in the current study was small. Importantly, however, it is unknown if there is a point at which overcorrecting for GIRD with early conservative treatment might diminish the effect of decreasing the injury risk or the effect that it may have on performance. There is some amount of physiological adaptation in overhead athletes that occurs from the repetitive motion,[31,47,57] and it is unknown whether this adaptation is protective of the athlete to a certain degree. The use of early treatment to correct GIRD needs further study to determine the effect that correcting GIRD has on the various injuries associated with ROM deficiencies.

Most researchers agree that GIRD is implicated in numerous shoulder conditions such as capsular tightness,[8,77] humeral retrotorsion,[31,39,49,54,69] scapular dyskinesia,[3,34,37,52,70] and rotator cuff tightness.[38,51] While these variants can be linked to other injuries, it is unclear if GIRD or a structural anatomic abnormality is the direct cause of the injury. The relationship between GIRD and UCL injuries of the elbow[13,21,57] as well as between SLAP lesions and internal impingement[7,24,31] has been documented in the literature. A cadaveric study found that excessive posteroinferior capsular tightness led to GIRD and can cause forceful internal impingement of the shoulder at maximum external rotation.[42,43] Wilk et al[74,75] reported that in professional baseball pitchers, insufficient external rotation led to a significant increase in the shoulder injury risk and that total rotation deficits increased the risk of elbow injuries. The observations of Wilk et al[74,75] suggest that injuries may be more likely associated with a ratio of the measurement of GIRD to the measurement of how much external rotation is gained when comparing the dominant and nondominant arms rather than simply the loss of IR.[4] Focused research into this ratio of GIRD to external rotation gain and its relationship with injuries would be beneficial in determining if the ratio is helpful in stratifying the risk of injuries.

There is evidence that in asymptomatic youth baseball players, the difference in ROM between dominant and nondominant arms in overhead athletes is not significant when the difference is corrected for humeral retrotorsion.[31] This may be because of bony remodeling in youth overhead athletes who are exposed early and often to the overhead motions associated with their chosen sport; GIRD due to humeral retrotorsion has been shown to increase with age in athletes consistently participating in overhead sports.[31] It may be necessary to correct the ROM values for humeral retrotorsion to determine how much of the rotational deficits or gains occur because of osseous change and how much is caused by changes in the soft tissues.[31,47,57] It has yet to be determined which one of these factors, if any, contributes more to the risk of injuries associated with GIRD. Understanding this may also be a better way to stratify the risk of injuries and would warrant further research.

Based on the current analysis, the clinical implications of finding GIRD of $\geq 15^\circ$ in the overhead throwing athlete would suggest that this patient is at an increased risk of upper extremity injuries on the ipsilateral side of the deficit. When accounting for the group as a whole, assuming athletes with a ROM deficit of $\geq 13.8^\circ \pm 5.6^\circ$ would benefit from training to prevent upper extremity injuries, 50% (n = 409) of the 819 participants identified in this review (Table 1) would have preventive training prescribed. If, however, the consensus definition (IR deficit of 18°-20°) were used as the basis for prescribing preventive training, approximately 280 athletes of the 819 (34.13%; area of the normal curve from the mean to +1 SD) would be judged not to be at risk of injuries and thus not receive potential treatment for injury prevention. Based on this systematic review, the clinical use of the current definition of GIRD will disregard a substantial number of overhead athletes who could potentially benefit from a prevention program.

As indicated by the current evidence available, athletes with a ROM deficit of $\geq 13.8^\circ$ should be referred to a preventive treatment regimen in an attempt to lower the risk of injuries from athletic participation. However, both the previous consensus and these current findings of the amount of GIRD that increases the risk of injuries are based on few studies with low levels of evidence, and this limits the recommendations that can be made based on the current literature available. There is a significant need for high-quality prospective studies analyzing the role that GIRD plays in increasing the risk of injuries in the overhead athlete as well as the use of preventive treatment for significant amounts of GIRD and the effects that this has on decreasing the injury risk in this population.

Limitations

A primary limitation of this meta-analysis is the low level of evidence available for a review. Ideally, there would have been more studies of higher quality available to strengthen both the results of the analysis and the clinical thresholds for the definition of GIRD. There is no other evidence available that is compatible with this statistical analysis to strengthen the impact of the results.

From the studies that were available and included, a somewhat asymmetric pattern was observed in the funnel plot, suggesting that there could be some combination of heterogeneity and bias in the studies included. The data in the analysis do show moderate heterogeneity ($I^2 = 69.0\%$), further suggesting that the studies included demonstrate high variability in their methods and the samples of athletes examined. The random-effects model was used in the analysis to correct for this level of heterogeneity and demonstrated that the SMD was still significant in the overall group as well as in the adult group. This level of heterogeneity should not be surprising considering the variability in participant age, sport, position within each sport, and sex among the studies included. For example, youth athletes in the study by Shanley et al,[63] when included in the overall group analysis, contributed to an overall decrease in both the mean age of the study population as well as the mean GIRD of both the injured and uninjured groups. The results from this further analysis suggest more age-appropriate clinical uses of the data in clinical evaluations.

Furthermore, there was a wide definition of injury in the studies used for the analysis. Even the timing of injury was not consistent across these studies; some cited a history of injuries, while others prospectively tracked injuries. Based on the available data, it is unclear whether an injury leads to GIRD or if GIRD contributes to the risk of injuries. The prospective studies often measured the smallest differences in ROM between injured and uninjured overhead athletes.[63,64,76] This may suggest that the greater differences between groups in other nonprospective studies were an effect of an injury rather than GIRD. Further prospective research is needed to clarify if GIRD contributes to the injury risk, if an injury contributes to GIRD, or if GIRD develops because of a history of injuries, contributing to a greater risk of further injuries.

High heterogeneity may also be attributed to the inherently low reliability of IR ROM measurements between different clinicians.[33] All studies in this analysis used the gold-standard method of measuring glenohumeral IR ROM: the patient supine, with the arm abducted and elbow flexed to 90°, while the examiner stabilizes the scapula with the finger on the coracoid process and the hand over the clavicle and scapular spine. A bubble goniometer was used to measure ROM in this position in all included studies. Kevern et al[33] found that the interrater reliability for the measurement of IR in this position is low (intraclass correlation coefficient = 0.54). This means that while there may be good reliability (intraclass correlation coefficient = 0.961-0.963)[33] within a single study using one examiner to measure ROM, comparing the ROM measurements between studies creates excessive variability. These limitations indicate the further need for focused research to establish an acceptable threshold of GIRD in overhead athletes.

CONCLUSION

First, this review suggests that the consensus definition for the clinical presence of GIRD (18°-20° IR deficit) likely means that athletes who could benefit from preventive treatment are overlooked. We found that the mean amount of GIRD for the adult athlete who sustained an injury to the ipsilateral upper extremity (15.0°) was lower than the current consensus and was significantly different compared with the uninjured adult athlete (9.9°). Youth and adolescent athletes with GIRD, when separated in the analysis, did not demonstrate a significant difference in GIRD between injured and uninjured athletes; the injured group, however, still demonstrated a lower amount of GIRD (11.4°) compared with the consensus. Second, despite the low level of research rigor in the reviewed studies (all were level 3 or 4), the data indicate a link between GIRD and upper extremity injuries in overhead athletes. It is important to note that there is a need for further high-quality prospective research to better quantify the amount of GIRD that is clinically concerning and what injuries are most likely for these athletes as well as how clinicians should address these findings in practice to prevent injuries in these athletes.

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