HSSJ
DOI 10.1007/s11420-019-09691-1

HSS Journal®

REVIEW ARTICLE

Clinical Outcomes and Quality of Literature Addressing Glenohumeral Internal Rotation Deficit: A Systematic Review

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Received: 5 January 2019/Accepted: 23 April 2019

Abstract *Background:* Glenohumeral internal rotation deficit (GIRD) can negatively impact shoulder function particularly in the throwing athlete. *Questions/Purpose:* This study aimed to systematically evaluate recent trends in clinical outcomes and quality of published evidence pertaining to GIRD. *Methods:* A systematic review was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, MEDLINE, PubMed Central, and Embase were searched from January 1, 2011, through April 23, 2017, for all articles evaluating GIRD. Two reviewers independently screened articles for eligibility and extracted data for analysis. *Results:* Eighty-two articles were included in the final review. In general, the overall number of articles published increased over time. Two-thirds of all studies were conducted in the USA. Seventy-eight percent ($N = 64$) of included studies were level-III to level-V evidence, with no level-I study performed during the study period. Eighty-five percent of studies were either epidemiologic, review, or imaging articles, and only 12% were clinical studies. Significant variability in the clinical definition of GIRD was identified. All studies evaluating non-operative management of GIRD demonstrated significant improvements in internal rotation of the affected extremity. *Conclusion:* Current trends in GIRD-related literature demonstrate limited focus on clinical, therapeutic, or patient-reported outcomes and mostly consist of low-level evidence. There is a lack of consensus in the literature on what clinically constitutes GIRD.

Keywords glenohumeral internal rotation deficit · throwers shoulder · literature

Level of Evidence: Level IV Systematic Review

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11420-019-09691-1) contains supplementary material, which is available to authorized users.

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Introduction

Glenohumeral rotation is an essential component of normal mechanics in the overhead athlete. Differences in side-to-side glenohumeral rotation and range of motion have been well documented [3, 7, 18, 22, 31]; however, the implication of these differences has only recently been understood. Adaptive changes that allow for greater external rotation of the arm are advantageous for achieving optimal arm position in the late cocking phase of the throwing motion, which is necessary to produce maximum hand and ball velocity [3, 16, 21, 30]. A concomitant loss in the magnitude of internal rotation is often observed when external rotation increases [3, 7, 9, 22, 27, 32]. A loss of glenohumeral internal rotation has been associated with altered glenohumeral biomechanics [3, 11, 14], and with both shoulder [3, 4, 25, 32] and elbow [8, 10] pathology secondary to increased loads downstream in the kinetic chain.

Glenohumeral internal rotation deficit (GIRD) is a specific entity in which the loss of glenohumeral internal rotation is considered pathologic. GIRD can result from repetitive microtrauma to the posterior capsuloligamentous structures, resulting in capsular hypertrophy and decreased tissue compliance. This capsular hypertrophy is associated

Published online: 17 June 2019

with posterior-superior migration of the humeral head [11, 18]. While GIRD in itself is not considered to be causative for shoulder injury, it is recognized as an important risk factor [17, 32]. GIRD, along with increased humeral retroversion in overhead throwing athletes, can be associated with internal impingement pathology including undersurface rotator cuff tears and labral pathology. Wilk and colleagues [32] reported a 1.9-fold increased risk of injury with a GIRD of 18° or greater. However, GIRD has also been observed in 35 to 43% of asymptomatic professional pitchers [29]. Despite a large volume of recent literature on GIRD, several important clinical questions remain unanswered. In particular, a lack of consensus regarding the threshold between physiologic and pathologic glenohumeral internal rotation coupled with inconsistent outcomes has made it difficult to clearly define the role of GIRD in injuries of the throwing shoulder.

The purpose of this systematic review was to evaluate the clinical outcomes and the quality of studies addressing GIRD from 2011 to 2017. We sought to identify trends in the literature to better assess current gaps in knowledge pertaining to both injury and prevention associated with GIRD. Our hypothesis was that there would be limited high-quality clinical evidence pertaining to the role of GIRD in shoulder pathology in the overhead athlete.

Methods

This study was conducted according to the methodology described in the *Cochrane Handbook for Systematic Reviews of Interventions* [15] and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [23].

Eligibility Criteria

We included studies that (1) were published in a peer-reviewed journal between 2011 and 2017, (2) reported on GIRD (as identified by the study) in patients of any age, gender, or sport or were biomechanical studies of GIRD, and (3) were published in English. There were no restrictions regarding level of evidence, country, sport, number of patients, length of follow-up, or journal of publication. We excluded studies that pertained to posterior glenohumeral internal impingement without addressing GIRD, studies without full text available, and studies that did not identify the patients as having GIRD.

Identification of Studies

A systematic literature search of potentially eligible trials was conducted in PubMed Central, PubMed, MEDLINE, and EMBASE, from January 1, 2011, through April 23, 2017. Investigators with methodological and content expertise developed and performed the search. Medical Subject Headings (MeSH) and Emtree headings and subheadings were used in various combinations in Ovid and supplemented with free text to increase sensitivity. The PubMed search included articles published online ahead of print. A manual search of related references and cited articles was also performed. We searched conference proceedings from the previous 3 years and ClinicalTrials.gov to identify relevant unpublished trials.

Screening and Assessment of Eligibility

Two reviewers (J.M.K. and N.K.B.) independently screened the titles and abstracts of all studies for eligibility using piloted screening forms. Duplicate articles were manually excluded. Both reviewers evaluated the full text of all potentially eligible studies identified by title and abstract screening to determine final eligibility. All discrepancies were resolved by a consensus decision requiring rationale with the first author.

Data Extraction

Data were extracted independently and in duplicate by both reviewers (J.M.K. and N.K.B.) using a piloted electronic data extraction form (Excel, Microsoft, Redmond, WA, USA). Extracted data included, but were not limited to, year and journal of publication, location of investigation, clinical treatment and reported outcomes, type of sport, level of evidence, distribution of research, and method of intervention when performed. Level of evidence was graded according to the criteria of Wright et al. [33]. Study design was categorized as clinical, review, epidemiologic, cadaveric, or imaging based (Table 1). The journal of publication was categorized as orthopedic, radiology, sports medicine, athletic training, physical medicine and rehabilitation, or physical therapy.

Statistical Analysis

Interobserver agreement for assessments of eligibility was calculated with the Cohen kappa (κ) statistic. A κ of 0–0.2 represented slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and above 0.80 almost perfect agreement [19]. Descriptive statistics and raw counts were used to summarize data using the Excel program (Microsoft, Redmond, WA, USA).

Results

The literature search generated 1370 relevant citations. Following duplicate removal and application of eligibility criteria, 1024 articles from the electronic search and four from the manual search underwent title and abstract screening. Following this, 135 articles underwent full-text review, ultimately producing 82 articles that met the inclusion criteria for this report (Fig. 1). The κ value for overall agreement between reviewers for the final eligibility decision was 0.98 (95% CI: 0.96–0.99), indicating almost perfect agreement.

All clinical studies evaluated various methods of non-operative management, with the exception of one study that evaluated surgical management (Table 2) [1,

Table 1 Definitions of categories used to characterize study design

Category	Description
Clinical	Evaluation of clinical outcomes in a group of study patients
Review	Expert opinion, systematic, and narrative reviews
Epidemiologic	Evaluation of the epidemiology, incidence, or relevance of a glenohumeral internal rotation deficit in a specific patient population
Cadaveric	Anatomic or biomechanical studies on cadaveric specimens
Imaging	Evaluation of anatomic parameters via various imaging modalities without the assessment of clinical outcome data

2, 5, 6, 12, 13, 20, 24, 26, 28, 34]. The definition of GIRD was highly variable across the clinical studies, with only one study defining GIRD as a side-to-side internal rotation deficit of 20° or greater [6]. The most common definition of GIRD for inclusion across all studies was a side-to-side internal rotation deficit of 10° or greater [12, 13, 26, 28]. Various methods of non-operative stretching with or without adjunctive modalities were evaluated, all of which demonstrated clinical improvement in internal rotation of the affected extremity. All non-operative studies were either level-II or level-III evidence. Codding and colleagues [5] described the only surgical series for patients with GIRD recalcitrant to 3 months of non-operative treatment. Patients had a significant improvement in mean American Shoulder and Elbow Surgeons (ASES) score (71.5 to 86.9) and internal rotation deficit (43.1 to 9.7°) with arthroscopic posteroinferior capsular release. Furthermore, 77% of patients were able to return to the same or higher level of competitive athletics.

The overall trend for number of publications per year tended to increase, except in years 2013, 2016, and 2017. The largest increase in publication volume (100%) was observed between 2013 and 2014 (Fig. 2). Two-thirds (66%) of all GIRD-related studies were performed in the USA; Germany had the second highest number of publications, four (5.4%), over the period of study. Overall, 41% ($N = 34$) of all publications were level-IV or level-V evidence, and 78% ($N = 64$) were level-III to level-V evidence (Fig. 3). No level-I study was performed during the study period.

The majority of articles (44%) were epidemiologic studies, followed by review articles (23%), imaging studies (18%), clinical research (12%), and cadaveric studies (3%) (Fig. 4). The majority of articles were in orthopedic ($N = 41$) and sports medicine ($N = 19$) journals. The largest number of GIRD-related publications came from the *American Journal of Sports Medicine*, followed by the *Journal for Shoulder and Elbow Surgery*. A similar number of articles were in journals of radiology, athletic training, physical medicine and rehabilitation, and physical therapy (Fig. 5).

The majority of studies (52%) involved baseball players. Articles that identified participants as "throwing or overhead" athletes from a variety of sports comprised the next most commonly studied population (18%). Handball players also constituted an appreciable sample of the study population (12%) (Fig. 6).

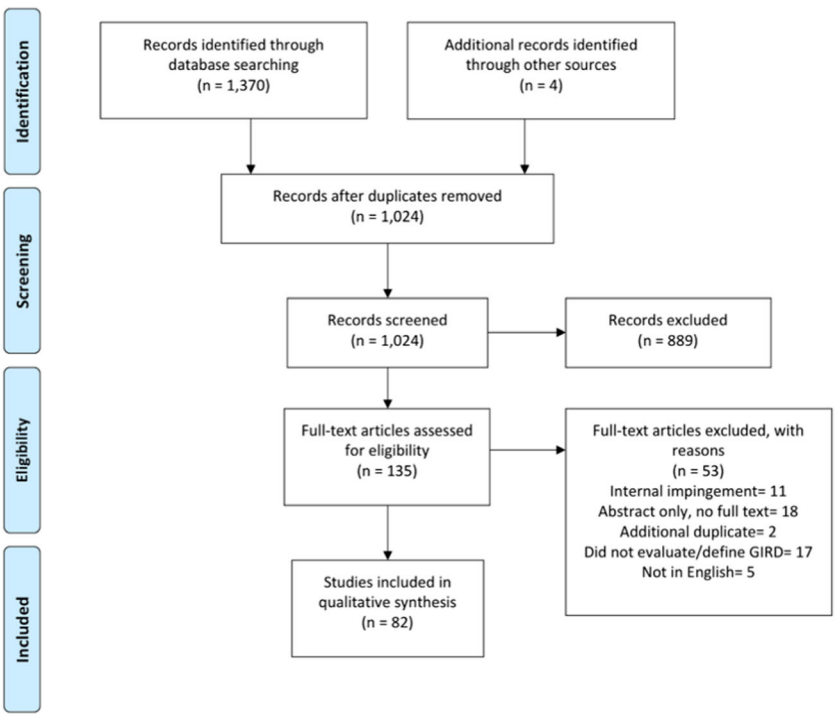

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram detailing article screening and reasons for exclusion.

Table 2 Clinical studies evaluating glenohumeral internal rotation deficit (GIRD)

Study and year of publication	Study design	Level of evidence	Number of patients
Maenhout et al. [20]	Case-controlled	III	62
Bailey et al. [1]	Case-controlled	III	60
Moore et al. [24]	Randomized controlled trial	II	61
Salamh et al. [28]	Randomized controlled trial	II	60
Yang et al. [34]	Randomized controlled trial	II	60
Bailey et al. [2]	Randomized controlled study	II	60
Guney et al. [12]	Randomized cohort study	II	59
Cools et al. [6]	Randomized cohort study	II	60
Hammons et al. [13]	Randomized cohort study	II	34
Park et al. [26]	Randomized cohort study	II	87
Codding et al. [5]	Case series	IV	13

Study and year of publication	Mean age (years) and standard deviation or range	Definition of GIRD	Intervention	Outcomes
Maenhout et al. [20]	Intervention: 21.4 ± 2.4 Control: 22.1 ± 2.2	GIRD ≥ 15°	Intervention: daily sleeper stretch for 6 weeks Control: no stretching	Stretching group dominant arm had significant increase in internal rotation (+ 13.5° ± 0.8°), horizontal adduction (+ 10.6° ± 0.9°), and acromial humeral distance (+ 0.5 to 0.6 mm) compared to control
Bailey et al. [1]	Intervention: 19 ± 2.6 Control: 19 ± 2.1	GIRD ≥ 15°	Intervention: instrument-assisted soft tissue mobilization plus self-stretching program Control: self-stretching program	Instrument-assisted soft tissue mobilization plus self-stretching program demonstrated significantly greater increase in internal rotation (+ 5° ± 2°), total arc motion (+ 8° ± 6°), horizontal adduction (+ 7° ± 2°), and decreased posterior rotator cuff stiffness (− 0.2 ± 0.3 kPa) compared to isolated self-stretching program
Moore et al. [24]	Manual therapy for glenohumeral horizontal abductors: 19.5 ± 1.0 Manual therapy for glenohumeral external rotators: 20.4 ± 1.1 Control: 19.8 ± 1.1	No formal definition	Single application of manual therapy for glenohumeral horizontal abductors and external rotators Control: no manual therapy	Patients treated with manual therapy for glenohumeral horizontal abductors demonstrated a significantly greater increase in internal rotation (+ 4.2° ± 5.3°) and horizontal abduction (+ 6.8° ± doi: 10.5°), compared to other treatment and control groups
Salamh et al. [28]	Intervention: 16.1 ± 1.2 Control: 16.5 ± 1.5	GIRD ≥ 10°	Intervention: horizontal adduction stretching + scapular stabilization Control: horizontal adduction	Horizontal adduction stretching with scapular stabilization demonstrated significant improvement in posterior shoulder tightness (83° ± 17° vs. 65° ± 13°) and internal rotation (51° ± 14° vs. 43° ± 9°) compared to stretching without scapular stabilization

			stretching—scapular stabilization	
Yang et al. [34]	Intervention: 54.8 ± 8.5 Control: 54.6 ± 7.9	GIRD ≥ 10%	Intervention: posterior deltoid, infraspinatus and teres minor massage, 2× per week for 4 weeks Control: no massage	Patients receiving massage therapy demonstrated significantly greater overall mean internal rotation (54.9° vs. 34.9°) compared to controls. Functional disability as measured by Flexilevel Scale of Shoulder Function (FLEX-SF) significantly improved in the massage group (40.5 vs. 31.7) compared to controls
Bailey et al. [2]	Instrumented manual therapy + self-stretching: 18.8 ± 2.6 Self-stretching alone: 18.6 ± 2.10	GIRD ≥ 15°	Intervention: randomly assigned to single treatment of instrumented manual therapy + self-stretching Control: self-stretching alone	Instrumented manual therapy + self-stretching resulted in a significantly greater increase in internal rotation (+ 5°, $P = 0.010$), total arc of motion (+ 6°, $P = 0.010$), and horizontal adduction (+ 7°, $P = 0.004$) compared with self-stretching alone. Both groups had significantly improved range of motion compared to baseline
Guney et al. [12]	Manual stretch: 22.95 ± 1.5 Sleeper stretch 23.83 ± 1.7 Cross-body stretch: 24.17 ± 4.1	GIRD ≥ 10°	Intervention: patients either received manual stretching, sleeper stretching or cross-body stretching. Control: no control	Manual stretching, sleeper stretch and cross-body stretch significantly increased internal rotation (mean Δ = 19.58 ± 5.54°, 9.05 ± 2.72°,9.66 ± 3.03°) and horizontal adduction (mean Δ = 9.51 ± 3.61°, 7.88 ± 3.67°, 7.35 ± 2.68°) while significantly decreasing external rotation (mean Δ = 10.08 ± 5.64°, 5.61 ± 2.71°, 5.78 ± 3.31°) and posterior capsule tightness (mean Δ = 8.20 ± 2.90 cm, 3.66 ± 1.64 cm, 5.83 ± 2.72 cm), respectively
Cools et al. [6]	Asymptomatic: 25.4 ± 6.7 Symptomatic: 24.5 ± 7.8	GIRD ≥ 20°	Intervention: both symptomatic and asymptomatic patients were randomized to either angular or non-angular stretching exercises. Control: no control	Angular and non-angular stretching exercises for 3 weeks significantly improved internal rotation in symptomatic and asymptomatic patients. This increase remained significantly improved at 6 weeks following initiation of the stretching program, however did not significantly differ compared to the 3-week time point
Hammons et al. [13]	Prone-passive stretch: 20.64 ± 3.34 Cross-body stretch: 20.05 ± 2.58	GIRD ≥ 10°	Intervention: asymptomatic patients were randomize to receive 12 treatments of either prone-passive or cross-body stretches. Control: no control	Prone-passive and cross-body stretches significantly increased glenohumeral internal rotation (13.23° ± 7.78°, 8.47° ± 8.71°), and total arc range of motion (14.81° ± 11.27°, 9.97° ± 11.99°), respectively. No significant difference was found between the prone-passive and the cross-body groups
Park et al. [26]	Local cryotherapy: 23.45 ± 1.90 Cross-body stretch: 23.35 ± 2.08 Control: 23.35 ± 2.08	GIRD ≥ 10°	Intervention: randomized patients to receive either local cryotherapy on their infraspinatus and posterior deltoid muscles, or to perform passive cross-body stretch Control: neither treatment	Local cryotherapy and cross-body stretch resulted in significant increased internal rotation and horizontal adduction immediately following the intervention and at 10-min follow-up post-intervention compared to controls
Codding et al. [5]	21 (16–33)	No formal definition, failure to resume sport after 3 months of physical therapy	Arthroscopic posterior-inferior capsular release	Significant improvement in mean American Shoulder and Elbow Surgeons score (71.5 to 86.9), internal rotation deficit (43.1° to 9.7°). 77% of patients returned to the same or higher level of sport

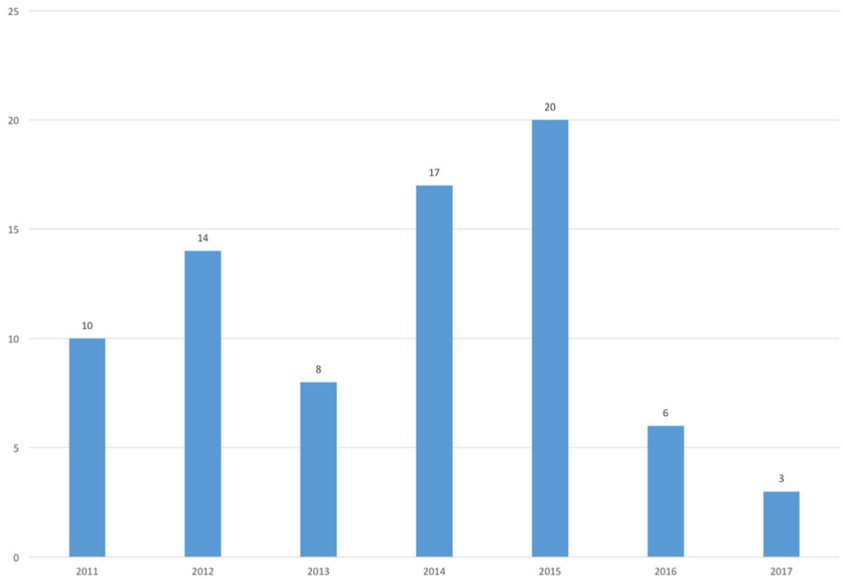

Fig. 2. Number of publications related to glenohumeral internal rotation deficit (GIRD) per year.

While the majority of studies mentioned a concomitant increase in dominant arm external rotation, none of the studies provided a precise side-to-side difference in external rotation.

Discussion

This systematic review of recent GIRD-related studies identified significant shortcomings in the available literature. The discrepancies in the literature are most apparent in the overall quality of clinical evidence and the distribution of research. Overall, there was an overwhelming number of studies with low-level evidence. Furthermore, the majority of studies included in this review were epidemiologic in nature or review articles. The lack of clinical and standardized patient-reported outcome data is somewhat discouraging as this information is critical for improving patient care and refining both surgical and non-surgical management. Of the included clinical studies, the definition of GIRD was highly variable and largely inconsistent with the most commonly accepted definition of GIRD [17]. Based on the available literature included in this report, successful non-operative management of GIRD can be achieved in the vast majority of patients through a variety of modalities emphasizing stretching and massage. Operative management is successful in restoring range of motion and returning athletes to competition when GIRD is unresponsive to stretching; however, specific information regarding which patients will be refractory to non-operative management is lacking.

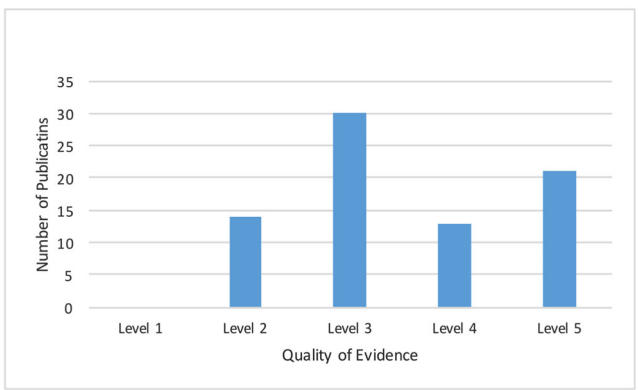

Fig. 3. Levels of evidence of publications related to glenohumeral internal rotation deficit (GIRD) from 2011 to 2017.

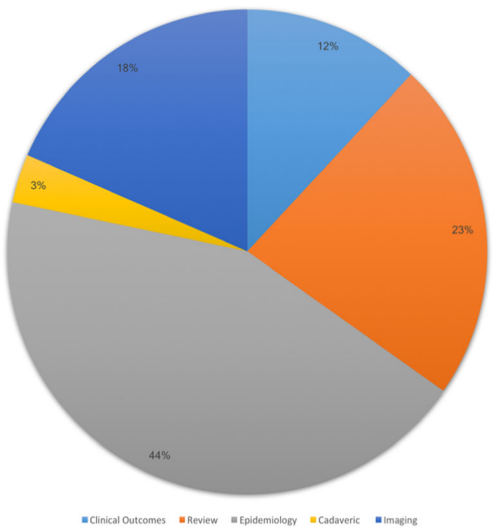

Fig. 4. Distribution of studies related to glenohumeral internal rotation deficit (GIRD) by research focus.

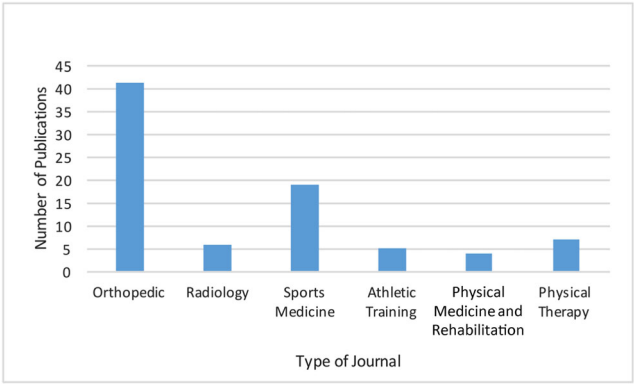

Fig. 5. Number of articles per journal type from 2011 to 2017.

This review also has several limitations. It is a review of current trends in clinical outcomes and study quality, and as such does not provide insight into more focused clinical practices regarding GIRD. It is likely that there is significant heterogeneity among studies that was not evaluated. Additionally, only articles published in English were included, which presents the potential for language and publication bias. This is particularly relevant considering that two-thirds of all included studies were conducted in the USA.

Four included studies were randomized controlled trials [2, 24, 28, 34], which were all deemed to be level-II evidence, either due to methodologic characteristics involving the process of randomization and risk of bias or due to the power of the study. Salamh and colleagues [28] evaluated asymptomatic volleyball players with GIRD who were treated with horizontal adduction stretching with or without the aid of scapular stabilization to evaluate the effect on internal rotation and posterior shoulder tightness. Both Moore et al. [24] and Yang et al. [34] investigated various massage techniques for improving rotational deficits. Bailey et al. [2] evaluated patients with GIRD randomized to either instrumented manual therapy with self-stretching or manual therapy alone. All studies demonstrated a significant improvement in internal rotation deficit, without a specific technique being unequivocally superior. In all of these studies [2, 24, 28, 34], there are inherent limitations due to their size, methodology, and significant risk of potential bias, which limits our interpretation of the findings.

The definition of GIRD was highly variable and inconsistent across all included clinical studies. Four of the included studies [12, 13, 26, 28] defined GIRD as a 10° or greater side-to-side discrepancy in internal rotation, and three [1, 2, 20] defined GIRD as a 15° or greater side-to-side difference with internal rotation. Yang et al. [34] used a 10% or greater side-to-side internal rotation deficit as part of their inclusion criteria. None of the above-mentioned definitions for GIRD match the current consensus definition for GIRD [17]. Moreover, Burkhart and colleagues [3] noted that an acceptable level of GIRD was less than 20° or less than 10% of the total motion in the non-throwing shoulder. Therefore, one must question the clinical implications of studies reporting on non-pathologic GIRD. Consistency and uniformity in the definition of clinical pathology is essential for comparative studies to evaluate clinical response to treatment. This review highlights significant discrepancies in this regard.

The distribution of research included in this review appears to favor studies assessing the epidemiology of GIRD and review articles as opposed to evaluating clinical, therapeutic, and patient-reported outcomes. While important clinical evidence can be gleaned from epidemiologic studies, clinical data evaluating the effects of different treatment modalities is also essential to enhance our understanding of patient management. Clinical studies comprised only 12% of included studies; only cadaveric studies represented a smaller contribution (3%). Of all included clinical studies [1, 5, 20, 24, 28, 34], only Codding and colleagues [5] discussed an option for surgical management, whereas all other clinical studies [1, 2, 6, 12, 13, 20, 24, 26, 28, 34] focused on various stretching and massage modalities.

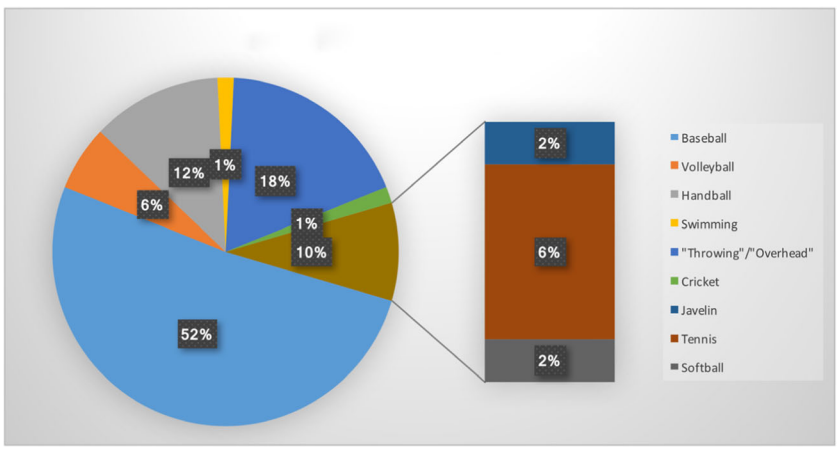

Fig. 6. Publications related to glenohumeral internal rotation deficit (GIRD) by sport.

This study highlights the need for more robust clinical evaluation of patients with GIRD. Establishing a standardized definition and method of measurement to limit variable assessment and reporting is paramount to draw more uniform conclusions. Once established, this will provide the foundation for prospective clinical assessment with validated outcome measures to determine the pathological characteristics and associated conditions of patients with GIRD. Future research that distinguishes the clinical characteristics and treatment options between symptomatic and asymptomatic patients would be highly relevant. Preventive treatment strategies, risk factors for additional injury, and failed non-operative treatment can then be assessed in a clinically meaningful way to best determine how to approach the overhead athlete with GIRD.

This systematic review has various strengths. This study provided a comprehensive evaluation of recent GIRD-related publications in an attempt to evaluate the most up to date clinical evidence for the management of GIRD. We utilized broad search terms and duplicate assessment of study eligibility. The use of piloted data extraction forms ensured comprehensive data extraction and analysis. The agreement between reviewers regarding study eligibility was near perfect. We are unaware of any studies to date that have provided an evaluation of the current trends in clinical outcomes and overall study quality in the literature pertaining to GIRD.

In conclusion, current trends in clinical outcomes and study quality pertaining to GIRD-related literature focus predominantly on epidemiologic and review articles, with limited interest in clinical, therapeutic, or patient-reported outcomes. There is a lack of high-quality evidence and a predominance of level-IV and level-V evidence. Clinical studies demonstrates that the vast majority of patients respond to non-operative treatment; however, inconsistent definition of GIRD and study heterogeneity limits a more robust analysis. Studies evaluating the characteristics of patients that are unlikely to respond to non-operative treatment are lacking and would have significant clinical importance. Future research addressing these knowledge gaps in the literature will improve our understanding and management of GIRD in the overhead athlete.

Compliance with Ethical Standards

Conflict of Interest: Jacob M. Kirsch, MD, Neil K. Bakshi, MD, Olufemi R. Ayeni, MD, MSc, FRCSC, and Moin Khan, MD, MSc, FRCSC, declare that they have no conflicts of interest. Asheesh Bedi, MD, reports being a paid consultant to Arthrex, outside the submitted work.

Human/Animal Rights: N/A

Informed Consent: N/A

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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