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Glenohumeral Rotational Range of Motion in Collegiate Overhead-Throwing Athletes During an Athletic Season

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Context: Repetitive throwing at high velocities leads to altered range of motion (ROM) in the dominant shoulder compared with the nondominant shoulder in overhead-throwing athletes. Loss of glenohumeral internal rotation (IR), or glenohumeral internal-rotation deficit (GIRD), is associated with shoulder injuries. Therefore, GIRD should be evaluated during the clinical examination of the thrower's shoulder.

Objective: To assess glenohumeral ROM in competitive baseball and softball athletes at 3 intervals over the course of an athletic season in order to (1) examine changes in ROM over time and (2) monitor the prevalence of GIRD.

Design: Observational, repeated-measures study.

Setting: Collegiate athletic training room.

Patients or Other Participants: Forty-eight healthy National Collegiate Athletic Association (NCAA) Division I or Division II athletes (age = 19 ± 1 years, height = 174 ± 14 cm, mass = 77.8 ± 18.1 kg; 19 softball, 29 baseball players).

Main Outcome Measure(s): We measured glenohumeral IR, external rotation (ER), total arc (ER + IR), and GIRD at 3 times: prefall, prespring, and postspring. We calculated GIRD in 2 ways: as the difference in IR between dominant and nondominant shoulders and as the percentage of the total arc.

Results: In the dominant shoulder, ER increased during the season ($F_{2,96}$ = 17.433, $P < .001$), but IR remained the same ($F_{2,96}$ = 1.839, P = .17). The total arc in the dominant shoulder increased between time intervals ($F_{2,96}$ = 14.030, $P < .001$); the mean difference between prefall and postspring measurements was 9.694° ($P < .001$), and the mean difference between prefall and postspring measurements was 10.990° ($P < .001$). In the nondominant shoulder, ER increased over the season ($F_{2,96}$ = 23.395, $P < .001$), but IR did not change over the season ($F_{2,96}$ = 0.087, P = .90). The total arc in the nondominant shoulder increased between prefall and prespring measurements and between prefall and postspring measurements ($F_{2,96}$ = 18.552, $P < .001$). No changes were noted in GIRD over time. However, more athletes with GIRD were identified with the GIRD (IR difference) calculation in prefall (n = 6) than in prespring (n = 1) and postspring (n = 4) (Cochran Q = 5.2, P = .07). In addition, more athletes with GIRD were identified with the GIRD (% total arc) calculation in postspring (n = 6) than in prefall (n = 5) or prespring (n = 4) (Cochran Q = 2.6, P = .27).

Conclusions: Healthy NCAA Division I and Division II athletes did not display changes in glenohumeral IR over an athletic season. However, they gained in ER and total arc during the season in both shoulders. Future researchers should investigate changes over multiple seasons. The 2 methods of calculating GIRD identified different athletes as having GIRD, indicating that additional investigation is warranted to determine the clinical benefits of each method.

Key Words: shoulder, upper extremity, glenohumeral internal-rotation deficit

Key Points

- No changes occurred in internal rotation over the course of the season.
- External rotation increased in the dominant shoulder by 11° among prefall, prespring, and postspring season measurements, but this gain was secondary to the demands of throwing.
- The total arc of motion increased in the dominant shoulder by 11° to accommodate the external rotation gains.
- The internal rotation difference and percentage of total arc calculations for glenohumeral internal-rotation deficit represent different deficits in range of motion.

Repetitive pitching at high velocities over time leads to chronic adaptations to soft[1,2] and osseous[3,4] tissues in the glenohumeral joint. These anatomic adaptations likely lead to differences in range of motion (ROM) when shoulders are compared bilaterally[5–7] and when overhead-throwing athletes are compared with non–overhead-throwing athletes.[2,8] Although ROM changes may be adaptive, some changes in ROM are associated with pain,[9] decreased performance,[2,9,10] and shoulder disorders.[2,11] Researchers have theorized that throwers experience an acute decrease in internal rotation (IR); however, these authors reported comparisons between throwing and nonthrowing shoulders,[9] between throwers and nonthrowers,[12] or among throwers of different ages.[9,13] No one has measured changes over time in the same group of throwers. Researchers[13] have demonstrated that differences in ROM are present between athletes aged 15 to 28 years and athletes aged 8 to 12 years, with the older athletes displaying greater ROM than the younger athletes. Reinold et al[14] reported acute changes in the ROM of professional pitchers, with a decrease in IR and total arc after a pitching session. Only Ellenbecker and Roetert[15] have monitored athletes for changes in shoulder ROM over 1 athletic season; however, they did not observe changes in ROM in these tennis players. In reports[5,7,16] suggesting a change in overhead-throwing athletes' ROM, investigators proposed that external rotation (ER) increased and IR decreased. When IR decreases beyond the gain in ER, the condition is called *glenohumeral internal-rotation deficit* (GIRD).[2] Burkhart et al[2] proposed that GIRD may be associated with injury and, therefore, suggested that clinicians assess ROM in competitive throwers. However, with no descriptions of the typical changes in throwers' glenohumeral ROM over a season, identifying atypical changes is difficult. Therefore, the purpose of our study was to assess passive glenohumeral ROM in competitive baseball and softball athletes at 3 intervals over the course of an athletic season in order to (1) examine changes in ROM over time and (2) monitor the prevalence of GIRD. We hypothesized that ER in the dominant shoulder would increase among prefall, prespring, and postspring season measurements. We also hypothesized that the magnitude of IR in the dominant shoulder would decrease and would result in a decrease in total arc of motion.

METHODS

We used an observational, repeated-measures design to investigate differences in glenohumeral ROM measured at 3 separate times over the course of 1 collegiate athletic season. Our independent variable was time of athletic season at 3 levels: prefall (last week of September), prespring (second week of January), and postspring (first week of May) seasons. Our dependent variables were 3 measures of glenohumeral ROM (ER, IR, and total arc) and GIRD.

Participants

Twenty-nine healthy male baseball athletes (age = 20 ± 1.5 years, height = 180.1 ± 14.2 cm, mass = 87.1 ± 10.9 kg; 14 pitchers, 12 infielders, 4 outfielders [1 athlete played both infield and outfield]) and 19 healthy female softball athletes (age = 20 ± 1.2 years, height = 165.8 ± 8.5 cm, mass = 64.7 ± 17.8 kg; 5 pitchers, 11 infielders, 3 outfielders) at National Collegiate Athletic Association Division I or II institutions in south Florida participated in this study. Each participant completed a health history and sport participation questionnaire (HHSPQ) about demographics, years of athletic participation, position played, and history of shoulder and neck disorders and pain. We used the HHSPQ to exclude volunteers without medical clearance at the time of testing and those reporting shoulder or neck surgery within the year before testing. Because our objective was to observe changes over an entire athletic season, we excluded from statistical analyses athletes who did not complete the season or who did not participate in all 3 testing sessions. Of the 76 athletes who volunteered to participate, we excluded 28, including 4 who sustained throwing-side shoulder or elbow injuries; 48 participants were available for data collection.

As this was strictly an observational study, no investigator was the team athletic trainer (AT) and no investigator altered or suggested changes to stretching regimens for any team or athlete participating in this study. Furthermore, we made no attempt to control the number of practice or game exposures for each athlete. The athletes participated in traditional baseball or softball team stretches and warm-ups comprising sporadic and unsupervised general upper and lower extremity stretching. Typical nonthrowing upper extremity active warm-ups included a series of large and small arm circles and included static stretches targeting the triceps, biceps, pectoralis, and wrist flexors and extensors. No team followed a structured, formally monitored, or clinician-led program. All participants provided written informed consent, and the study was approved by the institutional review board of each university.

Procedures

On each testing day, athletes reported to their athletic training rooms for testing before engaging in throwing, resistance training, or vigorous activity. We instructed the athletes to wear shirts that enabled observation of the glenohumeral joints and coracoid processes. Two ATs (P.M.D. and P.A.M.) were the investigators at their respective institutions.

To measure glenohumeral ROM, we used a mechanical inclinometer (Sears, Roebuck & Co, Hoffman Estates, IL) with a manufacturer-reported accuracy of 1°. We assessed passive rotational ROM for each glenohumeral joint using the standard goniometric technique and arm position for measures of maximal ER and IR.[16] We also used a visual inspection technique to control for scapulothoracic motion, which research[17] has indicated yields reliable measures of isolated glenohumeral motion. To perform the visual inspection technique, the investigator passively moved each athlete's shoulder into IR and ER and recorded the measure when the acromion began to rise or at a firm capsular end-feel. Authors[17] have suggested that this visual inspection technique is more easily applied clinically, requiring only 1 practitioner while providing an accurate measure of isolated glenohumeral motion. Our 2 investigators displayed excellent interrater and intrarater reliability using this technique in a pilot study, with intraclass correlation coefficient (2,1) values of 0.79 to 0.96 for all measures except nondominant IR (Table 1).

For each athlete, we randomly assigned the arm to be measured first and repeated the same measures on the other arm. The participant lay supine on a treatment table with the test arm abducted to 90°. The investigator placed a towel under the humerus to avoid horizontal extension of the glenohumeral joint. Using two 1-in (0.0254-m) elastic straps with hook-and-loop closures, the investigator firmly secured the inclinometer to the participant's forearm at the distal radius. Each measure began with the athlete's elbow flexed to 90° in neutral glenohumeral rotation and perpendicular to the floor. The tabletop stabilized the scapula posteriorly. The investigator rotated the glenohumeral joint while monitoring the scapula for motion (Figure 1). We considered maximal ROM to be achieved when rotation ceased upon a firm capsular end-feel or at the position immediately before appreciable motion of the scapula.[17] The investigator noted the angle indicated on the inclinometer before rotating the humerus back to the neutral position. We measured each motion twice and recorded the average of the 2 trials for each measurement session (prefall, prespring, and postspring seasons). There were 16 weeks between the prefall and the prespring

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Table 1. Interrater Reliability for Measures of Glenohumeral Internal and External Rotation and Total Arc of Motion in Dominant and Nondominant Shoulders

Motion	Intraclass Correlation Coefficient (2,1)	*P* Value	SD	SEM
Dominant internal rotation	0.79	.015	5.6	2.57
Dominant external rotation	0.94	<.001	12.1	2.94
Nondominant internal rotation	0.72	.045	5.2	2.75
Nondominant external rotation	0.96	<.001	9.3	1.66
Dominant total arc	0.93	<.001	11.5	2.89
Nondominant total arc	0.87	.002	8.2	2.96

measurements and 15 weeks between the prespring and postspring measurements. Next, we calculated GIRD using the following 2 commonly reported[2] definitions: (1) GIRD (IR difference) = nondominant IR − dominant IR and (2) GIRD (% total arc) = (nondominant total arc − dominant total arc)/nondominant total arc.

Statistical Analysis

The Levene test for homogeneity indicated that parametric tests were appropriate ($P > .05$). For each measure of glenohumeral ROM, we used a repeated-measures analysis of variance to assess changes among prefall, prespring, and postspring values. When results indicated differences in ROM or total arc, we performed post hoc pairwise comparisons with Bonferroni adjustments. We coded GIRD values as −1 (without GIRD) and 1 (with GIRD) to perform Cochran *Q* tests to assess differences in the prevalence of GIRD at prefall, prespring, and postspring for both GIRD calculations. The α level for all comparisons was set a priori at .05. We performed statistical analyses with SPSS (version 14.0; SPSS Inc, Chicago, IL).

Figure 1. Measuring technique for passive glenohumeral internal-rotation range of motion using a mechanical inclinometer and the visual inspection technique to limit scapulothoracic motion.

RESULTS

Changes in ROM

Dominant ER and total arc increased over time (31 weeks) (Table 2). Although this is not a significant finding ($F_{2,96} = 1.839$, $P = .17$, $1-\beta = .35$), athletes gained 2° of glenohumeral IR in the dominant shoulder between prefall and prespring measurements (16 weeks) and lost 1.5° between prespring and postspring measurements (15 weeks; n = 23), resulting in a net gain of less than 1° between prefall and postspring measurements (Figure 2). Nondominant ER and total arc increased over time (31 weeks) (Table 2). Although this is also not a significant finding ($F_{2,96} = 0.087$, $P = .90$, $1-\beta = .06$), athletes lost less than 1° of glenohumeral IR in the nondominant shoulder between prefall and prespring measurements and lost less than 1° between prespring and postspring measurements, equaling a loss of less than 1° between prefall and postspring measurements.

Changes in Prevalence of GIRD

We did not observe any changes over time in the number of athletes displaying GIRD (IR difference) ($Q = 5.2$, $P = .07$) or GIRD (% total arc) ($Q = 2.6$, $P = .27$). However, more athletes with GIRD were identified with the GIRD (IR difference) calculation in prefall (n = 6) than in prespring (n = 1) and postspring (n = 4). In addition, more athletes with GIRD were identified with the GIRD (% total arc) calculation in postspring (n = 6) than in prefall (n = 5) or prespring (n = 4). At the prefall measurement, only 2 athletes with GIRD were identified with both calculations. At the prespring measurement, 1 athlete with GIRD was identified with both calculations. At the postspring measurement, no athlete with GIRD was identified with both calculations. The athletes identified during the prefall measurement with the GIRD (IR difference) calculation were not identified at any other measurement time using the same calculation. One athlete with GIRD was identified with the GIRD (% total arc) calculation for all 3 measurement times.

DISCUSSION

Our primary purpose was to assess differences in passive glenohumeral rotational ROM in overhead-throwing athletes among prefall, prespring, and postspring season measurements. In the dominant shoulder, the ROM means we observed were comparable with values reported by Myers et al,[11] with ER values ranging from 96.2° to 106.9° and IR values ranging from 45.5° to 47.5° (Table 2). Based on previous research,[5–7] we hypothesized that over the course of an athletic season throwers' dominant shoulders would lose IR and gain ER, leaving the total arc unchanged. Our results indicated no changes in IR among the prefall, prespring, and postspring season measurements, which did not support our hypothesis. Although not a significant finding ($F_{2,96} = 1.839$, $P = .17$), we observed decreases in IR between prespring and postspring measurements in 23 of 48 participants. This observation may represent a trend toward a decrease in IR, which may have been evident if the sample size had been larger ($1-\beta = .35$). We observed an 11° increase in dominant ER from prefall

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Table 2. Comparisons of Throwers' Degrees of Glenohumeral Internal and External Rotation and Total Arc of Motion Among Prefall, Prespring, and Postspring Measurements in Dominant and Nondominant Shoulders

Motion	Measurement ° Prefall, Mean ± SD	Prespring, Mean ± SD	Postspring, Mean ± SD	$F_{2,96}$	*P* Value	Effect Size	Power (1−β)
Dominant internal rotation	45.5 ± 11.1	47.5 ± 8.5	45.8 ± 10.0	1.839	.17	NA	.35
Nondominant internal rotation	52.7 ± 11.8	52.6 ± 10.2	52.2 ± 11.3	0.087	.90	NA	.06
Dominant external rotation	96.2 ± 12.7[a,b]	104.0 ± 17.0[a,c]	106.9 ± 19.9[b,c]	17.433	<.001	0.27	NA
Nondominant external rotation	92.0 ± 10.0[a,b]	101.7 ± 15.2[a]	104.4 ± 17.8[b]	23.395	<.001	0.33	NA
Dominant total arc	141.7 ± 15.0[a,b]	151.4 ± 16.9[a]	152.4 ± 19.9[b]	14.030	<.001	0.23	NA
Nondominant total arc	144.7 ± 14.4[a,b]	145.3 ± 15.0[a]	156.6 ± 17.3[b]	18.552	<.001	0.28	NA

Abbreviation: NA, not applicable.

[a] Indicates difference for each measurement between prefall and prespring ($P < .05$).
[b] Indicates difference for each measurement between prefall and postspring ($P < .05$).
[c] Indicates difference for each measurement between prespring and postspring ($P < .05$).

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to postspring season measurements, which supported our hypothesis. We believe the gains in ER were secondary to the demands of throwing. The late cocking phase of throwing requires maximal ER to achieve optimal internal-rotation velocity.[2] Because the magnitude of IR did not change from prefall to postspring measurements in the dominant shoulder, the total arc of motion increased 11° to accommodate the ER gains, which did not support our hypothesis.

When investigating ROM in professional pitchers, Reinold et al[14] observed a decrease in IR in the dominant shoulder immediately and 24 hours after throwing, compared with prethrowing measurements. However, they did not observe a change in dominant shoulder ER; therefore, total arc decreased, reflecting the loss of IR. Our findings revealed different changes in ROM compared with the findings of these other investigators.[14] Such inconsistencies between studies may reflect differences between the populations and research designs. We included collegiate baseball and softball players of all positions, whereas Reinold et al[14] included professional baseball pitchers only. We measured ROM over an entire season, whereas Reinold et al[14] assessed players after a pitching session. However, we can compare the changes we observed over the spring

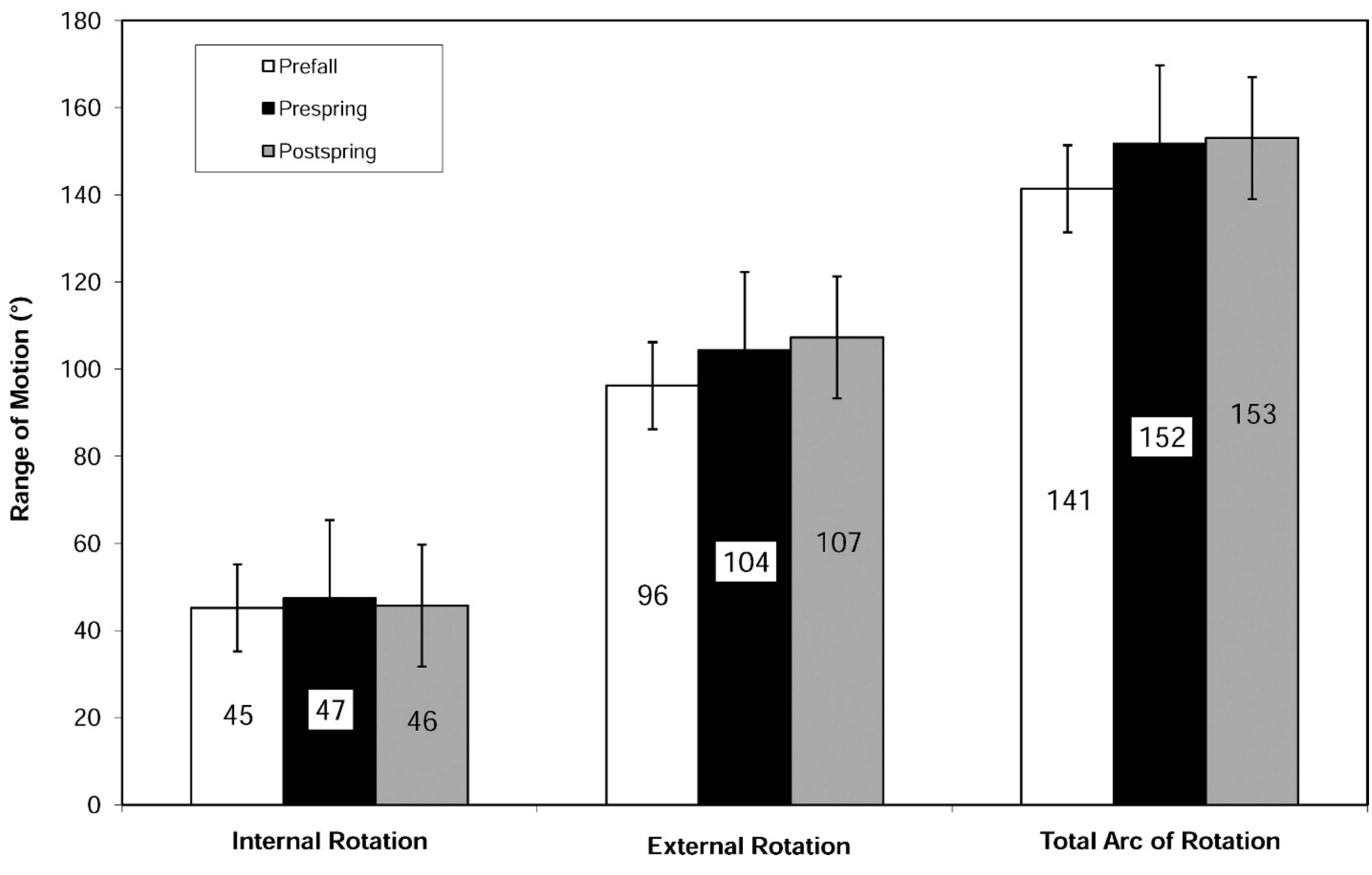

Figure 2. Comparisons in throwers' degrees of glenohumeral internal and external rotation and total arc of motion among prefall, prespring, and postspring measurements in the dominant shoulder.

season (prespring to postspring) with those that Ellenbecker and Roetert[15] observed in tennis athletes over a 4-month season. These researchers[15] did not observe changes in glenohumeral ROM over their tennis season, whereas we observed gains in ER and total arc over a similar period. We may attribute such contrasting results to the differences in biomechanical demands between baseball or softball and tennis or to differences in measurement techniques. We isolated glenohumeral motion from scapulothoracic motion using the visual inspection technique; however, some researchers have used anterior-posterior manual force[5,9] and others have not.[13,18]

Investigators[9,13] have compared ROM among throwers of different ages. Ruotolo et al[9] observed that athletes older than 21 years had similar magnitudes of IR or ER compared with athletes younger than 18 years; however, the younger athletes demonstrated a greater total arc of motion compared with the older athletes. Levine et al[13] investigated differences among athletes in 3 age groups (ranges, 8–12, 13–14, and 15–28 years) and reported that ER and IR were greatest in athletes aged 13 to 14 years, whereas the athletes aged 15 to 28 years demonstrated more IR than did those aged 8 to 12 years. This previous research indicated that differences exist among age groups, but the effect of time on individual throwers remains unknown. The collegiate overhead-throwing athletes in our study gained ER and total arc of motion over time in the dominant shoulder.

Our secondary purpose was to observe the prevalence of GIRD in throwers at prefall, prespring, and postspring measurements. The GIRD (IR difference) calculation revealed that more athletes displayed GIRD prefall ($n = 6$) than prespring ($n = 1$) or postspring ($n = 2$), whereas the GIRD (% total arc) calculation revealed that more athletes displayed GIRD postspring ($n = 6$) than prefall ($n = 5$) or prespring ($n = 4$). However, the number of athletes identified with either calculation was not different among the 3 periods. Both calculations for GIRD appeared to quantify a specific characteristic of relative ROM, yet they reflected different deficits. Researchers[2] have proposed use of these calculations based on the assumption that the nondominant shoulder displays ideal ROM. The GIRD (IR difference) calculation reflects solely bilateral differences in IR, whereas the GIRD (% total arc) calculation incorporates both IR and ER ROM. Clinicians should be aware that the 2 calculations represent different deficits in ROM.

Clinical Application

Because of the proposed relationship between GIRD and injury, clinicians should monitor changes in overhead-throwing athletes' glenohumeral ROM over a sport to identify at-risk participants. When monitoring changes in ROM, clinicians should be aware of the typical changes that may take place in healthy throwers over an athletic season. Our results indicated that throwers gain much ER and total arc over their seasons but that their IR does not change. Athletes displaying ROM changes that show large variation from the changes we observed in our healthy athletes (eg, gaining more than 11° of ER or losing more than 1° of IR) may have "atypical" acute adaptations that warrant further clinical investigation. Some changes in ROM are associated with pain,[9] decreased performance,[2,9,10] and shoulder disorders[2,11]; therefore, it is crucial to be aware of changes in ROM, whether they occur over a single season or over multiple seasons. Clinicians aiming to compare their values with those previously reported should also understand the differences among measurements taken using various techniques and calculations of GIRD. Our investigators demonstrated high reliability, so their findings could be compared with the findings of other clinicians; however, this might not always be applicable in the clinical setting.

Limitations

Our results were limited to collegiate baseball and softball athletes participating in the entire athletic season (fall through spring). Because we sought to observe the effects of an entire season, we included only athletes who were able to participate uninterrupted. We included athletes who reported pain as long as they continued to participate in practices and games. Only 4 of the 76 athletes who initially volunteered to participate sustained severe dominant-arm injuries during the season; therefore, we could not examine the relationship between ROM and injury. We observed small to medium effect sizes for our significant findings ($\eta^2 \leq 0.33$), indicating that although these changes were significant, the relative importance of such changes remains unclear. Those comparisons among IR values, yielding findings that were not significant, displayed limited observed power ($1-ß < .8$), indicating that our sample size ($N = 48$) may not have enabled us to observe such changes.

CONCLUSIONS

To our knowledge, we are the first investigators to monitor changes in glenohumeral ROM in throwers over the course of an athletic season. We observed an increase in glenohumeral ER in both the dominant and nondominant shoulders over the course of 1 athletic season; however, we did not observe a change in IR, as we had hypothesized. We also did not observe changes in the prevalence of athletes displaying GIRD over the athletic season. Future researchers should investigate the long-term effects of throwing on ROM in groups of competitive throwers of various ages.

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