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original research

Associations Among Hip and Shoulder Range of Motion and Shoulder Injury in Professional Baseball Players

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Context: The overhead throwing motion is complex, and restrictions in range of motion (ROM) at the hip may place additional demands on the shoulder that lead to injury. However, the relationship between hip and shoulder ROM in athletes with and without a history of shoulder injury is unknown.

Objective: To (1) determine if differences exist in hip and shoulder ROM between professional baseball players with a history of shoulder injury and those with no history of shoulder injury and (2) assess relationships between hip and shoulder ROM in these players.

Design: Cross-sectional study.

Patients or Other Participants: Fifty-seven professional baseball players.

Main Outcome Measure(s): Outcome measures consisted of hip extension and internal rotation, shoulder internal and external rotation, glenohumeral internal-rotation deficit, and history of shoulder injury. Differences in shoulder and hip ROM were assessed with a 1-way analysis of variance. Associations between hip and shoulder ROM were assessed with linear regression.

Results: Nonpitchers with a history of shoulder injury had more external rotation and less internal rotation of the shoulder than nonpitchers with no history of shoulder injury. Glenohumeral internal-rotation deficit was greater in both pitchers and nonpitchers with a history of shoulder injury. The relationship between dominant hip extension and shoulder external rotation was significant for pitchers with a history of shoulder injury and nonpitchers with a history of shoulder injury.

Conclusions: Shoulder injury may be associated with specific measures of hip and shoulder ROM, and hip extension and shoulder external rotation may be related in baseball players with a history of shoulder injury. Additional research is necessary to understand the specific mechanisms of shoulder injury in the throwing athlete.

Key Words: throwing athletes, injuries, glenohumeral internal-rotation deficit, kinetic chain

Key Points

- Shoulder internal rotation, nondominant hip internal rotation, and glenohumeral internal-rotation deficit were different in nonpitchers with and without a history of shoulder injury.
- Dominant hip extension and shoulder external rotation were associated with a history of shoulder injury in both pitchers and nonpitchers.

Shoulder injuries in baseball players are common. McFarland and Wasik[1] reported that upper extremity injuries were responsible for 75% of the total time lost because of injury in a collegiate baseball population, with rotator cuff tendinitis cited as the most frequent injury. Previous researchers[2] have demonstrated significant stresses on the shoulder during the overhead throwing motion, and it is generally believed that these stresses, combined with the innate repetition of the overhead arm motion in baseball, can lead to shoulder injuries.

Investigations[2–6] of the biomechanics of the pitching motion have focused almost exclusively on the shoulder and elbow. However, the pitching motion is very complex and involves an elaborate transfer of energy throughout the entire body. For example, the scapula and trunk are believed to play an important role in overhead athletic activity.[7,8] Thus, large forces are not restricted to the shoulder alone but rather are imparted across all the anatomical joints involved in the throwing motion.

Forces at the shoulder may be greater in an athlete who is compensating for injuries or range-of-motion (ROM) restrictions at joints some distance from the shoulder (eg, lower back, hip, ankle).[9] For instance, we hypothesize that poor extension (EXT) of the dominant hip (ie, the hip on the same side as the throwing shoulder) during the maximal cocking or acceleration phases of the pitching motion could cause the pitcher to increase the amount of shoulder external rotation (ER) in an attempt to achieve the desired throwing motion.

We further hypothesize that this phenomenon—commonly referred to as "flying open" in baseball—could increase stress on the anterior shoulder structures and potentially increase the likelihood of shoulder injury. Similarly, restricted internal rotation (IR) of the nondominant hip during the follow-through phase of the throwing motion may limit the lower extremity's ability to absorb or dissipate the energy generated during the acceleration phase. In turn, this may place greater demands on the rotator cuff to act as a brake to decelerate the arm during follow-through and thus lead to posterior shoulder dysfunction and rotator cuff injury.

Although hip ROM limitations could result in greater demands on the shoulder in an attempt to achieve the desired throwing motion, we are unaware of any data characterizing differences in hip and shoulder ROM between injured and uninjured professional baseball pitchers. Therefore, the purpose of our study was to determine if differences existed in hip and shoulder ROM between professional baseball players with a history of shoulder injury and those with no history of shoulder injury. In addition, we assessed the relationship between hip and shoulder ROM in professional baseball players. We hypothesized that limited ROM of the hip is associated with altered shoulder motion and the development of shoulder injuries.

METHODS

Participants

A total of 57 professional baseball players (average age, 26.3 years; range, 21–36 years) volunteered for this study. Inclusion in the study required the athletes to be participating in professional baseball. To avoid further injury, potential participants were excluded from the study if they had shoulder or hip pain at the time of ROM measurements. Of the 57 baseball players, 29 were pitchers, 28 played other positions (ie, infield, outfield, or catcher), 16 were left handed, and 41 were right handed. None of the throwers were ambidextrous. All throwers practiced or played (or both) a minimum of 3 times per week; however, throwing frequency data were not collected. The study received institutional review board approval, and we obtained informed consent from each participant.

ROM Measurements

Hip and shoulder ROMs were measured for all participants. Dominant hip IR and nondominant hip IR were measured in the sitting position, whereas dominant hip EXT and nondominant hip EXT were measured in the supine position. Dominant/throwing shoulder IR, dominant/throwing shoulder ER, nondominant shoulder IR, and nondominant shoulder ER were measured in the supine position on a standard plinth. All measurements were taken by a single examiner in a single testing session during preseason physical examinations. Measurements were taken using a goniometer (model G300; Whitehall Manufacturing, City of Industry, CA) with a bubble level attached to the arm, providing a reference point in the effort to optimize accuracy. Passive ROM goniometric assessment has been shown to be the gold standard and reliable when performed by the same tester.[10–14] With a single examiner using this method, a rotational measurement error of $\pm 3°$ has been reported.[10] End ROM was determined by joint end feel, allowing for measurement in a consistent manner.

Hip IR was measured with participants seated at the end of the table with the legs hanging down, with 3 to 4 in (7.62–10.16 cm) between the edge of the table and the popliteal space. The goniometer's axis was aligned through the knee joint, with the stable arm aligned perpendicular to the floor. The movable arm was aligned with the midshaft of the tibia, and the athlete was moved into hip IR until the iliac crest began to move. This procedure was repeated on the opposite side.

Hip EXT was measured using the modified Thomas test position.[15] The hip was not allowed to adduct or abduct during the test. Each participant sat at the edge of the table, with the ischial tuberosities on the edge, and was then asked to lie supine holding both knees to the chest. This procedure minimized movement of the pelvis. The athlete was asked to let go of 1 leg while holding the other to the chest, keeping the back flat on the table. Hip EXT measurements were taken using the same goniometer with the axis on the greater trochanter, the stable arm in line with the trunk, and the movable arm along the midline of the femur. Measurements were taken only when the back remained on the table. The process was repeated on the other side.

Shoulder rotation was measured with the athlete positioned supine on the table with the legs straight and the upper extremity in 90° of abduction in the coronal plane and 90° of elbow flexion with the elbow slightly off the table's edge. Maximum ER was measured with the goniometer's axis in line with the shaft of the humerus, the stable arm perpendicular to the floor, and the movable arm in line with the ulnar styloid. For shoulder IR, a second examiner placed the palm of his hand on the anterior portion of the shoulder to stabilize the scapula and anterior shoulder. Maximum IR was recorded when motion of the acromioclavicular joint was detected. This procedure is consistent with the approach described by Burkhart et al,[16(p406)] who stated that "glenohumeral rotation is measured with the patient supine, the shoulder abducted 90° in the plane of the body, and the scapula stabilized against the examination table by downward pressure applied by the examiner to the anterior aspect of the shoulder." In order to investigate the association between glenohumeral IR deficit (GIRD) and history of shoulder injury, we used these data to calculate the difference between each participant's dominant shoulder and nondominant shoulder IR.

All ROM testing of the dominant and nondominant hips and shoulders was conducted in random order. In addition, the investigator who performed the ROM measurements was blind to each participant's injury history and playing position (ie, pitcher versus nonpitcher).

Each player also completed an injury participation questionnaire. The questionnaire included past medical history, skill level, throwing arm, and positions played. Players were asked about any personal history of shoulder, hip, or elbow injury. An *injury* was defined as a problem within the previous year requiring more than 2 days of nonplay or being on the disabled list and restricted from throwing. The injury was reported by recall, that is, a self-reported recollection of the particular injury event from the athlete's past playing experience.

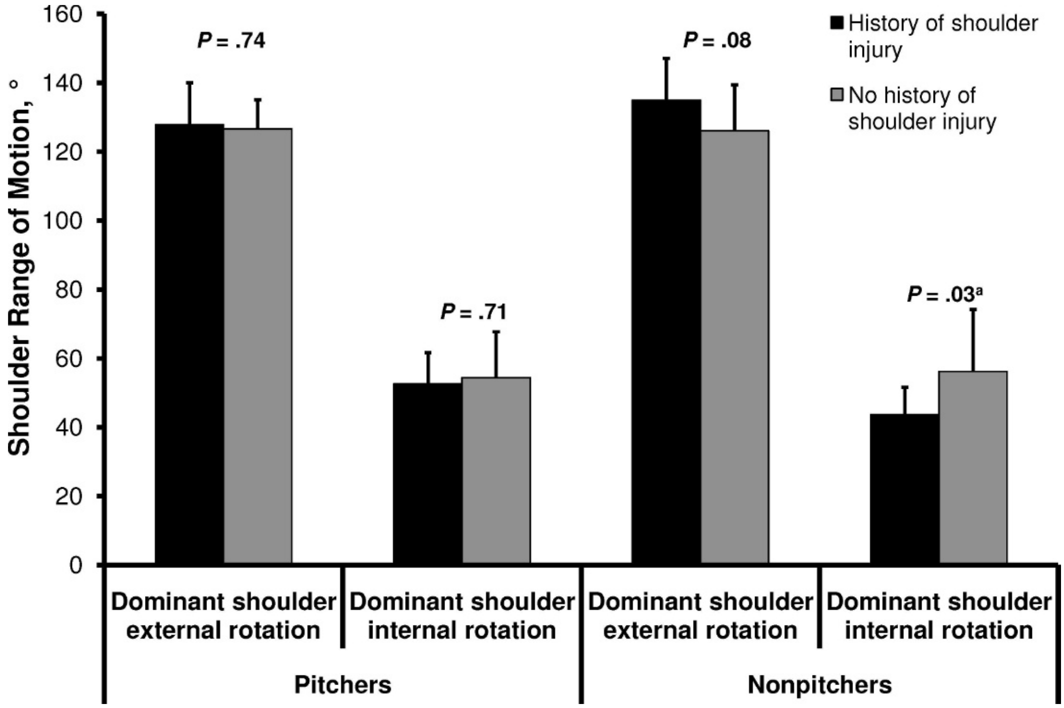

Figure 1. Dominant shoulder range of motion in professional baseball pitchers and nonpitchers. [a] Difference between athletes with and without a history of shoulder injury for dominant shoulder internal rotation in nonpitchers ($P = .03$).

Statistical Analysis

Differences in shoulder and hip ROM measurements between injured and uninjured participants were assessed with a 1-way analysis of variance. In addition, differences between dominant and nondominant shoulder IR were assessed with a 1-way analysis of variance. Data from pitchers and nonpitchers were analyzed separately because we believed that the physical demands and usage characteristics (eg, number of pitches or throws per game) were markedly different between pitchers and nonpitchers. Linear regression was used to assess associations between (1) dominant hip EXT and dominant shoulder ER, (2) dominant hip EXT and dominant shoulder IR, (3) nondominant hip IR and dominant shoulder ER, and (4) nondominant hip IR and dominant shoulder IR. Significance was set at $P < .05$ for all statistical tests.

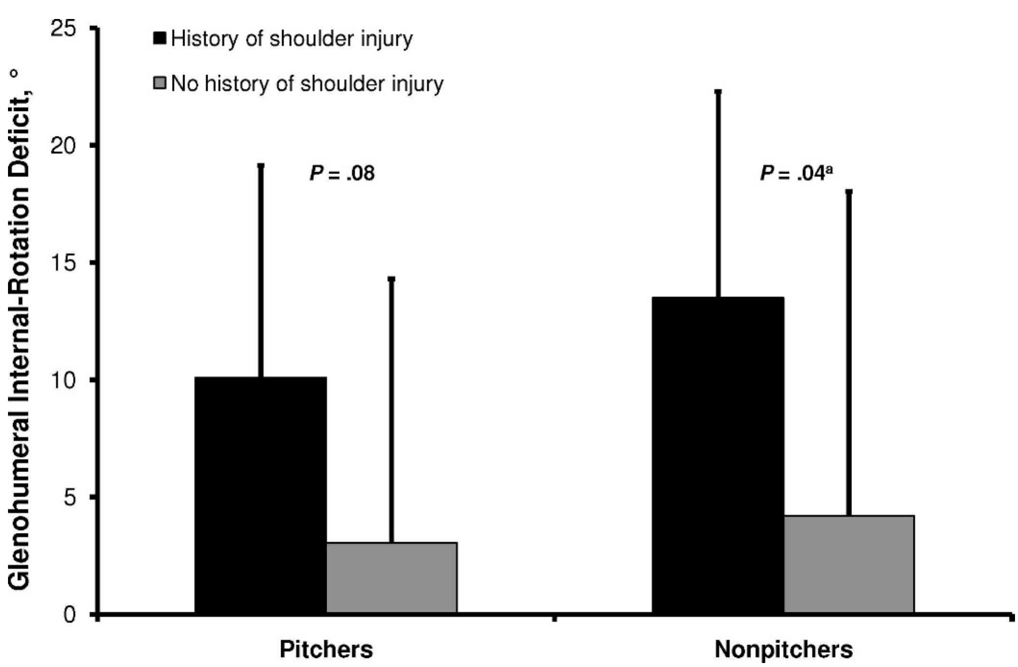

Figure 2. Glenohumeral internal-rotation deficit (difference in internal rotation between the throwing and nonthrowing shoulders) was greater in professional baseball players (both pitchers and nonpitchers) with a history of shoulder injury than in those with no history of shoulder injury. [a] Difference in nonpitchers.

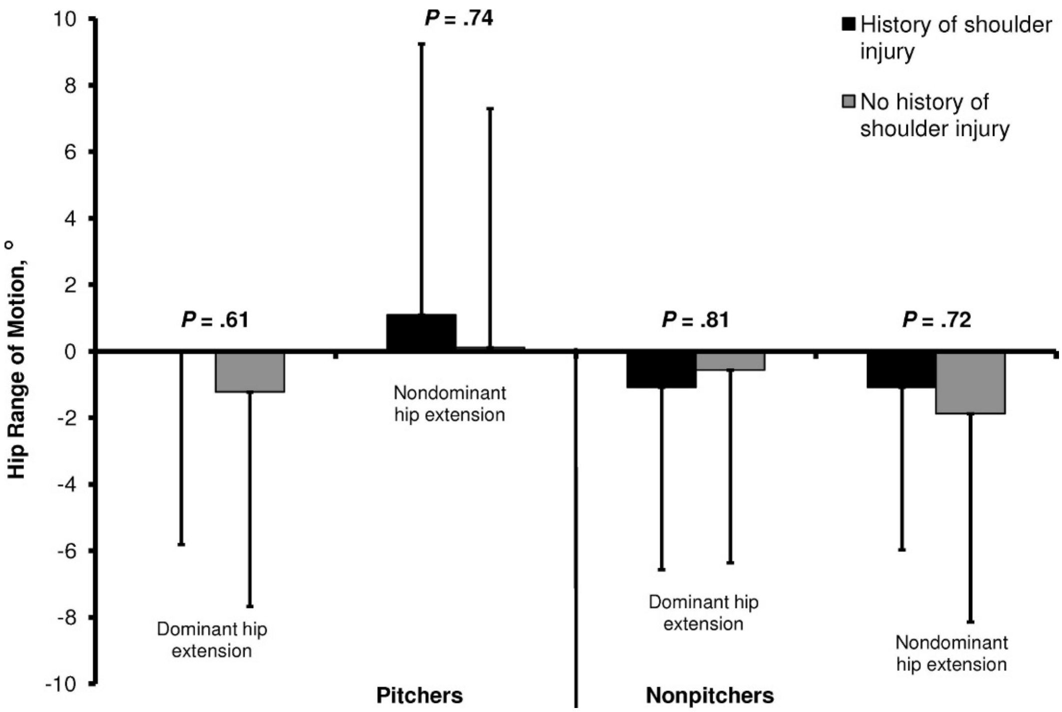

Figure 3. Dominant hip extension and nondominant hip extension in professional baseball pitchers and nonpitchers. No differences were detected between athletes with and without a history of shoulder injury.

RESULTS

On the medical history questionnaire, 11 pitchers reported a history of injury and 18 pitchers reported no history of injury. Of the nonpitchers, 12 reported a history of injury and 16 reported no history of injury.

For shoulder rotation, no differences were detected between pitchers with a history of shoulder injury and pitchers with no history of shoulder injury for either dominant shoulder IR or dominant shoulder ER ($P > .71$; Figure 1). In contrast, nonpitchers with a history of shoulder injury had more dominant shoulder ER ($P =$

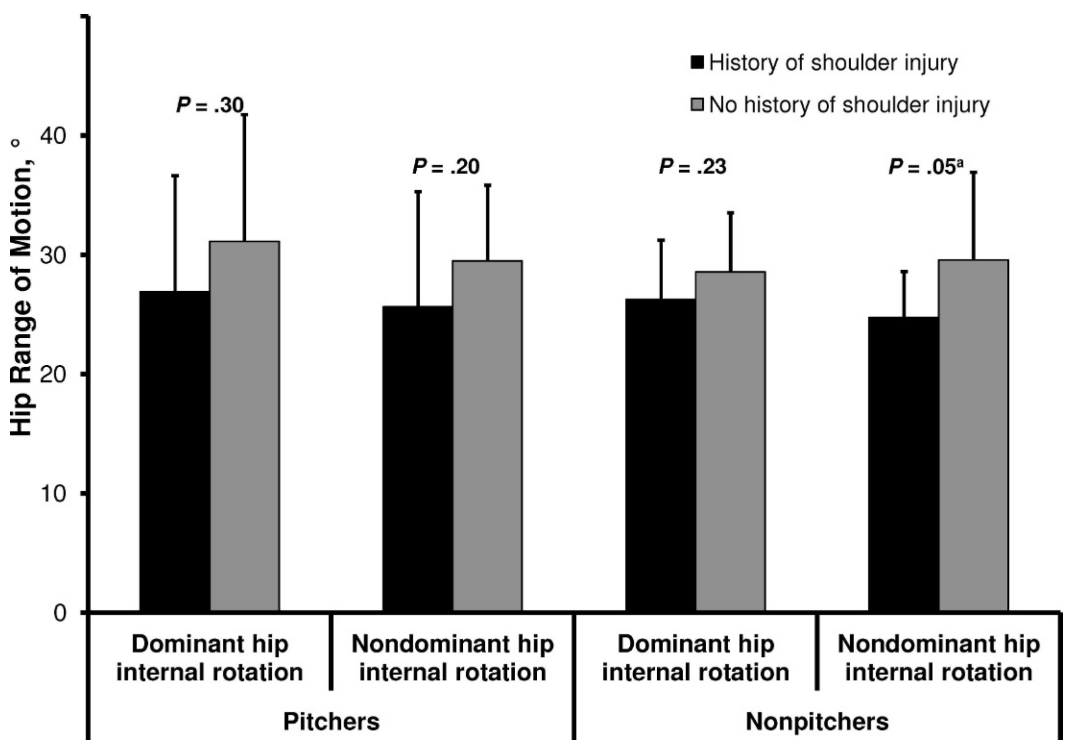

Figure 4. Dominant hip internal rotation and nondominant hip internal rotation in professional baseball pitchers and nonpitchers. [a] Difference in nondominant hip internal rotation between nonpitchers with and without a history of shoulder injury ($P = .05$).

Table 1. Associations Between Dominant Hip Extension and Shoulder Range of Motion

Playing Position	History of Shoulder Injury?	Dominant Shoulder, *r* Value (*P* Value) External Rotation	Internal Rotation
Pitcher	Yes	0.62 (.04)	0.40 (.23)
	No	0.18 (.49)	−0.25 (.32)
Nonpitcher	Yes	−0.64 (.02)	0.51 (.09)
	No	−0.07 (.79)	−0.59 (.02)

.08) and less dominant shoulder IR (P = .03) than nonpitchers with no history of shoulder injury (Figure 1).

Compared with pitchers and nonpitchers without a history of shoulder injury, those with a history of shoulder injury had a greater difference in IR between the dominant and nondominant shoulders (reported as nondominant shoulder IR minus dominant shoulder IR). Specifically, pitchers with a history of shoulder injury had a 10.1° ± 9.0° difference in shoulder IR, whereas pitchers with no history of shoulder injury had a 3.1° ± 11.2° difference in shoulder IR (P = .08; Figure 2). Nonpitchers with a history of shoulder injury had a 13.5° ± 8.8° difference in shoulder IR, whereas nonpitchers with no history of shoulder injury had a 4.2° ± 13.8° difference in shoulder IR (P = .04; Figure 2).

No differences were detected between pitchers with and without a history of shoulder injury in terms of dominant hip EXT (P = .61; Figure 3) or nondominant hip EXT (P = .74; Figure 3). Similarly, no differences were observed between nonpitchers with and without a history of shoulder injury in terms of dominant hip EXT (P = .81; Figure 3) or nondominant hip EXT (P = .72; Figure 3).

Dominant hip IR and nondominant hip IR were not different between pitchers with and without a history of shoulder injury (P = .30 and P = .20, respectively; Figure 4). Nonpitchers with and without a history of shoulder injury displayed no difference in dominant hip IR (P = .23; Figure 4) but a difference in nondominant hip IR (P = .05; Figure 4).

The relationship between dominant hip EXT and dominant shoulder ER was significant for both pitchers (r = 0.62, P = .04; Table 1) and nonpitchers with a history of shoulder injury (r = −0.64, P = .02; Table 1). In contrast, the relationship between dominant hip EXT and dominant shoulder IR was significant only for nonpitchers with no history of shoulder injury (r = −0.59, P = .02; Table 1).

As indicated in Table 2, the relationship between nondominant hip IR and dominant shoulder ER was not significant for pitchers with a history of shoulder injury (P = .91), pitchers with no history of shoulder injury (P = .91), nonpitchers with a history of shoulder injury (P = .28), or nonpitchers with no history of shoulder injury (P = .47). Similarly, the relationship between nondominant hip IR and dominant shoulder IR was not significant for pitchers or nonpitchers, regardless of shoulder injury history ($P > .41$; Table 2).

Table 2. Associations Between Nondominant Hip Internal Rotation and Shoulder Range of Motion

Playing Position	History of Shoulder Injury?	Dominant Shoulder, *r* Value (*P* Value) External Rotation	Internal Rotation
Pitcher	Yes	0.04 (.91)	0.20 (.55)
	No	−0.03 (.91)	0.06 (.80)
Nonpitcher	Yes	−0.34 (.28)	−0.22 (.49)
	No	0.19 (.47)	0.22 (.41)

DISCUSSION

The purpose of our study was to determine if differences existed in hip and shoulder ROM between professional baseball players with a history of shoulder injury and those with no history of shoulder injury. Bilateral differences in shoulder IR (Figure 1) and nondominant hip IR (Figure 4) were detected only in nonpitchers. In addition, we sought to assess the relationship between hip ROM and shoulder ROM in professional baseball players. Relationships between dominant hip EXT and dominant shoulder ER were detected in both pitchers and nonpitchers with a history of shoulder injury and between dominant hip EXT and dominant shoulder IR in nonpitchers with no history of shoulder injury (Table 1).

We failed to detect differences between pitchers with and without a history of shoulder injury in dominant shoulder ER (P = .74; Figure 1) or IR (P = .71; Figure 1). Differences in GIRD between pitchers with and without a history of shoulder injury were appreciable (7°) but not statistically significant (P = .08; Figure 2). This finding is consistent with the findings of previous authors,[17–22] who have reported that overhead athletes often demonstrate less IR of the throwing shoulder relative to the nonthrowing shoulder. The GIRD condition is believed to be associated with the development of rotator cuff tears and labral injuries in the overhead athlete.[16] Interestingly, the IR difference relative to the nonthrowing shoulder was significant when comparing nonpitchers with and without a history of shoulder injury (P = .04; Figure 2). It is important to recognize that this difference in IR between the dominant and nondominant shoulders for both pitchers (10.1° ± 9.0°) and nonpitchers with a history of shoulder injury (13.5° ± 8.8°) is less than the 20° difference in IR that defines GIRD, according to Burkhart et al.[16] However, even though our study was not designed to investigate relationships between shoulder ROM and specific injuries, the data lend further support to the concept of GIRD being associated with shoulder injuries. Furthermore, these data indicate that shoulder injuries may be associated with even smaller differences in IR than previously believed and that GIRD may be an unrecognized condition in nonpitchers.

Hip IR was different between nonpitchers with and without a history of shoulder injury (P = .05; Figure 4). Specifically, nondominant hip IR was approximately 5° less in athletes with a history of shoulder injury. Although this measurement corresponds with a medium to large effect size of 0.74, we note that a 5° goniometric measurement may not be clinically significant. The throwing motion of nonpitchers is likely more varied than that of pitchers and may include throwing while running or throwing from a "crow hop" (ie, a common crossover stepping and hopping maneuver used by outfielders to provide additional velocity for the throw). Under these circumstances, IR of the nondominant hip may be responsible for decelerating the athlete's body. Thus, it is plausible that a lack of IR in the nondominant hip may transfer some of the demands of decelerating the body from the hip to the shoulder, thereby dissipating less force through the trunk and increasing forces at the shoulder. In turn, the athlete with limited nondominant hip IR may be predisposed to shoulder injury.

Dominant hip EXT was associated with a history of shoulder injury in both pitchers and nonpitchers (Table 1), but the associations for these groups were different. Specifically, an increase in dominant hip EXT was associated with an increase in dominant shoulder ER in pitchers with a history of shoulder injury ($r = 0.62$; Table 1), whereas an increase in dominant hip EXT was associated with a decrease in dominant shoulder ER in nonpitchers with a history of shoulder injury ($r = -0.64$; Table 1). For the pitchers, it is possible that they are attempting to maximize the throwing shoulder's "whip-like" motion (ie, rapid ER transitioning to rapid IR) through the simultaneous combination of long stride length (ie, dominant hip EXT) and maximal shoulder ER. In contrast, it is plausible that the nonpitchers compensate for a lack of dominant hip EXT (ie, small stride length) by increasing dominant shoulder ER to throw long distances or at high speeds. In turn, this increased ER at the shoulder may increase soft tissue forces and predispose the nonpitcher to shoulder injury.

We anticipated that IR of the nondominant hip would be negatively associated with IR of the shoulder in pitchers and nonpitchers with a history of shoulder injury. This hypothesis was based on the belief that hip IR is required to decelerate the body after ball release in the throwing motion. In addition, we postulated that the body would compensate for limited hip IR by increasing shoulder IR as a mechanism for decelerating the arm after ball release. However, the data failed to support this hypothesis. One explanation for this finding is that most of the deceleration of the forward-moving arm is accomplished through trunk and scapular mechanisms and, therefore, changes in rotation at the shoulder may occur only at the extremes of attempted adaptations.

The findings of associations between dominant hip EXT and shoulder ER in athletes with a history of shoulder injury have important training implications. Specifically, we recommend that training of the throwing shoulder be accompanied by improved hip flexibility (dominant hip EXT and nondominant hip IR) and strengthening of the muscles that are important to throwing athletes. Areas requiring improved flexibility are the shoulder, particularly the posterior capsule and rotator cuff (ie, the posterior shoulder); the dominant hip flexors; the nondominant hip internal and external rotators; and the dominant latissimus dorsi (for its connection directly from the pelvis to the arm).

Our study had several limitations. First, it is important to recognize that, in this observational study, several regions of the body or points along the kinetic chain that may be important factors were not evaluated. Although this does not detract from the significance of the relationships we observed, it does emphasize that a causal relationship cannot be inferred and that mechanisms of injury may not necessarily be substantiated by associations between hip and shoulder ROM. Second, each player's history of shoulder injury was based only on participant recall. Clearly, the limitation of recall bias could potentially lead to inaccurate conclusions. Third, hip and shoulder ROM were measured under static conditions and not during the throwing motion. Collecting ROM measurements during the throwing motion was beyond the scope of this study and, therefore, we based our investigation on the belief that static ROM measurements are representative of dynamic ROM during throwing. Fourth, shoulder injury may be associated with throwing exposure (eg, total pitch count[23]) rather than changes in ROM at the shoulder or hip. However, throwing exposure was not documented in this study. Fifth, our statistical approach of using 4 separate regression models to analyze associations between hip and shoulder ROM instead of 2 multiple regression models may have caused us to overlook multicollinearity among the reported ROM variables. Lastly, previous and recent shoulder or hip use can have large effects on the amount of rotation and, consequently, the timing of these measurements (which were obtained during the preseason) may have influenced the results of this study.

In summary, we found differences between nonpitchers with and without a history of shoulder injury in terms of shoulder IR, nondominant hip IR, and GIRD. Furthermore, we observed an association between dominant hip EXT and shoulder ER in both pitchers and nonpitchers with a history of shoulder injury. These data suggest a complex relationship between hip and shoulder ROM during the throwing motion. We may be the first to demonstrate an association between shoulder and hip motion and the development of shoulder injuries. However, we emphasize that our results do not elucidate a cause-and-effect relationship but merely point out associations between hip and shoulder ROM and injury. Further research is necessary to identify the specific mechanism(s) of injury associated with the development of shoulder injuries in the overhand throwing motion.

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