Lack of a Relationship Between Glenohumeral External-Rotation Strength and Posterior Shoulder Tightness in Baseball Players

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Context: Posterior shoulder tightness has been associated with altered shoulder range of motion (ROM) and several pathologic entities in baseball players. This tightness is hypothesized to be the result of the cumulative stress placed on the posterior shoulder during the deceleration phase of the throwing motion. The role of the posterior shoulder static restraints is to absorb this load while the glenohumeral (GH) external rotators eccentrically decelerate the arm after ball release and therefore also help dissipate this force. As such, the authors hypothesized that if the GH external rotators are weak, an excessive amount of this deceleration force is placed on the static restraints, which may lead to subsequent tightness. Objective: To compare the relationship between GH external-rotation strength and posterior shoulder tightness as measured by GH horizontal-adduction and internal-rotation ROM. Design: Descriptive study. Setting: Laboratory. Participants: 45 professional baseball players. Main Outcome Measures: GH external-rotation strength and GH horizontal-adduction and internal-rotation ROM. Results: GH external-rotation strength showed no relationship with either GH horizontal-adduction ROM ($r^2 = .02, P = .40$) or GH internal-rotation ROM ($r^2 = .002, P = .77$). Conclusion: There is little to no relationship between GH external-rotation strength and posterior shoulder tightness in professional baseball players. The posterior static restraints of the shoulder may absorb a large majority of the deceleration forces during the throwing motion. Although strengthening of the posterior shoulder dynamic restraints should not be overlooked, routine stretching of the static restraints may be more beneficial for decreasing posterior shoulder tightness and the subsequent risks associated with this tightness, although future research is warranted.

Keywords: throwing athletes, GH internal rotation, GH horizontal adduction

The deceleration phase of the throwing motion has been described as a reversal of the forces and motion created during the windup, early cocking, late cocking, and acceleration phases.1 Baseball players spend most of the throwing-motion sequence generating large amounts of force in these first 4 phases.2 Power is initially developed in the lower extremity and then transferred to the core as it rotates and flexes forward toward the intended target.2,3 The sum of these forces is then transferred to the shoulder, elbow, and finally to the wrist and hand as the ball is released.2,4 After ball release, the athlete is faced with the challenge of dissipating all the previous forces and decelerating the arm that has been reported to internally rotate at speeds of greater than 10,000°/s.5

The deceleration phase produces the largest forces acting on the shoulder during the throwing motion, and these forces occur in several directions.6 Previous investigations that assessed the kinetics of the deceleration phase have reported compressive forces of greater than 1000 N,6 adduction torques of 110 N-m,7 and horizontal-adduction torques of 97 N-m.8 A few of the structures responsible for absorbing these forces include the posterior glenohumeral (GH) capsule and the GH external rotators,8 which eccentrically control this motion during deceleration. Therefore, it is conceivable that players with less GH external-rotation strength would have increased stress placed on the posterior shoulder restraints, potentially resulting in increased posterior shoulder tightness.

Because of the repetitive nature of throwing in baseball players and the accumulation of forces absorbed by the posterior shoulder, such athletes often present with posterior shoulder tightness in the form of lost GH internal-rotation9–11 and horizontal-adduction range of motion (ROM).11,12 Furthermore, excessive posterior shoulder tightness has been associated with various shoulder pathologies.13–16 Because of these pathologic associations, several investigations have targeted the effects of various stretching techniques for improving posterior shoulder tightness.17–20 Although an extensive amount of work has examined stretching and posterior shoulder tightness, no current data are available detailing the relationship between this tightness and GH strength.
As such, the purpose of this study was to determine the relationship between GH external-rotation strength and posterior shoulder tightness in baseball players. We hypothesized that players with less GH external-rotation strength would have more stress to the posterior capsule, and therefore posterior shoulder tightness, than players with higher GH external-rotation strength.

Methods

Participants

Participants included 45 professional baseball players (20 pitchers and 25 position players: age 22.7 ± 2.5 y, height 186.7 ± 5.1 cm, mass 87.6 ± 8.2 kg). All participants reported no recent history (within 2 y) of upper extremity injury or any previous upper extremity surgeries. An injury was defined as an upper extremity pathology that resulted in time lost from practice or competition.

Instrumentation

We used the Pro 3600 digital inclinometer (SPI-Tronic, Garden Grove, CA) to measure GH horizontal-adduction and internal-rotation ROM. This device provides a real-time digital reading of angles with respect to either a horizontal or a vertical reference and is accurate up to 0.1°, as reported by the manufacturer. The digital inclinometer was modified with a reference line positioned along the midline of the device, which was used for proper alignment during the ROM testing.

We assessed a priori reliability and validity of the GH horizontal-adduction ROM measurement. We measured 24 shoulders (separate participants from the current study) without previous injury or surgery using an intraclass correlation coefficient formula (ICC2,3). Each participant’s ROM was measured and reassessed a minimum of 48 hours later. The ICC and standard error of measurement (SEM) for GH horizontal-adduction ROM were .93 and 1.6°, respectively. Furthermore, the validity of this method was shown to have a moderate to good linear relationship with GH internal-rotation ROM ($r = .72, P = .001$). Similarly, a priori intratester reliability was assessed for the GH internal-rotation-ROM measurement. Twenty shoulders (separate participants from the current study) without any previous injury or surgery were measured using an ICC2,3 formula. Each participant’s GH internal-rotation ROM was measured and then reassessed approximately 24 hours later. The ICC and SEM for GH internal-rotation ROM were .98 and 2°, respectively.

We used the Lafayette manual muscle test system (Model 01163, Lafayette Instrument Co, Lafayette, IN) to measure GH external-rotation strength. This system is a handheld digital dynamometer capable of measuring peak force, time to peak force, and torque. The device is capable of measuring up to 136 kg of force and is compact and portable, so it is easily adaptable for measuring strength when more bulky systems are not appropriate. This device includes an automatic drift compensation to produce accurate and reliable measurements and has an accuracy of ±1% as reported by the manufacturer.

We assessed the intraclass reliability of this method for measuring GH external-rotation strength a priori. Fifteen shoulders (separate participants from the current study) without any previous injury or surgery were measured using an ICC2,3 formula. We measured GH external-rotation strength and then reassessed it a minimum of 24 hours later. The ICC and SEM values for this measurement were .89 and 1.7 kg, respectively. The handheld digital dynamometer has been previously shown to be a valid tool for measuring strength.21

Procedures

All participants attended 1 testing session in the athletic training room of a professional baseball organization’s spring training facility. Before participation, each participant provided informed consent. The university institutional review board approved the study before data collection, and the rights of all participants were protected conforming to the Code of Ethics of the Declaration of Helsinki. We examined the GH external-rotation strength and posterior shoulder tightness, defined as the amount of GH horizontal-adduction ROM and GH internal-rotation ROM, in the dominant arm of each participant. One measurement was recorded for each ROM and strength test in a randomized order for all participants. The testing sessions were conducted by the same investigators, and no testing was performed after an extensive throwing session.

GH Horizontal-Adduction ROM

To assess GH horizontal-adduction ROM, we placed participants in a supine position with both shoulders flush against a standard examination table. We positioned the test shoulder and elbow into 90° of abduction and flexion, respectively, and stabilized the lateral border of the scapula by providing a posteriorly directed force (toward the examination table) to limit scapular protraction, rotation, and abduction motions. We then held the proximal portion of the participant’s forearm, slightly distal to the elbow, and passively moved the humerus into end-range horizontal adduction. To measure GH horizontal-adduction ROM, a second investigator aligned the digital inclinometer with the ventral midline of the humerus. The angle created by the end position of the humerus with respect to 0° of horizontal adduction (plane perpendicular to the examination table as determined by the digital inclinometer; Figure 1) was then recorded as the total amount of GH horizontal-adduction ROM.

GH Internal-Rotation ROM

To measure GH internal-rotation ROM, we positioned each participant supine with the shoulder and elbow in 90° of abduction and flexion, respectively. We placed a folded towel under the humerus to ensure a neutral horizontal position (humerus level with acromial process).
We then passively internally rotated the participant’s humerus while simultaneously stabilizing the scapula with pressure to the anterior acromion until termination of humeral rotation. At this position, we aligned the digital inclinometer with the ulna (using the olecranon process and ulnar styloid for reference), providing an angle between the forearm and a plane perpendicular to the examination table.

**GH External-Rotation Strength**

To measure GH external-rotation strength, we positioned each participant prone on an examination table with the test shoulder and elbow in 90° of abduction and flexion, respectively. We then positioned the digital dynamometer over the distal portion of dorsal forearm and provided a downward force against the effort of the participant as he attempted to externally rotate his arm (Figure 2). Participants were allowed ample time to practice the movement before testing to become familiar with the procedures.

Each test consisted of the participant maximally contracting against the external force until this external force, applied by the examiner, caused a “break” in the test position of the participant. The force required to break the test position was then recorded as the relative strength of the GH external rotators.

For data analysis, each participant’s GH external-rotation-strength measurement was normalized. This normalization consisted of dividing the participant’s maximum force produced by his body mass and then converting to a percentage.

**Statistical Methods**

We used a linear-regression analysis to determine whether there were relationships between GH external-rotation strength (independent variable) and GH horizontal-adduction ROM and GH internal-rotation ROM (dependent variables; \( P < .05 \)). We used SPSS (version 16.0, SPSS Inc, Chicago, IL) to analyze these data.

**Results**

The descriptive statistics for GH horizontal-adduction and internal-rotation ROM and GH external-rotation strength are shown in Table 1. These values are similar to those reported in previous research in professional baseball players using analogous methodology. \(^{10,11}\) There was no relationship between GH external-rotation strength and GH horizontal-adduction ROM \((r^2 = .017, \ P = .40; \text{Figure 3})\) or between GH external-rotation strength and GH internal-rotation ROM \((r^2 = .002, \ P = .77; \text{Figure 4})\).

**Discussion**

Clinicians have often emphasized the importance of stretching the soft-tissue structures of the posterior shoulder, especially for baseball players, in an effort to limit posterior shoulder tightness and any associated dysfunctions. \(^{24,25}\) Nonetheless, little research has aimed to determine potential causes of this tightness. We hypoth-
esized that if the GH external rotators were weak and therefore unable to absorb the deceleration forces during the throwing motion, more stress would be placed on the posterior static and dynamic restraints, potentially resulting in decreased GH horizontal-adduction and internal-rotation ROM. However, our results indicate that there is little to no relationship between GH external-rotation strength and GH horizontal-adduction or internal-rotation ROM in professional baseball players.

During the deceleration phase of the throwing motion the posterior GH capsule has been hypothesized to rotate into a posterocentral location, where the capsule can more effectively resist the distraction forces. This hypothesis may partially explain why our study did not
show a significant relationship between GH external-rotation strength and GH horizontal-adduction ROM. If the posterior capsule is the primary restraining structure during the deceleration phase, it is plausible that GH external-rotator strength would have little to no impact on the absorption of these forces. Therefore, stretching the posterior shoulder may be more beneficial in preventing and treating posterior shoulder tightness than GH external-rotation strengthening.

Besides the GH posterior capsule, various scapular muscles and the GH external rotators have been shown to produce high levels of activity during the deceleration phase as they work eccentrically to decelerate the arm. As such, based on the lack of a relationship found between GH external-rotation strength and GH horizontal-adduction and internal-rotation ROM, it is possible that the periscapular muscles absorb a large amount of the deceleration forces. Therefore, the influence of muscles such as the latissimus dorsi, posterior deltoid, lower trapezius, and rhomboids may be one cause of the large variance among our findings. The specific influence the strength of these muscles has on GH horizontal-adduction ROM should be examined in future research and may be considered when designing an injury-prevention or -treatment program for baseball players.

Regardless of what structures are primarily responsible for resisting the humeral distraction forces during the deceleration phase, when GH horizontal-adduction and internal-rotation ROM are decreased their association with shoulder injury is evident. Furthermore, posterior capsular tightness has been associated with not only decreased GH horizontal-adduction ROM and GH internal-rotation ROM but also altered humeral-head translation and scapulothoracic motion. These associations between posterior shoulder tightness and shoulder dysfunction emphasize the importance of determining potential causes of this tightness. Our results indicate that GH external-rotation strength has little to no relationship with decreased GH horizontal-adduction or internal-rotation ROM, so exercises aimed at strengthening the GH external rotators may not be necessary as a means of limiting this lost ROM. Therefore it is imperative that future research investigate other possible causes, and subsequent preventive techniques, aimed at limiting the amount of stress placed on the posterior soft tissue of the throwing shoulder in overhead athletes.

We acknowledge a few limitations in our study design. One major limitation is that humeral retroversion was not measured. Past research has shown a relationship between increased humeral retroversion and decreased GH internal-rotation ROM. Therefore, the lack of a relationship we found between GH external-rotation strength and GH internal-rotation ROM may have been strongly influenced by a bony adaptation rather than by soft tissue. Data were collected at the beginning of the baseball season, potentially before the development of any significant restrictions in GH horizontal-adduction and internal-rotation ROM. We measured peak strength, which has been used more to describe joint stability than control of motion. However, previous research has described the break test as a measure of eccentric strength, which is appropriate for looking at the function of the GH external rotators as eccentric controllers of the deceleration motion. During the initial push of the break test for GH external-rotator strength, a small eccentric contraction was elicited. Based on the force–velocity curve, an eccentric contraction produces more force than an isometric contraction. As such, the peak strength registered using the dynamometer was most likely the force created during the eccentric portion of the test. However, this eccentric strength was only produced during a short arc of motion during our testing rather than through a total arc of motion as occurs during the deceleration phase of the throwing motion. Finally, we did not assess the contribution of the scapular muscles that may play a role in the deceleration motion and therefore may help explain the large variance between GH external-rotation strength and both GH horizontal-adduction and internal-rotation ROM.

**Conclusion**

To our knowledge, our study is the first to investigate a possible cause of the decreased GH horizontal-adduction and internal-rotation ROM found in the dominant arm of baseball players compared with the nondominant arm. Our results show that there is little to no relationship between GH external-rotation strength and GH horizontal-adduction or internal-rotation ROM among baseball players. This study may provide clinicians with a better understanding of the prevention and treatment considerations of baseball players, but more research needs to be conducted to determine precise causes of this ROM alteration and subsequent shoulder disorders.

**References**

7. Fleisig GS, Kingsley DS, Loftice JW, et al. Kinetic comparison among the fastball, curveball, change-up, and


