Assessment of Shoulder Strength in Professional Baseball Pitchers

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Study Design: A bilateral comparison of strength and range of motion testing in professional baseball pitchers.

Objective: We studied 39 professional male baseball pitchers to determine if the shoulder used for throwing was weaker or had less passive range of motion, compared to the nondominant arm.

Background: Shoulder muscle weakness has been proposed as a possible risk factor for developing injury. Therefore, objective quantification of the strength of glenohumeral and scapular rotator muscle groups should be studied in a population of professional baseball pitchers.

Methods and Measures: Passive internal and external range of motion was bilaterally measured at 90° of abduction. Muscle strength of the following muscles was measured bilaterally with a hand-held dynamometer: external and internal glenohumeral rotators, supraspinatus, middle trapezius, lower trapezius, and serratus anterior.

Results: Passive external rotation of the glenohumeral joint at 90° of abduction on the pitching side was significantly greater than on the nonpitching side. Passive internal rotation range of motion on the nonpitching side was significantly greater than on the pitching side. The pitching arm's internal rotators, when tested in abduction, were significantly stronger than the nonpitching arm. The nonpitching arm's external rotators in the plane of the scapula, and in abduction, were significantly greater than those of the pitching arm. The pitching arm's middle and lower trapezius muscles were significantly stronger than those of the nonpitching arm.

Conclusion: The range of motion and strength characteristics measured in this study can assist clinicians in evaluating athletes who use overhead throwing motions. J Orthop Sports Phys Ther 2000;30:544-551.

Key Words: professional baseball pitchers, rotator cuff strength, scapular muscle strength

The action of overhead throwing places significant demands on the shoulder. Shoulder injuries in overhead throwing athletes include rotator cuff tendinitis, subtle instabilities, labral degenerative changes and tears, and secondary subacromial and parascapular problems. Repetitive microtrauma and eccentric overload occur commonly in professional baseball pitchers, resulting in muscle-tendon injury. Subtle instabilities of the glenohumeral joint may cause impingement within the subacromial space.

Wuelker et al studied the forces and translational movements of the glenohumeral joint during elevation. Increased forces were observed during the final stages of shoulder elevation. Humeral head translation was found to be 9 mm superiorly and 4.4 mm anteriorly during elevation of the glenohumeral joint. Subtle changes in the translation of the humeral head, combined with the forces under the acromion and coracoid process, are the proposed etiological factors of shoulder impingement. Weakness of the rotator cuff mus-
cles could be a contributing factor in the subtle changes of the humeral head translations.

Using high-speed motion analysis, Fleisig et al. evaluated elbow and shoulder kinetics in 26 highly skilled, nonimpaired adult pitchers. The biomechanical analysis of the pitching motion identified large forces at the shoulder and elbow. The compressive forces and varus torques were identified as predisposing factors in the development of overuse injuries such as glenohumeral labral tears, impingement, rotator cuff and elbow tendon overload. Pappas et al also used high-speed motion analysis to determine normal kinetic and kinematic patterns of the throwing motion. They developed graphs showing the forces in internal and external rotation and torque in the shoulder and elbow as a result of the throwing motion. These motion analysis studies demonstrate that shoulder stability is controlled, to a large extent, by proper positioning of the arm and appropriate balance of musculature around the shoulder.

Magnusson et al. reported significant muscle weakness in the pitching arm of professional baseball pitchers. The study identified significant muscle deficits of 3 glenohumeral muscles: the supraspinatus, the external rotators, and the abductors. Injury history had no effect on strength and range of motion; however, the study suggested that muscle weakness resulted from the demands of the pitching motion. Furthermore, weakness of the supraspinatus muscle in pitchers was implicated as a subclinical pathology or chronic fatigue. Their study did not test scapular rotator muscles, and reliability was not reported for the manual muscle testing positions used in the data collection. The only muscle testing reliability reported in the study was based on previous studies investigating inter- and intra-rater reliability of hand-held dynamometry.

Pitching requires scapular and glenohumeral stabilization. The balance of the scapulothoracic and glenohumeral joints is sustained by the strength of the scapular and glenohumeral rotator muscles. The scapular rotator muscles control the scapula, providing a stable glenoid, and they maintain optimal length-tension relationships of the glenohumeral muscles. The rotator cuff muscles dynamically stabilize the humeral head in the glenoid fossa and provide the main deceleration forces to the pitching arm during the follow-through phase of pitching. Several studies have investigated shoulder strength of baseball pitchers. Consistent findings among these studies are as follows: (1) isokinetic studies of baseball pitchers show significantly greater pitching arm internal rotation muscle strength with no apparent difference in external rotation, (2) the ratio of external rotation to internal rotation strength ranges from 63 to 70% in the pitching arm, and (3) the pitching shoulder's adductors are significantly stronger than those of the nonpitching side.

Inconsistent with the studies mentioned above, the studies of Wilk et al. and Hinton reported that the external rotator muscles of the nonpitching shoulder were significantly stronger than the pitching side. The throwing shoulder exhibits a natural tendency toward relative external rotation weakness. Shoulder muscle weakness has been proposed as a possible risk factor for developing injury. Therefore, objective quantification of the strength of glenohumeral and scapular rotator muscle groups should be studied in a population of professional baseball pitchers.

The purposes of this study were to compare the passive range of motion and muscle strength of the glenohumeral and scapular rotators in the pitching and the nonpitching arms in a group of professional baseball pitchers.

METHODS

Forty-three minor league male professional baseball pitchers volunteered to participate in this study. Subject consent was obtained before the data were collected. The Institutional Review Board of Stryker Physiotherapy Associates (Memphis, Tenn) approved the testing methodology and protocol prior to data collection. The pitchers had played professional baseball for an average of 1.8 years (range, 0.082-6 years). The average number of innings pitched at the professional level was 103.9 innings (range, 0-800 innings). The average age of the pitchers tested was 20.7 years (range, 17-28 years).

Testing was performed during the first week of extended spring training. All players were asked to fill out questionnaires regarding history of shoulder-arm pain or existing injuries. To be included in this study, subjects had to be currently free from injury in the shoulder and elbow bilaterally, and had not been on the disabled list for a period of 8 months prior to the date of data collection. Four of the pitchers had prior surgical treatment for shoulder and elbow injuries, and were excluded from the study. This left 39 study participants. None of the pitchers were presently experiencing pain from an injury, nor did they have pain during the muscle testing or range of motion measurements.

Range of motion and muscle testing were performed on both the pitching arm and the nonpitching arm. Otis et al. established normative values for arm strength by comparing the dominant and nondominant arms of adult men. Comparison of dominant with nondominant arm strength allows the clinician to assess strength deficits more accurately in a specific population.

Range of Motion Measurement

One tester, masked to each subject’s pitching arm, measured all subjects’ passive internal and external
Methods of Strength Testing

One experienced tester, masked to the subject’s pitching and nonpitching arms, performed all the manual muscle tests. A second tester stabilized the subject’s arm during the muscle testing. None of the manual muscle tests were done the day of, the day before, or the day after the subjects pitched in a game situation.

All muscle testing positions elicit contraction of several muscle groups. However, the manual muscle test positions that were chosen as the optimal test position for the glenohumeral and scapular muscles were based on good test-retest reliability, no provocation of pain, and minimal contribution from involved shoulder synergists. Three active resistance tests were performed bilaterally for each muscle group. An active resistance test is manual resistance against an actively contracting muscle or muscle group (ie, against the direction of the movement as if to prevent that movement). The resistance was increased to meet the demands of the contracting muscle. After the hand-held dynamometer was located proximal to the styloid process of the radius, the subject was instructed to increase force gradually until maximum contraction was achieved.

Shoulder internal and external rotation strength was measured with the subject in the supine position, with the humerus placed on a wedge at 30° anterior to the frontal plane and elevated to 45°, and in the frontal plane with 90° of abduction (Figure 2). The elbow was flexed to 90° in both positions and the hand-held dynamometer was placed on the ulnar styloid process. In a study by Greenfield et al., external rotator muscle strength was shown to be markedly greater in the plane of the scapula (30° anterior to the frontal plane) than in the frontal plane.

The supraspinatus muscle’s strength was measured with the subject in the sitting position. The subjects stabilized themselves by grasping the stool with the arm not being tested. The humerus was held in maximum internal rotation (thumb pointing downward). The position of “scaption” has been reported to produce maximal levels of supraspinatus muscle activation. The arm was held at 90° of abduction and 30° anterior to the frontal plane. A goniometer was used to determine and verify the 30° anterior position by placing the stationary arm of the goniometer on the spine of the scapula. The axis of the goniometer was placed on the tip of the acromion and the moving arm was placed on the proximal humerus.

The muscle strength for the serratus anterior muscle was measured with the subject in the supine position, with the arm held at 90° of flexion and the elbow fully extended. The subject was asked to reach
FIGURE 2. Manual muscle test for the glenohumeral rotator muscles. (A) The hand-held dynamometer is placed on the ulnar styloid process. The humerus is placed on a wedge at 30° anterior to the frontal plane (plane of scapula). The humerus is abducted to 45°, and the elbow is flexed to 90°. (B) The humerus is abducted to 90°, and the elbow is flexed to 90°.

with the test arm projecting the upper extremity anteriorly (upward from the table). Pressure with the hand-held dynamometer was against the subject's fist, transmitting the pressure downward through the extremity, to the scapula.

FIGURE 3. Manual muscle test for the lower trapezius muscle group. The arm is abducted to 145° and the thumb is pointing upward (external rotation of the humerus). The hand-held dynamometer is placed on the styloid process of the ulna.

Lower trapezius muscle strength was measured with the subject in the prone position (Figure 3). The arm was positioned diagonally overhead with the thumb pointing upward. The arm was held in 145° of abduction. The strength of the middle trapezius muscle was also measured with the subject prone. The arm was held at 90° of abduction and the thumb pointing upward. The degree of abduction was determined by placing the goniometer along the lateral border of the scapula, the axis on the head of the humerus, and the moving arm on the proximal humerus.

Data Analysis

Shoulder range of motion was analyzed by first taking the mean of 3 trials of each measurement. A repeated measures ANOVA was used to determine initial significance. The repeated factor was dominance (pitching and nonpitching arms) and range of motion (external rotators in neutral and in 90° of abduction, and internal rotators in 90° of abduction). The dependent variable was range of motion. Once significance was established, further analysis consisted
TABLE 1. Range of motion measurements* (N = 39).

<table>
<thead>
<tr>
<th></th>
<th>Pitching arm, ° (SD)</th>
<th>Nonpitching arm, ° (SD)</th>
<th>Significance</th>
<th>t ratio</th>
<th>df</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>External rotation (neutral)</td>
<td>54.48° (10.47)</td>
<td>54.75° (13.69)</td>
<td>NS</td>
<td>−.150</td>
<td>38</td>
<td>.882</td>
</tr>
<tr>
<td>External rotation (90° abduction)</td>
<td>103.69° (8.82)</td>
<td>95.03° (8.53)</td>
<td>pitching &gt; nonpitching (P &lt; .001)</td>
<td>6.393</td>
<td>38</td>
<td>.000</td>
</tr>
<tr>
<td>Internal rotation (90° abduction)</td>
<td>40.33° (8.99)</td>
<td>50.37° (9.63)</td>
<td>pitching &lt; nonpitching (P &lt; .001)</td>
<td>−6.858</td>
<td>38</td>
<td>.000</td>
</tr>
</tbody>
</table>

* Each number is followed by the standard deviation (SD).

of paired sample t tests to compare the differences in means. The alpha level was set at .05.

Shoulder strength was also analyzed by first taking the mean of 3 trials of each strength measurement. A repeated measures ANOVA was used to determine initial significance. Our repeated factors were dominance (pitching and nonpitching arms) and muscle (middle trapezius, lower trapezius, supraspinatus, internal rotators [POS], external rotators [POS], internal rotators [90° of abduction], and external rotators [90° of abduction]). The dependent variable was isometric force. Once significance was established, further analysis consisted of paired sample t tests to compare the differences in means across groups, dominance, and strength. The alpha level was set at .05.

To examine test-retest reliability of the muscle and range of motion testing, the examiner retested every fifth subject. An intraclass correlation coefficient (ICC 2,k) was used to determine the degree of test-retest reliability.27

RESULTS

Range of Motion

There were significant differences in internal and external rotation passive range of motion between the dominant and nondominant extremity (Table 1). On further analysis (paired sample t tests), there were no significant differences in the external rotation (neutral) range of motion between pitching and nonpitching arms. However, external rotation range of motion at 90° of abduction was significantly greater in the pitching arm than in the nonpitching arm (Table 1). Furthermore, internal rotation passive range of motion at 90° of abduction was significantly less in the pitching arm than in the nonpitching arm (Table 1).

Strength

The second analysis of variance revealed that there were significant differences between the pitching and nonpitching arms. On further analysis (paired sample t tests), the means for external rotation (POS and at 90° of abduction), internal rotators (at 90° of abduction), lower trapezius and middle trapezius muscle groups indicated significant strength differences (Table 2). The pitching arm showed significantly stronger middle trapezius muscles, lower trapezius muscles, and internal rotators in 90° of abduction. Of particular importance, the pitching arm’s external rotators were significantly weaker than those of the nonpitching arm, when tested in the POS (P < .01) and in 90° of abduction (P < .001).

Unilateral strength ratios (external-internal rotation ratios) were formed manually by dividing each subject’s external rotation strength by their corresponding internal rotation strength values. The ex-

TABLE 2. Strength measurements* (N = 39).

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Pitching</th>
<th>Nonpitching</th>
<th>t</th>
<th>df</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle trapezius</td>
<td>6.66 kg (1.66)</td>
<td>5.84 kg (1.73)</td>
<td>3.221</td>
<td>38</td>
<td>.003</td>
</tr>
<tr>
<td>Lower trapezius</td>
<td>6.85 kg (1.90)</td>
<td>6.08 kg (1.22)</td>
<td>2.543</td>
<td>38</td>
<td>.015</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>8.78 kg (2.06)</td>
<td>8.98 kg (2.50)</td>
<td>−.743</td>
<td>38</td>
<td>.462</td>
</tr>
<tr>
<td>Internal rotators (plane of scapula)</td>
<td>19.57 kg (4.03)</td>
<td>18.75 kg (3.18)</td>
<td>1.626</td>
<td>38</td>
<td>.112</td>
</tr>
<tr>
<td>External rotators (plane of scapula)</td>
<td>13.27 kg (3.59)</td>
<td>14.50 kg (3.11)</td>
<td>−3.253</td>
<td>38</td>
<td>.002</td>
</tr>
<tr>
<td>Internal rotators (90°)</td>
<td>18.20 kg (3.96)</td>
<td>17.43 kg (3.65)</td>
<td>2.275</td>
<td>38</td>
<td>.029</td>
</tr>
<tr>
<td>External rotators (90°)</td>
<td>15.05 kg (3.67)</td>
<td>17.14 kg (4.09)</td>
<td>−4.528</td>
<td>38</td>
<td>.000</td>
</tr>
</tbody>
</table>

* Each measurement is followed in parentheses by the standard deviation.
ternal-internal rotation ratios in this study were 68% on the pitching arm and 78% on the nonpitching arm when measured in the plane of the scapula, and 83% on the pitching arm and 99% on the nonpitching arm in 90° of glenohumeral joint abduction (Table 3).

Reliability

Intraclass correlation coefficients (ICC) showed high intrarater reliability of the muscle tests for the middle trapezius (0.933), lower trapezius (0.891), supraspinatus (0.955), internal rotator muscles in the plane of the scapula (0.822) and at 90° of abduction (0.932), and external rotator muscles in the plane of the scapula (0.815) and at 90° of abduction (0.960). The range of motion measurement intrarater reliability was 0.969 for internal rotator muscles at 90° of abduction and 0.792 for external rotation at 90° of abduction. There was poor intrarater reliability for the serratus anterior muscle test (0.266). For this reason, we did not include the results of the manual muscle strength testing for the serratus anterior muscle group in the data analysis.

DISCUSSION

Passive Range of Motion

When compared with the nonpitching arm, the bilateral glenohumeral passive range of motion tests showed statistically greater passive external rotation in 90° of abduction and less passive internal rotation range of motion in the pitching arm. This finding is consistent with previous research on athletes who throw using one arm, and identifies a consistent pattern of glenohumeral rotation in the athletic shoulder.44 The consequences of internal rotation loss, according to Harryman et al,14 include increased anterior humeral head translation and superior migration. The exact mechanism for the loss of internal rotation range of motion is still being investigated. Hypotheses include fibrous tissue formation in the posterior capsule, musculotendinous tightness in the posterior rotator cuff, as well as osseous changes secondary to the repetitive demands of throwing and overhead activity.21 Changes in glenohumeral rotation in response to sport-specific demands, are an example of anatomic variation found in athletes undergoing musculoskeletal evaluation, and may have consequences when evaluating and treating athletes in this population.

Glenohumeral Muscle Strength

The eccentric overload of the glenohumeral external rotator muscles has been implicated as a destructive force in the shoulder.5,6 These muscles are responsible for decelerating the humerus during the follow-through phase and they undergo extreme eccentric overload with repetitive overhead throwing. Andrews and Angelo3 found that most rotator cuff tears in throwers were located from the midsupraspinatus posterior to the mid infraspinatus area. They believe these tears are a consequence of tensile failure as the rotator cuff muscles try to resist distraction, horizontal adduction, and internal rotation at the shoulder during arm deceleration. Fleisig et al9 believe that the posterior shoulder muscles are susceptible to injury during arm deceleration as they resist glenohumeral distraction and horizontal adduction.

The strength of the glenohumeral rotators in professional baseball pitchers has been reported in previous studies primarily using isokinetic dynamometers.5,5,7,22,31 Three of these studies report internal rotator muscle strength to be significantly stronger in the pitching arm with no significant weakness or equal the strength of the external rotator muscle in the pitching arm, when compared with the nonpitching arm.4,5,8 Wilk et al31 and Magnusson et al22 reported significant deficits of the external rotator muscles on the dominant arm, as compared to the nondominant arm.

In our study, we found a significant deficit of the glenohumeral external rotator muscles, significantly stronger internal rotator muscles at 90° of abduction, and no significant difference in the strength of the supraspinatus muscle group in the pitching arms of professional baseball pitchers, when compared with their nonpitching arms.

The absence of strength deficits of the supraspinatus muscle group may be a result of significantly stronger middle and lower trapezius muscle groups on the pitching side. The strength of the scapular rotators assists in stabilizing the scapula during the overhead throwing motion, and helps prevent impingement. Andrews and Angelo3 believe tears of the supraspinatus are a consequence of tensile failure as the rotator cuff muscles attempt to control distraction, horizontal adduction, and internal rotation at the shoulder during arm deceleration. Horizontal adduction of the glenohumeral joint is accompanied by protraction of the scapula. Therefore, the strength of the scapular retractors (the middle and lower trapezius muscles) could play a crucial role in stabilizing.

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TABLE 3. External-internal rotation ratios.

<table>
<thead>
<tr>
<th>Position</th>
<th>Pitching arm Mean, SD</th>
<th>Nonpitching arm Mean, SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plane of the scapula 90 degrees abduction</td>
<td>68.5%, 15.92</td>
<td>78.4%, 16.96</td>
</tr>
<tr>
<td>90 degrees abduction</td>
<td>83.9%, 16.97</td>
<td>99.3%, 18.33</td>
</tr>
</tbody>
</table>

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the scapula and preventing injury to the supraspinatus muscle group.

Muscle strength ratios of the external to internal rotator muscles vary from 63 to 70\%.\(^3\) In our study, the mean strength of the external rotators in the dominant arm was 68% of the strength of the internal rotators when tested in the POS, and 83% of the internal rotators when tested at 90° of abduction. These manually assessed muscle strength ratios, between the internal and external rotators, are within the ranges reported in the literature for uninjured professional baseball pitchers.

### Scapular Muscle Strength

A unique aspect of this study was the muscle testing of the middle and lower trapezius muscles in professional baseball pitchers. When comparing the pitching with the nonpitching arm, our study demonstrated significantly stronger pitching arm middle and lower trapezius strength. During the late cocking phase of pitching, the rhomboids and the trapezius muscles are responsible for full retraction of the scapula, thus, preventing impingement of the glenohumeral muscles on the acromion during maximum external rotation.\(^5\) The serratus anterior muscle protracts the scapula and maintains congruency of the glenohumeral joint, allowing an optimal length-tension relationship of the glenohumeral muscles.

### CONCLUSION

This study provides the clinician with a comprehensive profile of range of motion and muscle strength measurements in the pitching and nonpitching arms of professional baseball pitchers. Significantly less passive internal rotation range of motion of the glenohumeral joint in the pitching arm of pitchers and greater pitching arm external rotation was measured. Statistically significant strength deficits of the glenohumeral external rotators in the pitching arm were recorded, while significantly greater strength of the internal rotators at 90° of abduction was measured compared to the nonpitching arm. Significantly greater strength was also measured in the middle and lower trapezius muscles on the pitching arm. However, no statistically significant difference existed between extremities in supraspinatus strength. Our results provide an important base line for assessing deficits in strength and motion for athletes who use one arm for overhead throwing.

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