The Relationship of Periscapular Strength on Scapular Upward Rotation in Professional Baseball Pitchers

Kevin G. Laudner, Justin M. Stanek, and Keith Meister

Context: Deficiencies in scapular upward rotation and periscapular strength have been associated with various shoulder pathologies and decreased athletic performance. Therefore, proper periscapular strength and concomitant scapular upward rotation are important factors among overhead athletes, such as baseball players. Objective: To assess the relationships between lower trapezius and serratus anterior strength and the quantity of scapular upward rotation. Design: Descriptive study. Setting: Laboratory. Participants: 24 professional baseball pitchers. Measures: Scapular upward rotation was measured at 0°, 60°, 90°, and 120° of humeral elevation. The maximum isometric strength of the lower trapezius and serratus anterior were measured. Results: There was a moderate-good positive relationship between lower trapezius strength and scapular upward rotation at 90° (r² = .56, P = .001) and 120° (r² = .53, P = .001). The relationships between scapular upward rotation and serratus anterior strength were all poor. Conclusion: A moderate-good relationship existed between lower trapezius strength and scapular upward rotation.

Proper scapular kinematics are material to the overall function of the shoulder, especially in sports requiring repetitive overhead motions such as baseball. Proper positioning of the scapula promotes optimum function of the bony constraints to shoulder movement, as well as the most efficient position for the rotator cuff muscles to produce glenohumeral compression. If the scapula is not functioning in a fluid and coordinated movement pattern with the humerus, the integrity of the glenohumeral joint may be compromised and risk of injury increased. As such, individuals with subacromial impingement syndrome have been reported to have decreased periscapular muscular activity and strength and less scapular upward rotation. Similarly, patients diagnosed with glenohumeral instability have also been reported to have decreased scapular upward rotation when compared with a control group.

Due to the repetitive nature of the throwing motion and the ensuing muscular fatigue, proper periscapular musculature strength may be influential for maintaining proper scapular upward rotation among throwing athletes; however, there is...
limited empirical data that describe any relationship between periscapular strength and scapular upward rotation.

The purpose of this study was to determine if, in a group of professional baseball players, a relationship exists between periscapular strength (lower trapezius and serratus anterior) and the quantity of scapular upward rotation. The authors of this study hypothesized that those athletes with less strength of the serratus anterior and lower trapezius would have less scapular upward rotation. Identification of such associations may allow clinicians to address potentially hazardous shoulder characteristics prior to soft tissue damage.

Methods

Participants

Twenty-four professional baseball pitchers participated in this study. Complete subject demographics appear in Table 1. Each subject had their scapular upward rotation motion and serratus anterior and lower trapezius muscle strength measured. All measurements were taken on the throwing shoulder and no participants had a recent history (past two years) of shoulder pathology or any previous shoulder surgeries.

Instrumentation

Scapular upward rotation was measured using the Pro 3600 Digital Inclinometer (SPI-Tronic, Garden Grove, CA). This device provides a real-time digital reading of angles with respect to either a horizontal or vertical reference and is accurate up to 0.1° as reported by the manufacturer. Two adjustable plastic locator rods, approximately 10 cm in length (Figure 1), were attached to the inclinometer as an adaptation for measuring scapular upward rotation. These locator rods are Y-shaped and designed to rest comfortably over the bony contours of the scapula. A bubble level was secured to the inclinometer to ensure minimal anterior/posterior tilt of the device about an axis parallel to the scapular spine (Figure 1). A priori intratester reliability of the scapular upward rotation measurements was assessed by the authors of this study. Twenty shoulders, without any previous injury or surgery were measured using an intraclass correlation coefficient (ICC) formula. Each subject’s scapular motion was measured and then reassessed a minimum of 24 hours.

<table>
<thead>
<tr>
<th>Table 1 Subject Characteristics</th>
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<tr>
<td>Mean ± SD</td>
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<tr>
<td>Age (yrs)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Mass (kg)</td>
</tr>
<tr>
<td>Professional Baseball Experience (yrs)</td>
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Note. 23 right hand dominant, 1 left hand dominant
later. The ICC and standard error of measurement (SEM) values were .95 (.5°), .93 (.8°), .95 (1°), and .92 (1.1°) for scapular upward rotation at 0°, 60°, 90°, and 120° of humeral elevation, respectively. Johnson et al9 reported good to excellent validity of this measurement by comparing the method to both static ($r = 0.74$ to 0.92) and dynamic ($r = 0.59$ to 0.73) humeral positions using an electromagnetic spatial tracking device.

The Lafayette Manual Muscle Test System (Model 01163; Lafayette Instrument, Lafayette, IN) was used for measuring periscapular strength. This system is a hand-held 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 where more bulky systems are not appropriate. This device contains an automatic drift compensation to produce accurate and reliable measurements and has an accuracy of ±1% as reported by the manufacturer. The intratester reliability of using this instrument for measuring serratus anterior and lower trapezius strength was assessed by the investigators of this study. Twenty shoulders, without any previous injury or surgery were measured using an ICC$(2,k)$ formula.10 Each muscle was measured and then reassessed a minimum of 24 hours later. The ICC and SEM values for the serratus anterior and lower trapezius showed strong reliability with values of .97 (1.1 kg) and .94 (1.1 kg), respectively. Validity for these measurements have also been previously established by comparing the amount of lower trapezius$^{11}$ and serratus anterior$^{12}$ muscle activity during the strength tests described below to subsequent methods.

**Procedures**

Each subject attended one testing session and provided informed consent as mandated by the University’s Institutional Review Board prior to participation.
Scapular upward rotation was assessed by the principal investigator in the scapular plane at humeral elevation angles of 0°, 60°, 90°, and 120°. Humeral elevation angles were predetermined prior to scapular measurement by aligning the inclinometer along the long axis of the upper arm. Subjects elevated their arm in the scapular plane (used wall as guide against dorsal hand) with the thumb positioned toward the ceiling throughout the testing procedure. The starting position began with the test arm in the resting position (arm at side of body) and the subject looking forward. Subjects elevated their arms until reaching the specific humeral angle (0°, 60°, 90°, or 120°). At each angle, the subject was instructed to hold that position while the digital level was positioned over the scapula and the amount of scapular upward rotation was measured. These angles were measured in sequence (0°, 60°, 90°, or 120°), and only one trial was measured for each angle. The locator rods were positioned over the posterolateral acromion and the root of the scapular spine (Figure 1). After each level of arm elevation the subject returned to the resting position and an ample rest period (approximately 20 to 60 seconds), determined by each individual subject, was provided before initiation of the next arm position to minimize fatigue.

All strength tests were performed by the same investigator and no test was performed following an extensive throwing session. All shoulder strength measurement positions were adapted from the recommendations of Kendall et al. These positions were chosen in an attempt to isolate the desired muscle and have been previously reported to result in the highest amount of muscle activation of both the serratus anterior and lower trapezius. Subjects were allowed ample time to practice the movements before each test to become familiar with the testing procedures. Each test consisted of the subject maximally contracting against the external force until this external force, applied by the tester, caused a “break” in the test position of the subject. The force required to break the test position was then recorded as the relative strength of the specific muscle.

To measure serratus anterior strength, subjects were seated in an upright position with the nondominant arm holding onto the examination table for stability. Subjects were placed in a position of approximately 120 to 130° of shoulder flexion. The digital dynamometer was then positioned over the distal portion of the humerus, followed by the examiner providing a downwardly directed force against the effort of each subject as they attempted to elevate their humerus (Figure 2). This testing position emphasizes the ability of the serratus anterior to upwardly rotate the scapula in an abducted scapular position rather than emphasizing scapular protraction when testing in a supine and/or standing position.

To measure lower trapezius strength, each subject was positioned prone on an examination table with their shoulder abducted so the arm was approximately in line with the muscle fibers of the lower trapezius. The digital dynamometer was positioned over the spine of the scapula, while the investigator applied a force parallel to the axis of the humerus (superior and lateral; Figure 3).

**Statistical Methods**

A stepwise multiple regression analysis (SPSS version 11.5, SPSS Inc, Chicago, IL) was used to determine if a relationship existed between periscapular strength (independent variable) and scapular upward rotation (dependent variable).
Results

The mean values for static scapular upward rotation among the baseball pitchers are shown in Table 2. These values are similar to those reported among both professional pitchers and position players using similar methodology.15
There was a moderate-good positive relationship between lower trapezius strength (20.7 ± 4.1 kg) and static scapular upward rotation at 90° ($r^2 = .56$, $P = .001$; Figure 4) and 120° ($r^2 = .53$, $P = .001$; Figure 5) of humeral elevation. These coefficients of determination ($r^2$) demonstrated that 56% and 53% of the error variance in scapular upward rotation was explained by lower trapezius strength. Poor relationships were shown between serratus anterior strength (29.8 ± 6.8 kg) and scapular upward rotation at all four levels of humeral elevation ($r^2 < .22$). Correlation coefficient values and coefficients of determination for both muscles and scapular upward rotation at all four levels of humeral elevation are shown in Table 3.

### Table 2  Mean values for Static Scapular Upward Rotation

<table>
<thead>
<tr>
<th>Angle of Humeral Elevation</th>
<th>Mean (°)</th>
<th>±SD (°)</th>
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<tbody>
<tr>
<td>0°</td>
<td>5.3</td>
<td>3.2</td>
</tr>
<tr>
<td>60°</td>
<td>9.2</td>
<td>5.5</td>
</tr>
<tr>
<td>90°</td>
<td>13.7</td>
<td>5.8</td>
</tr>
<tr>
<td>120°</td>
<td>19.5</td>
<td>6.6</td>
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**Figure 4** — Linear relationship between scapular upward rotation at 90° of humeral elevation and lower trapezius strength.
Figure 5 — Linear relationship between scapular upward rotation at 120° of humeral elevation and lower trapezius strength.

Table 3  Correlation Coefficient Values ($r$) and Coefficients of Determination ($r^2$) for Periscapular Strength and Scapular Upward Rotation

<table>
<thead>
<tr>
<th>Scapular Upward Rotation</th>
<th>Lower Trapezius $r \ (r^2)$</th>
<th>Serratus Anterior $r \ (r^2)$</th>
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<tbody>
<tr>
<td>0° Humeral Elevation</td>
<td>0.38 (.14)</td>
<td>0.004 (.00002)</td>
</tr>
<tr>
<td>60° Humeral Elevation</td>
<td>0.51 (.26)</td>
<td>0.30 (.09)</td>
</tr>
<tr>
<td>90° Humeral Elevation</td>
<td>0.75 (.56) *</td>
<td>0.40 (.16)</td>
</tr>
<tr>
<td>120° Humeral Elevation</td>
<td>0.73 (.53) *</td>
<td>0.47 (.22)</td>
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*Indicates statistically significant correlation ($P < .05$).

A poor relationship was reported between lower trapezius and serratus anterior strength ($r^2 = .20, \ P = .03$); however, both lower trapezius and serratus anterior strength together were shown to have a moderate-good correlation with scapular upward rotation at 90° ($r^2 = .56, \ P = .001$) and 120° ($r^2 = .53, \ P = .001$) of humeral elevation.
The results of this study demonstrate that baseball players with deficits in lower trapezius strength tended to have decreased scapular upward rotation at the higher degrees of humeral elevation. Deficiencies in scapular upward rotation have been associated with altered shoulder kinematics and an increased risk of shoulder injury. Therefore, proper periscapular strength and concomitant scapular upward rotation are significant factors among overhead athletes such as baseball players.

Upward rotation of the scapula occurs about an axis perpendicular to the scapular plane and coordinates with humeral elevation. This motion, originally termed by Inman et al as “scapulohumeral rhythm” has often been described as a 2:1 ratio between the humerus and the scapula. As such, an insufficient amount of scapular upward rotation may result in lost center of rotation and a change in alignment between the humeral head and the glenoid cavity. This scapular dyskinesis is hypothesized to result in an altered base of support for the numerous muscles, which attach to the scapula and ultimately a decrease in force production.

Inadequate scapular upward rotation may also result in a diminished function of the kinetic chain between the upper and lower extremity. MacWilliams et al reported high correlations between the large forces produced by the lower extremity and increased wrist velocity during the throwing motion. These authors hypothesized that lower extremity force generation initiates forward momentum of the body and is ultimately transferred up the kinetic chain to the shoulder, elbow, and wrist, thereby creating greater velocities of the upper extremity and finally a greater amount of ball velocity.

Although the regression analysis showed moderate-good associations, there were still a large percent of the error variance that cannot be explained by lower trapezius strength. One potential cause of this variance may be due to the contribution of other scapular muscles, primarily the upper trapezius, in upward rotation of the scapula.

Another potential source of variance may be due to the contribution of the inferior portion of the glenohumeral capsule. Tension is hypothesized to develop in the inferior capsule as the humerus elevates. As such, when the humerus reaches the higher stages of humeral elevation, the increased tension in the inferior capsule may passively pull the scapula into a more upwardly rotated position.

The poor relationship between serratus anterior strength and scapular upward rotation may be explained by several factors. First, humeral elevation while in 120 to 130° of shoulder flexion has been shown to produce the highest amount of muscle activity of the serratus anterior, the force produced in this position may have been the result of accessory muscle contributions, such as the upper trapezius, anterior deltoid, pectoralis major, and biceps brachii. Second, the serratus anterior may have less of a mechanical advantage for producing scapular upward rotation compared with the lower trapezius. And finally, scapular upward rotation was measured in the scapular plane, but the serratus anterior was tested in the sagittal plane, potentially affecting a possible relationship.

Our results may have important clinical implications. Previous research has reported that subjects diagnosed with subacromial impingement, as well those with inferior and multidirectional glenohumeral instability, have decreased scapular
upward rotation compared with control subjects. Conflicting results regarding the exact scapular kinematics present among such patients, however, have led to some confusion.\textsuperscript{24,25} The results of the current study indicate that weakness of periscapular musculature may make athletes particularly susceptible to such pathologies.

These previous investigations and various hypotheses\textsuperscript{1,3,8,11,14,26,27} emphasize the importance of early identification of decreased scapular upward rotation and periscapular strength to limit soft tissue damage. The results of the current study demonstrate that there is a moderate-good relationship between scapular upward rotation and lower trapezius strength. More specifically, lower trapezius strength appears to be a good indicator of the amount of scapular upward rotation at the higher levels of humeral elevation. This finding may be of particular importance to the clinician because of the association between decreased scapular upward rotation and pathologies, such as subacromial impingement and instability, which often occur at these higher levels of humeral elevation.

Limitations of This Study

The authors of this study recognize several methodological limitations that must be addressed. Scapular kinematics have been well documented as occurring in three dimensions (upward/downward rotation, internal/external rotation, anterior/posterior tilt, superior/inferior translation, anterior/posterior translation);\textsuperscript{28-30} however, the methods used for the present investigation simply measured scapular upward rotation. Although this study assessed a two-dimensional motion, previous literature emphasizes the importance of scapular upward rotation to the overall function of the shoulder.\textsuperscript{1,3,17} Secondly, our measurement of peak strength is generally used as a precursor to joint stability rather than control of motion. The intention of this study, however, was to demonstrate the relationship between two measurements that are readily available in most clinical settings. Furthermore, the investigators of this study recognize that the poor relationship between scapular upward rotation and serratus anterior strength may have been due to the strength measurement occurring at a higher amount of humeral elevation (120°-130°) than was tested during scapular upward rotation (0°, 60°, 90°, 120°) thereby decreasing the function of the serratus anterior. Finally, this study used baseball pitchers without a history of upper extremity pathology or surgery. Individuals with shoulder pathologies, such as subacromial impingement, instability, and SLAP lesions, may present with different results and should be addressed in future investigations.

Conclusion

A thorough understanding of scapular motion and the muscles controlling this motion are critical in the prevention and treatment of shoulder injuries. The results of this study indicate that a positive relationship exists between lower trapezius strength and scapular upward rotation at 90° and 120° of humeral elevation. Therefore, strengthening of the lower trapezius muscle should be considered as a preventative measure and/or during rehabilitation of pathologies, such as subacromial impingement and shoulder instability.
References


