Scapular Muscle Activation in Individuals With Shoulder Pathology During Early Phase Scapular Stabilization Exercises

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ABSTRACT

Rehabilitation exercises to restore scapular stabilization promote balance in activation between the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) muscles. Research examining early stage scapular rehabilitation exercises is limited to asymptomatic adults. The study’s purpose was to determine whether scapular muscle activation ratios (UT/MT, UT/LT, and UT/SA) differ between glenohumeral joint pathology (n = 14) and asymptomatic controls (n = 12) during concentric and eccentric phases of five scapular stabilization rehabilitation exercises (2 per ratio). UT, MT, LT, and SA activity was measured using surface electromyography during concentric and eccentric phases of exercises. Activation ratios were calculated using normalized mean surface electromyography. Results found no group differences in activation ratio (P ≥ .095), but did identify differences (P < .009) between concentric and eccentric phases of sidelying forward flexion, prone horizontal abduction/external rotation exercises. These findings can be a valuable resource for clinicians in developing a rehabilitation program that promotes desirable scapular muscle activation ratios. [Athletic Training & Sports Health Care. 2015;7(4):151-159]

The function of the scapula in providing stability and mobility for coordinated glenohumeral joint (GHJ) movement is well documented. Imbalances in activation and strength among scapular muscles may lead to or contribute to shoulder pain and injury. A particular concern is that decreased activation and strength in the middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) muscles compared to the upper trapezius (UT) could promote an undesirable force couple balance that increases susceptibility to shoulder pathology.

Accordingly, preventative and rehabilitation programs for the shoulder complex should include a focus on promoting coordinated and synchronous activation of the muscles responsible for scapular stabilization to provide functional mobility of the scapula. Existing research recommends incorporating exercises that promote maximal activation of the individual muscles that govern the scapula. However, the absence of substantial information that addresses the synergy between muscle activation properties warrants continued research.

In response to shoulder injuries that are attributed to poor force couple balance, studies have examined and, subsequently, recommended exercises to effectively restore the balance. Given increased reliance on the UT, the suggested exercises are theoretically intended to inhibit UT activation while facilitating MT, LT, and SA activity. A primary focus of initial research involved assessment of the effectiveness of the prone horizontal abduction exercise in restoring and improving scapular kinematics. A concern that emerged regarding this specific exercise is the limitation of only identifying the UT/LT ratio. Subsequently, studies were conducted to examine more scapular muscle activation ratios and rehabilitation exercises to determine how the UT activates relative to the MT, LT, and SA as a ratio.
In identifying the effectiveness of exercises to restore force couple balance involving scapular stabilization, consideration must be given to both the execution of the exercise and the phase of muscle contraction used to perform the exercise. Current exercise recommendations are based on an overall activation ratio in the absence of examination of potential ratio changes relative to the concentric or eccentric contraction phase of the exercise. It has been reported that there is a decreased activation of the LT during the eccentric phase of the prone horizontal abduction exercise in asymptomatic individuals and individuals with shoulder pain. However, no explanation was offered for the activation difference relative to the contraction phase.

An understanding of the effectiveness of an exercise, as well as the impact of the muscle contraction phase of the exercise, can advance the ability of the clinician to develop and implement a rehabilitation program that promotes optimal activation and strength among scapular muscles. For example, performing only the concentric phase of the prone horizontal abduction exercise may be more advantageous in optimizing LT activation.

The purpose of the current study was to examine the effect of specific exercises on the activation ratios of the UT/LT, UT/MT, and UT/SA in an asymptomatic population and in individuals with GHJ pathology. Activation ratios for both concentric and eccentric phases were determined. It was hypothesized that participants with GHJ pathology would exhibit greater activation ratios values, indicating overcompensation by the UT and inhibition of the MT, LT, and SA.

**METHODS**

A cross-sectional design was used for this study. The independent variables included the rehabilitation exercises, the muscle contraction phase (ie, concentric, eccentric), and the participant group (ie, individuals with GHJ pathology and individuals free of any GHJ pathology). The UT/MT activation ratio was examined using the prone extension exercise and the sidelying forward flexion exercise. The UT/LT activation ratio was studied using the sidelying forward flexion exercise and the prone horizontal abduction with external rotation exercise. The UT/SA activation ratio was assessed using the standing forward flexion exercise and the sitting diagonal exercise. The dependent variables included normalized muscle activation (ie, percent maximum voluntary isometric contraction [% MVIC]) using mean surface electromyography (EMG) from the UT, MT, LT, and SA. Scapular muscle activation ratios (ie, UT/MT, UT/LT, UT/SA) were calculated using the normalized data. The institutional review board approved this study and informed consent was obtained prior to testing.

**Participants**

A total of 29 participants were tested. The initial sample consisted of 15 individuals with GHJ pathology and 14 asymptomatic individuals with no history of GHJ pain or pathology. Due to instrument error during testing, the final sample consisted of 14 individuals with GHJ pathology and 12 asymptomatic individuals. Table 1 presents descriptive information of each group.

A musculoskeletal examination was performed on each participant by an experienced athletic trainer (SJC) as a means for classifying participants as either injured or asymptomatic. The examination included range of motion, strength, and special tests for GHJ pathologies. Selection of special tests was based on clinical utility and previous research for subacromial impingement (painful arc, Neer test, infraspinatus test, and Hawkins–Kennedy test), rotator cuff injury (cross-body adduction, drop arm test, infraspinatus strength test, and empty-can test), GHJ instability (apprehension test, relocation test, anterior release, and sulcus sign), and labral pathologies (crank test, anterior slide test, Speed test, and biceps load I and II tests). Individuals were delegated to the GHJ pathology group based on the following criteria: (1) testing positive on three or more of the tests administered and (2) responding positively to two of the following three questions: (A) Do you experience weakness, throbbing pain, pain with motion, and/or pain with overhead activities?, (B) Do you feel looseness and/or instability in your shoulder?, and (C) Do you experience sensations of clicking, popping, cracking, snapping, and/or catching? Exclusion criteria of the GHJ pathology group included self-report of any of the following: surgery to the test extremity prior to testing, neurovascular disorders, lack of available range of motion needed for testing (130° shoulder abduction and flexion), or any other current GHJ pathologies (eg, frozen shoulder, acromioclavicular joint pathology, fractures, and spine injuries).

Participants were considered asymptomatic if they exhibited full, pain-free range of motion and function in the test extremity. Exclusion criteria for the asympto-
tomatic control group included: self-report of injury or surgery prior to testing, any injuries sustained to the test extremity within the 6 months prior to testing, neurovascular disorders, and lack of available range of motion needed for testing (130° shoulder abduction and flexion). Asymptomatic participants were matched to shoulder injury participants on sex, age, mass, height, and arm dominance.

### Instrumentation

The instrumentation in this study involved the use of EMG and electro-goniometer. Surface EMG was recorded from the UT, MT, LT, and SA during the five early phase scapular stabilization rehabilitation exercises examined using the Myosystem 1200 EMG acquisition system (Noraxon USA, Inc., Scottsdale, AZ). A single-ended amplifier was used (impedance > 10 MΩ, gain = 1,000) with a fourth order Butterworth filter (10 to 500 Hz), and a common mode rejection ratio of 130 dB. A receiver with a sixth order filter (gain = 2, total gain = 2,000) was used to further amplify the signal. The signal was passed to a computer through a 16-channel NorBNC connector system and a 12-bit analog-to-digital card (Noraxon USA, Inc.). The sampling rate was 1,000 Hz. EMG files were stored on the computer and MyoResearch software (version MR-XP 1.07; Noraxon USA, Inc.) was used for processing data.

A two-dimensional electro-goniometer (Biometrics LTD, Newport, UK) was used to track shoulder movements during the rehabilitation exercises. The sensors were applied according to manufacturer guidelines. Double-sided adhesive tape was used to secure goniometer sensor endblocks to the skin on the lateral border of the scapula and lateral aspect of the proximal test arm. The sensor endblocks were attached to a pre-amplified cable that connected to an external amplification and power supply box (nominal output range: ± 180°). The leads were connected to the NorBNC analog input channels (Noraxon USA, Inc.), which sent the signal into a personal computer where data were displayed using MyoResearch software (version MR-XP 1.07; Noraxon USA, Inc.). The electro-goniometer signals were synchronized with EMG data and later used to mark the start and end of the concentric and eccentric phase of each rehabilitation exercise.

### Procedures

Prior to testing, participants signed an informed consent and completed a demographic and injury history form. Participants also completed the Disabilities of Arm, Shoulder, and Hand (DASH) Outcome Measure, a self-report questionnaire consisting of 30 questions and a 4-question sport/performing arts module intended to measure physical function, symptoms, and emotional and social function associated with musculoskeletal disorders of the upper limb. The testing was completed in a research laboratory during a single test session.

In preparation for the EMG, the skin was shaved and cleaned prior to the placement of self-adhesive surface electrodes on the skin overlying the UT, MT, LT, and SA, as well as positioning a reference electrode on the ipsilateral clavicle (Ag-AgCl, 10 mm diameter and 10 mm inter-electrode distance, Noraxon USA, Inc.). Following placement of the electrodes, using standardized procedures outlined in Table 2, the EMG activity was monitored during

### Table 1

Demographic Information of Participants Tested by Group (Mean ± SD)

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SEX</th>
<th>AGE (Y)</th>
<th>MASS (KG)</th>
<th>HEIGHT (CM)</th>
<th>ARM DOMINANCE</th>
<th>DASH TOTAL (OUT OF 100 PTS)</th>
<th>DASH SPORT/PERFORMING ARTS MODULE (OUT OF 100 PTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHJ pathology (n = 14)</td>
<td>Male: n = 7; Female: n = 7</td>
<td>31.6 ± 16.1</td>
<td>77.7 ± 22.9</td>
<td>172.2 ± 12.8</td>
<td>Right: n = 13; Left: n = 1</td>
<td>27.2 ± 13.7*</td>
<td>30.4 ± 27.6*</td>
</tr>
<tr>
<td>Asymptomatic control (n = 12)</td>
<td>Male: n = 4; Female: n = 8</td>
<td>26.9 ± 12.5</td>
<td>68.4 ± 17.2</td>
<td>169.1 ± 8.5</td>
<td>Right: n = 10; Left: n = 2</td>
<td>1.4 ± 3.7</td>
<td>1.6 ± 5.4</td>
</tr>
<tr>
<td>Total (n = 26)</td>
<td>Male: n = 11; Female: n = 15</td>
<td>29.5 ± 14.5</td>
<td>73.4 ± 20.6</td>
<td>170.8 ± 10.9</td>
<td>Right: n = 23; Left: n = 3</td>
<td>15.2 ± 16.6</td>
<td>17.1 ± 25.0</td>
</tr>
</tbody>
</table>

SD = standard deviation; GHJ = glenohumeral joint; DASH = Disabilities of Arm, Shoulder, and Hand Outcome Measure

*Indicates between-group difference of P < .002.
isolated muscle testing to ensure accurate placement of electrodes.

Using standardized manual muscle testing methods, the MVIC was determined for the UT, MT, LT, and SA of the test extremity\(^\text{19}\) (Table 2). Participants were instructed to resist with maximal effort against the investigator’s manual pressure for 5 seconds. The average of three MVICs of each muscle was used for
EMG normalization during data processing. Prior to each test, the EMG signal calibrated with the participant in a relaxed, seated (UT, SA), or prone (MT, LT) position to establish baseline activity.

Following MVIC tests, the electro-goniometer was secured to the test extremity in preparation for completing selected early phase rehabilitation exercises. Instructions were provided for executing the exercises. Participants were allowed unlimited time to practice the exercises and were provided with verbal feedback concerning the accuracy of their performance. The exercises were performed in two phases, concentric and eccentric, while holding a 1 kg dumbbell. Each phase occurred over 5 seconds; the timing was controlled using a digital metronome (60 beats per minute). Participants were required to perform five acceptable repetitions, determined by the investigator (SJC) and defined as maintaining form, movement quality, and speed, of each exercise while EMG and electro-goniometer data were recorded. The middle three acceptable repetitions for each exercise were used in data analysis. The order in which the exercises were performed was counterbalanced among participants. An explanation of the exercises is found in Table 3 and displayed in Figures 1-5.

Data Reduction

Using MyoResearch software, raw EMG data were full-wave rectified (ie, linear envelope detection), integrated with a sixth order Butterworth filter, and smoothed over a 15 ms moving window (version MR-XP 1.07; Noraxon USA, Inc.). The peak of three MVICs were averaged for each muscle and used for normalizing EMG in the rehabilitation exercise trials. The electro-goniometer signal was used to designate the start and end of concentric and eccentric phases for acceptable repetitions of each rehabilitation exercise. The mean EMG data for each muscle was normalized as a percentage of the MVIC (% MVIC). Data were exported to a spreadsheet and scapular muscle activation ratios were calculated by dividing normalized EMG values of the UT by normalized EMG values of the MT, LT, and SA to generate ratios UT/MT, UT/LT, and UT/SA, respectively. As such, a high muscle activation ratio value corresponded with more UT activity and a low value represented less UT activity with respect to the MT, LT,
and SA. Following calculation of the scapular muscle activation ratios, data were imported to SPSS v18.0 software (IBM Corporation, Somers, NY) for data analysis.

**Data Analysis**

Descriptive and inferential analyses were performed on collected data. An independent samples t test evaluated DASH score differences between groups.

Prior to analyses, normalized EMG data were evaluated for outliers and sphericity using the Kolmogorov–Smirnov test. Separate 2 (rehabilitation exercise) × 2 (phase) × 2 (group) analyses of variance with repeated measures using the multivariate approach were used to examine differences in the UT/LT, UT/MT, and UT/SA muscle activation ratios. Effect size was calculated as the mean change between groups divided by the pooled standard deviation. An effect size of 0.8 or greater presents a large change, 0.5 is a moderate change, and 0.2 or less is considered a small change. The alpha level was set at .05 a priori for repeated measures analyses. Independent t tests with Bonferroni correction (ie, 2 tests, alpha ≤ 0.025) were used for all indicated post hoc analyses. SPSS software (version 18.0; IBM Corporation) was used to analyze data.

**RESULTS**

Demographic data of participants, by group and total, are presented in Table 1. The participants with GHJ pathology presented with labral pathology (n = 6), subacromial impingement (n = 4), rotator cuff pathology (n = 3), and subacromial impingement + rotator cuff pathology (n = 1). The GHJ pathology group reported higher total and sport module scores on the DASH, indicating more disability and symptoms than the asymptomatic group (Table 1, P < .001 for DASH Total and P = .002 for DASH Sport/Performing Arts module).

EMG data from 1 GHJ pathology participant and 2 asymptomatic control participants were removed from analyses because values exceeded ± 3 standard deviations. Accordingly, all analyses were performed and reported on 14 GHJ pathology and 12 asymptomatic participants.

Significant differences were found for the scapular muscle activation ratios between concentric and eccentric phases of rehabilitation exercises (P ≤ .009). However, there were no differences between GHJ pathology and asymptomatic control groups (P = .095, .095, and .199 for UT/MT, UT/LT, and UT/SA, respectively). The effect sizes for the activation ratios ranged between 0.54 and 0.73 for UT/MT, 0.38 and 0.84 for UT/LT, and 0.21 and 0.64 for UT/SA.

A significant rehabilitation exercise × phase interaction (F = 16.1, P = .001) and post hoc analyses found the UT/MT activation ratio was significantly greater during the concentric phase compared to the eccentric phase of the sidelying forward flexion rehabilitation exercise (P = .001; 0.86 ± 0.89 and 0.69 ± 0.73, respectively, effect size = 0.74, Table 4). There were no other significant differences found for the UT/MT activation ratio (P > .05, ES = 0.36).

A significant rehabilitation exercise × phase interaction (F = 24.0, P = .009) and post hoc analyses found the UT/LT activation ratio was significantly greater during the eccentric phase compared to the concentric phase of the prone horizontal abduction exercise. Figure 4. Standing forward flexion rehabilitation exercise.

Figure 5. Sitting diagonal rehabilitation exercise.
Scapular Muscle Activation/Cayton et al

with external rotation rehabilitation exercise ($P < .001$, 1.3 ± 0.87 and 1.1 ± 0.79, respectively, effect size $= 0.84$, Table 5). There were no other significant differences found for the UT/LT activation ratio ($P > .05$, effect size $= 0.02$).

There were no significant differences found for the UT/SA activation ratio ($P > .05$, Table 6). The effect size between concentric and eccentric phases for standing forward flexion and sitting diagonal was 0.16 and 0.13, respectively.

**DISCUSSION**

Limited information is available to report on scapular stabilization rehabilitation exercises and muscle activation characteristics in patients with GHJ pathology. Cools et al. studied exercises commonly used early in rehabilitation to determine which exercise should be prescribed theoretically for promoting activation of individual scapular muscles (ie, MT, LT, and SA) relative to UT activity to reestablish balance of scapular activation ratios in asymptomatic individuals. In an effort to expand the clinical utility of these early phase scapular stabilization rehabilitation exercises, the current study used the recommendations by Cools et al. to examine the effect of specific exercises on the activation ratios of the UT/LT, UT/MT, and UT/SA in GHJ pathology versus asymptomatic individuals. It was hypothesized that individuals with GHJ pathology would display

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**TABLE 4**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>PRONE EXTENSION</th>
<th>SIDELEYING FORWARD FLEXION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONCENTRIC UT/MT</td>
<td>ECCENTRIC UT/MT</td>
</tr>
<tr>
<td>GHJ pathology</td>
<td>0.53 ± 0.34 (0.33, 0.74)</td>
<td>0.55 ± 0.34 (0.35, 0.75)</td>
</tr>
<tr>
<td>Asymptomatic control</td>
<td>0.76 ± 0.39 (0.55, 0.98)</td>
<td>0.82 ± 0.40 (0.60, 1.0)</td>
</tr>
<tr>
<td>Groups combined</td>
<td>0.64 ± 0.38 (0.49, 0.79)</td>
<td>0.67 ± 0.38 (0.52, 0.83)</td>
</tr>
<tr>
<td></td>
<td>0.62 ± 0.46 (0.36, 0.89)</td>
<td>0.50 ± 0.38 (0.29, 0.72)</td>
</tr>
</tbody>
</table>

UT = upper trapezius; MT = middle trapezius; GHJ = glenohumeral joint.
Values are reported as mean ± standard deviation (95% confidence intervals) and reflect percent maximum voluntary isometric contraction. Indicated statistical significance, $P < .025$.

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**TABLE 5**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>PRONE HORIZONTAL ABDUCTION WITH EXTERNAL ROTATION</th>
<th>SIDELEYING FORWARD FLEXION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONCENTRIC UT/LT</td>
<td>ECCENTRIC UT/LT</td>
</tr>
<tr>
<td>GHJ pathology</td>
<td>0.84 ± 0.53 (0.53, 1.1)</td>
<td>0.94 ± 0.53 (0.64, 1.2)</td>
</tr>
<tr>
<td>Asymptomatic control</td>
<td>1.4 ± 0.95 (0.79, 2.0)</td>
<td>1.6 ± 1.0 (0.99, 2.3)</td>
</tr>
<tr>
<td>Groups combined</td>
<td>1.1 ± 0.79 (0.78, 1.4)</td>
<td>1.3 ± 0.87 (0.92, 1.6)</td>
</tr>
<tr>
<td></td>
<td>0.65 ± 0.67 (0.26, 1.0)</td>
<td>0.69 ± 0.96 (0.14, 1.2)</td>
</tr>
</tbody>
</table>

UT = upper trapezius; LT = lower trapezius; GHJ = glenohumeral joint.
Values are reported as mean ± standard deviation (95% confidence intervals) and reflect percent maximum voluntary isometric contraction. Indicated statistical significance, $P < .025$.

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**TABLE 6**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>STANDING FORWARD FLEXION</th>
<th>SITTING DIAGONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONCENTRIC UT/SA</td>
<td>ECCENTRIC UT/SA</td>
</tr>
<tr>
<td>GHJ pathology</td>
<td>1.6 ± 1.2 (0.9, 2.3)</td>
<td>2.0 ± 2.0 (0.87, 3.2)</td>
</tr>
<tr>
<td>Asymptomatic control</td>
<td>2.4 ± 1.7 (1.3, 3.5)</td>
<td>2.4 ± 1.7 (1.3, 3.5)</td>
</tr>
<tr>
<td>Groups combined</td>
<td>2.0 ± 1.5 (1.4, 2.6)</td>
<td>2.2 ± 1.8 (1.4, 2.9)</td>
</tr>
<tr>
<td></td>
<td>1.3 ± 0.93 (0.81, 1.9)</td>
<td>1.3 ± 0.84 (0.79, 1.8)</td>
</tr>
<tr>
<td></td>
<td>2.2 ± 1.8 (1.0, 3.3)</td>
<td>2.0 ± 1.5 (1.0, 2.9)</td>
</tr>
<tr>
<td></td>
<td>1.7 ± 1.4 (1.2, 2.3)</td>
<td>1.6 ± 1.2 (1.1, 2.1)</td>
</tr>
</tbody>
</table>

UT = upper trapezius; SA = serratus anterior; GHJ = glenohumeral joint.
Values are reported as mean ± standard deviation (95% confidence intervals) and reflect percent maximum voluntary isometric contraction.
higher scapular muscle ratios, indicating an imbalance suggestive of increased UT activation. No significant group differences in scapular muscle activation ratios were found in the current study. However, there were differences between rehabilitation exercise and phase.

The UT/MT ratio was measured during concentric and eccentric phases of both sidelying forward flexion and prone extension exercises. Although there was no significant difference in muscle activation ratio during the prone extension exercise, the sidelying forward flexion exercise resulted in a muscle activation ratio that was higher during the concentric phase compared to the eccentric phase of the movement. The finding of an imbalance in the activation ratio between concentric and eccentric phases indicates a change in activation within or between the UT and MT. On further inspection of raw EMG data, the increased concentric phase activation ratio was due to a higher UT activity and less MT activity compared to the eccentric phase, which indicated less UT and more UT activation. Because the goal is to maximize MT activity relative to UT activity, clinicians may consider modifying the sidelying forward flexion exercise by delaying integration of the concentric phase or reducing the load until UT/MT balance has been reestablished. Furthermore, emphasis on the eccentric phase may be beneficial for both minimizing UT activity and increasing muscle activation and torque generation of the MT. Research has demonstrated benefits of eccentric contractions over concentric contractions for stimulating tissue growth and muscle torque while at the same time requiring less activation of the involved muscles, suggesting efficiency in firing. However, more research is needed to further examine suggested benefits in a human shoulder model to determine the impact of eccentric exercises for use in promoting LT, MT, and SA activation and re-balancing force couples.

The UT/LT ratio was examined during concentric and eccentric phases of the sidelying forward flexion and prone abduction with external rotation exercises. In these exercises and the phases within each, the UT/LT ratio was increased (ie, more imbalanced in favor of the UT) during the eccentric phase of prone abduction with external rotation exercises. These results are not consistent with previous research that demonstrated decreased muscle activation by as much as 61% during eccentric contractions. The change in forearm position associated with the external rotation portion of the exercise in the concentric phase and corresponding de-rotation back to a neutral forearm position in the eccentric phase may contribute to the phase differences found. Therefore, it may be advantageous for clinicians to consider using the sidelying forward flexion over prone abduction with external rotation, or modifying prone abduction with external rotation to delay use of, modify forearm position, or minimize the eccentric phase.

Research has not determined the best rehabilitation exercise for addressing UT/SA imbalances. It has been suggested that sitting diagonal movements address the UT/SA activation ratio, producing increased activation in the SA. The results of the current study did not reveal significant differences between groups, exercises, or contraction phase. Clinicians may consider these exercises in addressing the SA, but should remain cautious on the ability to reestablish UT/SA imbalances.

Overall, the results of the current study did not reveal group differences in any of the muscle activation ratios. The original expectation was higher ratios, due to increased UT activation in the GHJ pathology group. The lack of differences may be due to the high variability in EMG measures; however, examination of effect sizes provides insight regarding clinical significance and statistical significance of our results. Effect sizes for the UT/MT and UT/LT activation were consistently moderate to strong, whereas the UT/SA activation ratio effect sizes were low. Therefore, effect sizes for the UT/MT and UT/LT activation ratios suggest both statistical and clinical significance of results between groups and between concentric and eccentric phases of an exercise. Comparison of ratios in the asymptomatic participants in this study to those reported by others show asymptomatic participants displayed higher ratios overall. Differences in testing methods, function and disability as indicated by DASH scores, and preexisting activation imbalances in the asymptomatic participants may explain the disagreement in scapular muscle activation ratio values. However, clinically, the scapular muscle activation ratio values can be extrapolated to demonstrate that ratios may become more balanced as a patient undergoes rehabilitation.

There were limitations to the current study. Testing more participants per group may provide more insight regarding group differences between the scapular sta-
bilitation rehabilitation exercises examined. The use of a 1 kg dumbbell as resistance during exercises for all participants may have affected muscle activation. In the future, resistance should be determined as a percent of one’s maximum to account for individual differences. More exercises, especially those categorized as functional, should be examined.

**IMPLICATIONS FOR CLINICAL PRACTICE**

The results of this study provide insight about scapular muscle activation ratios, and neither strongly support nor refute the use of these exercises in addressing scapular imbalances in patients with GHJ pathology. Although a strong recommendation for use of these exercises cannot be provided, it is suggested that clinicians consider using sidelying forward flexion and prone abduction with external rotation to elicit a lower UT/MT ratio and the concentric phase of the prone horizontal abduction with external rotation exercise to promote a lower UT/LT ratio. Sidelying forward flexion may also be beneficial to reduce UT activity. Evidence does not support the recommendation of a specific exercise to promote a lower UT/SA ratio. Clinicians should always exercise caution and monitor patients as they perform each exercise. Proper instruction, along with tactile and verbal cues, can encourage improved scapular muscle balance.

**REFERENCES**