Conscious Correction of Scapular Orientation in Overhead Athletes Performing Selected Shoulder Rehabilitation Exercises: The Effect on Trapezius Muscle Activation Measured by Surface Electromyography

**OBJECTIVES:** To assess the effect of conscious correction of scapular orientation on the activation of the 3 sections of the trapezius muscle during exercises in overhead athletes with scapular dyskinesis.

**METHODS:** Absolute (upper trapezius [UT], middle trapezius [MT], lower trapezius [LT]) and relative (UT/MT and UT/LT) muscle activation levels were determined with surface electromyography in 30 asymptomatic overhead athletes with scapular dyskinesis, during 4 selected exercises performed with and without conscious correction of scapular orientation. Repeated-measures analyses of variance were used to determine if a voluntary scapular orientation correction strategy influenced the activation levels of the different sections of the trapezius during each exercise.

**RESULTS:** With conscious correction of scapular orientation, activation levels of the 3 sections of the trapezius muscle significantly increased during prone extension (mean ± SD difference: UT, 5.9% ± 8.6% maximal voluntary isometric contraction [MVIC]; MT, 13.8% ± 11.0% MVIC; LT, 9.6% ± 10.8% MVIC; P < .05) and sidelying external rotation (UT, 2.2% ± 4.4% MVIC; MT, 6.7% ± 10.6% MVIC; LT, 13.3% ± 24.4% MVIC; P < .05). There was no difference between conditions for sidelying forward flexion and prone horizontal abduction with external rotation. The UT/MT and UT/LT ratios were similar between conditions for all 4 exercises.

**CONCLUSION:** Conscious correction of scapular orientation during prone extension and sidelying external rotation exercises can be used to increase the activation level in the 3 sections of the trapezius in overhead athletes with scapular dyskinesis. Although lack of kinematic data limits the interpretation of the results, this study suggests that conscious correction of scapular orientation can be performed without altering the favorable UT/MT and UT/LT ratios that have previously been reported for these exercises. J Orthop Sports Phys Ther 2013;43(1):3-10. Epub 16 November 2012. doi:10.2519/jospt.2013.2483

**KEY WORDS:** muscle balance, overhead injury, scapular dyskinesis, shoulder pathology

Several researchers have found scapular dyskinesis to be associated with chronic shoulder pain in overhead athletes. In addition to scapulothoracic and glenohumeral soft tissue restrictions and the influences of thoracic posture, alterations in scapular muscle recruitment and strength have been found in these individuals compared to healthy controls. Because scapular orientation and movement can influence function of the glenohumeral joint and the rotator cuff musculature, it has been suggested that the scapulothoracic joint may require specific attention during physical therapy treatment, particularly in individuals who perform repetitive overhead movements. To assist in the clinical reasoning process, a scapular treatment algorithm has previously been presented to show how exercise training might be effective when a lack of muscle performance is present.
In the literature, scapular exercise selection is primarily based on 2 different concepts. The first concept is the selection of exercises focused on promoting the normal 3-D movement patterns of the scapula. In general, exercises in which the scapula moves into upward rotation, external rotation, and posterior tilt are of interest. For example, Mottram et al demonstrated the potential to teach healthy individuals to move the scapula into posterior tilt and upward rotation by activating all 3 portions of the trapezius muscle. In addition, Oyama et al showed that various scapular retraction exercises can be beneficial on the basis of their scapular and clavicular kinematics and amounts of muscle activity. There is also evidence for the effectiveness of corrective movement training, thought to influence the force couples around the scapula, in patients with shoulder impingement syndrome.

The second concept is to select exercises focusing on high activation levels in the muscles around the scapula, whether or not they also produce the desired 3-D movement of the scapula. Previous research has shown that the push-up plus, dynamic hug, and wall slide exercises elicit high amounts of serratus anterior muscle activity, with the push-up plus exercise producing minimal upper trapezius (UT) activation. In regard to trapezius muscle rehabilitation, Cools et al have identified 4 exercises that demonstrated low UT/middle trapezius (MT) and UT/lower trapezius (LT) muscle ratios in healthy individuals: prone extension, sidelying external rotation, sidelying forward flexion, and prone horizontal abduction with external rotation (Figure 1). Individuals with scapular dyskinesis often show hyperactivity of the UT with reduced MT and LT muscle activation, which is associated with decreased amounts of scapular upward rotation, external rotation, and posterior tilt. These 4 exercises are considered indicated in the rehabilitation of these individuals because they promote high MT and LT muscle activation levels while minimizing UT activation.

Within the scapular treatment algorithm, conscious control of the scapula is indicated as an essential component when training for correction of neuromuscular coordination as well as strength deficits (Figure 2). Consciously positioning the scapula into a more neutral resting position is considered important within this context. However, it is unclear how conscious correction of scapular orientation may affect the activation of the trapezius muscle during various dynamic movements performed under loaded conditions, as during the performance of the 4 previously selected exercises.

Therefore, the purpose of this study was to investigate the influence of conscious correction of scapular orientation on the absolute and relative trapezius muscle activation levels during the performance of the 4 previously selected exercises in overhead athletes with scapular dyskinesis. The results of this study could add evidence to the fundamental principles of shoulder rehabilitation strategies for individuals with scapular dyskinesis and related shoulder disorders.

**METHODS**

**Subjects**

Thirty healthy subjects participated in this study (18 men and 12 women; mean ± SD age, 22 ± 3 years; height, 1.76 ± 0.08 m; weight, 67.1 ± 8.7 kg). All subjects were active in overhead sports, including volleyball, swimming, and badminton, at a recreational level. Twenty-nine of the subjects were right handed. Subjects were included if they were between 18 and 30 years of age and showed altered scapular resting position and dyskinesis during dynamic clinical examination on the basis of a yes/no method. Yes indicated that the clinician observed an abnormal pattern of scapular movement (dyskinesis), which could have been prominence of the inferior medial scapular angle (type 1), the entire medial border (type 2), or the superior border of the scapula (type 3). Uhl et al demonstrated that this method had a sensitivity and positive predictive value of 76% and 74%, respectively, when compared with the results of 3-D motion analysis. The subjects also needed to be able to perform the exercises in a pain-free manner. Subjects were excluded if they had shoulder- or cervical spine-related symptoms,
a history of dislocations or shoulder surgery, or did not reach full range of motion during shoulder elevation. All subjects gave their written consent to participate. The study was approved by the Ethical Committee of the Ghent University Hospital.

**Instrumentation**

After shaving and preparation with alcohol to reduce skin impedance (typically 10 kΩ or less), bipolar surface electromyographic (EMG) electrodes (Blue Sensor; Ambu A/S, Ballerup, Denmark) were placed at a 2-cm interelectrode distance over the UT, MT, and LT of the dominant shoulder. Electrodes for the UT were placed midway between the spinous process of the seventh cervical vertebra and the posterior tip of the acromion process, along the line of the trapezius. The MT electrode was placed midway on a horizontal line between the root of the spine of the scapula and the vertebral border of the scapula and the seventh thoracic spinous process. The LT electrode was placed obliquely upward and laterally along a line between the intersection of the spine of the scapula and the vertebral border of the scapula and the seventh thoracic spinous process. A reference electrode was placed at the ipsilateral clavicle. To ensure the consistency of electrode placement, the same investigator placed all the electrodes. The electrodes were connected to a 16-channel MyoSystem 2000 EMG receiver (Naraxon USA Inc, Scottsdale, AZ). Correct electrode placement was confirmed by visual inspection of the EMG signals on a computer screen during specific muscle testing. The sampling rate was 1000 Hz. All raw myoelectric signals were preamplified (overall gain, 1000; common rate rejection ratio, 115 dB; signal-to-noise ratio, less than 1 µV root-mean-square baseline noise).

**Testing Procedure**

First, verification of EMG signal quality was completed for each muscle by having the subject perform maximal voluntary isometric contractions (MVICs) using manual muscle test positions specific to each muscle. For the UT, resistance was applied to abduction of the arm from a seated position. The MT was tested in a prone position, and resistance was applied to horizontal abduction in external glenohumeral rotation. The LT was also tested in a prone position, with the arm placed diagonally overhead in line with the fibers of the LT. Resistance was applied against further elevation. Subjects performed three 5-second MVICs against manual resistance for each muscle. There was a 5-second pause between each MVIC. A metronome was used to control duration of contraction. Five minutes of rest was provided after MVIC testing.

The baseline testing condition, performed without instructions on scapular orientation, consisted of 5 trials for each exercise (concentric phase lasting 3 seconds, metronome controlled). The order of testing for the 4 exercises was randomized. All exercises were performed with handheld weights, with the amount of weight determined by gender and body weight (Table). Subjects were provided with a 3-second rest between trials and allowed to rest for 2 minutes between exercises.

Subsequently, conscious correction of scapular orientation was taught to the subjects in the manner described in previous studies. The starting position was determined in each individual by actively positioning the scapula between maximal upward and downward rotation, external and internal rotation, and posterior and
anterio tilt. Visual, auditory, and kinesi- thetic cues were provided based on the individual’s resting posture in standing and in exercise-specific positions (prone or sidelying). For example, for individuals with an anterior-tilted scapula, instructions included, “Gently bring the tip of your shoulder blade toward your spine”; for those with a downwardly rotated scapula, instructions included, “Gently lift the top of the shoulder”; and for those with a predominantly protracted scapula, instructions included, “Gently spread the front of your shoulder apart to draw your shoulder blade toward midline.” Drawing the scapula down and in (retraction and depression) was not considered an appropriate command. Substitutions such as retraction with maximum depression, retraction with elevation, or excessive fixation of the humerus were avoided. The contraction force used to achieve the scapular position had to remain low to ensure low tonic muscle recruitment. The participants practiced the posture exercise until satisfactory correction, as judged by the investigator, was achieved. All participants could correct scapular posture satisfactorily following this intervention.

Once the corrected scapular position could be held for 5 seconds without assistance, the 4 exercises performed for the baseline condition were repeated in randomized order. Subjects were now instructed to perform each exercise, starting from the neutral position, while maintaining the corrected orientation during the concentric phase of each exercise (3 seconds). When a participant lost the corrected scapular orientation, appropriate verbal cues were provided. Because individuals are typically not able to correct impaired movement patterns over the total range of motion, each exercise was limited to 90°. Furthermore, analysis of the data was limited to the concentric phase of the exercise, because the intervention time was too brief for the subjects to also learn proper scapular control throughout the isometric and eccentric phases of the movement.

During all measurements, synchronized video recordings were made using a Handycam (DCR-HC37; Sony Europe Limited, Zaventem, Belgium) to determine when subjects started the exercise movement. All EMG signals were processed with MyoResearch 98 software (Noraxon). The raw EMG signals were analog-digital converted (12-bit resolution) at 1000 Hz. After cardiac artifact, reduction and rectification and smoothing of the EMG signal with a 100-millisecond root-mean-square moving window to create the linear envelope, the average EMG activation of the UT, MT, and LT was determined over a window of 2 seconds after the start of each exercise, then normalized according to the MVIC method. This was done by calculating the mean activity of the second, third, and fourth repetitions of each exercise. Data for the first and last repetitions were not presented.

### TABLE

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<th>Subject Sex/Body Mass</th>
<th>Prone Extension</th>
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Abbreviation: ER, external rotation.

*Values are in kg.

### FIGURE 3

Absolute mean ± SD normalized electromyographic signal amplitude of the 3 sections of the trapezius muscle for the 4 exercises performed with and without conscious control of scapular orientation, expressed as percentage of MVC. Abbreviations: LT, lower trapezius; MT, middle trapezius; MVC, maximal voluntary isometric contraction; UT, upper trapezius. *Significant differences between conditions (P<.05).
 Statistical Analysis
The sample size for this study was based on a minimal relevant difference of 10% in EMG signal amplitude between conditions. Statistical significance was set at 5%, with a desired power of 80%.

All statistical analyses were performed with SPSS Version 18.0 for Windows (SPSS Inc, Chicago, IL). Group means and standard deviations were calculated for the normalized EMG signal amplitude of each section of the trapezius for each exercise, and for both scapular conditions. Because conscious correction of scapular orientation may also influence the UT/MT and UT/LT muscle activation ratios, making the exercises less or more appropriate in individuals with trapezius muscle imbalance, these were also calculated. Because a Kolmogorov-Smirnov test showed normal distribution of the data, parametric tests were used for statistical analysis.

To determine if conscious correction of scapular orientation influenced the activation levels of sections of the trapezius during each exercise, 4 separate (1 for each exercise) 3-by-2 repeated-measures analyses of variance were performed. The factor of muscle had 3 levels (UT, MT, and LT), and the factor of scapular orientation had 2 levels (baseline and corrected). Because the influence on the trapezius muscle ratios (UT/MT and UT/LT) was also of interest, 4 separate (1 for each exercise) 2-by-2 repeated-measures analyses of variance were performed. The factor of muscle ratio had 2 levels (UT/MT and UT/LT) and the factor of scapular orientation had 2 levels (baseline and corrected). A statistical significance of .05 was chosen a priori for these comparisons. For any significant difference, a Bonferroni post hoc test, with significance level set at an alpha value of .05, was used for follow-up analysis.

RESULTS
There was a significant muscle-by-scapular orientation interaction for prone extension (F = 5.84, P = .005). Post hoc pairwise comparisons with Bonferroni correction showed significantly (P < .05) higher activation levels for all 3 sections of the trapezius when scapular orientation was performed (mean ± SD differences: UT, 5.9% ± 8.6% MVIC; MT, 13.8% ± 11.0% MVIC; LT, 9.8% ± 10.8% MVIC). The differences in the magnitude of changes among the 3 sections of the trapezius are consistent with the significant interaction.

For the sidelying external rotation exercise, a significant muscle-by-scapular orientation interaction was also observed (F = 3.84, P = .049), with post hoc tests indicating significantly higher activation levels for all sections of the trapezius muscle when conscious correction of scapular orientation was performed (mean ± SD differences: UT, 2.2% ± 4.4% MVIC; MT, 6.7% ± 10.6% MVIC; LT, 13.3% ± 24.4% MVIC).

In contrast, with the sidelying forward flexion exercise, there was no significant interaction (F = 0.1, P = .82) or main effect for scapular orientation (F = 3.9, P = .057). Nor was there a significant interaction (F = 3.1, P = .63) or main effect of conscious correction of scapular orientation (F = 0.1, P = .76) for the prone horizontal abduction with external rotation exercise (FIGURE 3).

There was no significant muscle ratio-by-scapular orientation interaction for all 4 exercises (FIGURE 4). During the prone extension exercise, there was also no main effect of muscle ratio or scapular orientation. For both sidelying exercises, there was a main effect for muscle ratio: external rotation mean ± SD difference, 6.0% ± 3.0% MVIC (F = 6.0, P = .02); forward flexion difference, 20.0% ± 6.0% MVIC (F = 13.0, P = .001). For prone horizontal abduction with external rotation, there was a main effect for scapular orientation: mean ± SD difference, 16.0% ± 7.0% MVIC (F = 5.1, P = .03).

DISCUSSION
It was hypothesized that conscious correction of scapular orientation would have an influence on the abso-
lute (UT, MT, and LT) and relative (UT/MT and UT/LT) trapezius muscle activation levels during each of the 4 exercises. However, the primary finding of this study was that conscious correction of scapular orientation significantly increased the absolute muscle activation levels in the 3 sections of the trapezius muscle only for the prone extension and sidelying external rotation exercises. All exercises showed UT/MT and UT/LT values close to those observed in a previous study, but none of them changed by conscious correction of scapular orientation.

The rationale behind the relevance of conscious correction of scapular orientation is based on improving proprioception, normalizing scapular resting position, and promoting trapezius muscle activation. More specifically, conscious control of the scapular musculature is considered relevant for restoration of neuromuscular coordination as well as strength deficits. In rehabilitation training, the value of an exercise is based on the activation level at which the different muscles are activated. Because overhead athletes with a lack of scapular control (scapular dyskinesis) often show a lack of muscle activation, exercises promoting high trapezius muscle activation are considered important to facilitate neuromuscular recruitment and better scapular motion. In an attempt to realize these goals, it is often suggested that conscious correction of scapular resting position might help to facilitate neuromuscular firing in the different sections of the trapezius, especially in the stabilizing MT and LT muscles. Because the scapulothoracic joint almost solely depends on muscle activity for its functional stability, minor changes induced by conscious correction of scapular orientation can be important in the treatment of overhead athletes with scapular dyskinesis. However, the clinical benefit of conscious correction of scapular orientation during exercise training remains unclear. A 10% difference in muscle activation is considered clinically important in terms of muscle strengthening purposes, but no such value is available in the literature with regard to neuromuscular training.

Various authors have studied the possibility of humans to selectively activate the different portions of the trapezius, as well as the influence of scapular orientation on these recruitment patterns. Holtermann et al showed that the upper and lower sections of the trapezius muscle can be independently activated by voluntary command in a lying position, demonstrating the neuromuscular compartmentalization of this muscle. From a more clinical perspective, Mottram et al studied scapular muscle activation levels and showed that optimal scapular posture can be accurately trained in healthy individuals by activating all 3 portions of the trapezius muscle in a seated position. Furthermore, Wegner et al recently demonstrated a significant increase in LT muscle activation during a typing task following conscious correction of scapular position in patients with neck pain. However, none of these studies investigated the influence of conscious correction of scapular orientation on the trapezius muscle activation levels during particular shoulder exercises. Although Kibler et al completed an EMG analysis of specific exercises for scapular control for the early phases of rehabilitation, a specific scapular orientation approach, as used in this study, has not been previously investigated.

In this study, the influence of conscious correction of scapular orientation on the trapezius muscle activation levels is demonstrated when applied in overhead athletes performing dynamic shoulder exercises. The results indicate that, during prone extension and sidelying external rotation, conscious control of the scapula significantly increases the activation in the 3 sections of the trapezius, suggesting that this approach may be clinically relevant when used with these 2 exercises. The results are in agreement with those by Mottram et al, who studied the influence of scapular orientation exercises performed in a seated position without additional arm movements, that showed increased UT, MT, and LT activation. Conscious correction of scapular orientation did not change the activation of the 3 sections of the trapezius for the sidelying forward flexion and prone horizontal abduction with external rotation exercises, showing that this strategy does not lead to increased recruitment of the trapezius muscle during these 2 exercises. It is noted that prone horizontal abduction with external rotation already produced a high activation level when performed without conscious correction of scapular orientation, which might explain why no statistically significant differences were found between conditions.

Conscious correction of scapular orientation did not affect UT/MT and UT/LT ratios for all 4 exercises tested in this study. Because the ratios in this study were close to those reported in the original study by Cools et al and were neither decreased nor increased with an effort to control scapular position, the basis for which these 4 exercises are considered useful for improving scapular control remains when this strategy is used. These findings also suggest that the presence of scapular dyskinesis has limited influence on the trapezius muscle ratios when compared to a general group of healthy overhead athletes, as in the study by Cools et al. However, in that study, subjects were not screened on the presence or absence of scapular dyskinesis, making it impossible to definitively conclude that scapular dyskinesis did not affect muscle recruitment during the selected exercises.

Some limitations of the present study need to be considered when interpreting the results. First, it must be noted that correction of altered scapular resting positions and impaired overhead movement patterns are 2 separate entities. The present study only investigated the relevance of correcting scapular orientation prior to performing the exercises, suggesting that a setting phase is present in the initial phase of arm movement, in which the scapula has little contribution to total shoulder motion. However, no
consensus exists on the presence of such a setting phase. In addition, one could question the relevance of the intervention for neuromuscular training purposes and could argue that functional upper extremity movement training might be more effective in altering the function of the force couples around the scapula. Second, we did not monitor other scapulothoracic muscles such as the rhomboids, serratus anterior, and pectoralis minor. Scapular dyskinesis is likely to be the result of a combination of suboptimal motor control of a variety of scapulothoracic muscles, not only the trapezius. Therefore, the results of this study should not be interpreted as separate from other scapular muscle contributions. Third, it is also suggested that scapular dyskinesis is related to alterations in the timing of scapular muscle activation. Possibly, conscious correction of scapular orientation also has an influence on the trapezius muscle timing during the selected exercises, but this was not monitored in this study. Fourth, a great amount of variability among subjects was found, which could be due to the inclusion of various types of dyskinesis, requiring different fine motor control strategies across subjects. This was done because classification of scapular abnormalities by visual observation shows low reliability. Fifth, the use of asymptomatic subjects, despite the presence of scapular dyskinesis, limits the generalizability of the results to patients with shoulder pathology. It remains to be determined how correction of scapular orientation may prevent injuries in overhead athletes and impact symptoms in patients with various shoulder conditions. Therefore, the most appropriate intervention strategy for a specific shoulder condition remains speculative until comparative effectiveness research is performed. Accordingly, the results of this study are to be seen as a first step in the evaluation of the value of conscious correction of scapular orientation in the treatment of shoulder conditions.

On the basis of our research question and our results, we believe that further study is warranted. First, more studies are needed to define the ability of individuals to maintain corrected scapular positions during each exercise by measuring multiple muscle contributions (eg, serratus anterior) in combination with 3-D movement analysis of the scapula. Second, studies examining the effect of exercises focusing on high activation levels in the stabilizing muscles of the scapula compared to those focusing on correction of the 3-D movement patterns would provide greater insight into this topic. Investigation of whether changes in muscle activation are also apparent in standing, when the thoracic spine has some axial loading, would also be of interest. Third, the long-term effect of scapular orientation and trapezius muscle balance rehabilitation exercises should be investigated by prospective research.

**CONCLUSION**

This study demonstrated that conscious correction of scapular orientation increases the activation of all 3 sections of the trapezius during the prone extension and sidelying external rotation exercises. In addition, the UT/MT and UT/LT ratios were not changed by the intervention for any of the 4 exercises that were included in the study. These findings suggest that these 4 exercises remain relevant for trapezius muscle balance rehabilitation, when conscious scapular orientation is performed. The findings of this study may help physiotherapists in the selection of shoulder rehabilitation exercises in overhead athletes with scapular dyskinesis.

**KEY POINTS**

**FINDINGS:** During prone extension and sidelying external rotation, conscious correction of scapular orientation promotes higher muscle activation of all 3 sections of the trapezius. It has no significant impact during sidelying forward flexion and prone horizontal abduction with external rotation. Conscious correction of scapular orientation did not change the relative level of activation between the 3 sections of the trapezius.

**IMPLICATIONS:** Conscious correction of scapular orientation may be a useful component of performing scapular muscle rehabilitation exercises in overhead athletes with scapular dyskinesis, especially for the prone extension and sidelying external rotation exercises.

**CAUTION:** This study did not assess the effect of this intervention on scapular orientation and movement during the exercises.

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