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Original article

Alterations of scapular kinematics and associated muscle activation specific to symptomatic dyskinesis type after conscious control

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ABSTRACT

Background: Scapular orientation and movements can affect the function of the shoulder. However, evidence is limited on whether symptomatic subjects can actively maintain the scapula in a neutral position through conscious control.
Objective: To investigate whether symptomatic subjects with scapular dyskinesis can achieve optimal scapular movements and associated muscle activities through conscious control.
Design: A cross-sectional study.
Methods: Sixty subjects with scapular dyskinesis (16 inferior angle pattern I, 16 medial border pattern II, and 28 mixed pattern) performed 3 selected exercises (arm elevation, side-lying elevation, and side-lying external rotation) with and without conscious control. Three-dimensional electromagnetic motion and electromyography were used to record the scapular kinematics and muscle activation during the exercises.
Results: For scapular kinematics, significant increases in scapular external rotation ($4.6 \pm 3.2^\circ$, $p < 0.0125$) were found with conscious control during arm elevation and side-lying elevation in three groups. Significant increases in activation of the middle and lower trapezius (MT: $4.9 \pm 2.4\%$ MVIC; LT: $10.2 \pm 6.8\%$ MVIC, $p < 0.0 25$) were found with conscious control in 3 exercises among the 3 dyskinesis groups. Increased serratus anterior activation (SA: $11.2 \pm 4.8\%$ MVIC, $p < 0.0 25$) was found in the concentric phase of side-lying external rotation in the pattern I and I + II groups.
Conclusion: Conscious control of the scapula can alter scapular orientation and MT, LT, and SA activation during 3 selected exercises in subjects with symptomatic dyskinesis. Specifically, conscious control during side-lying external rotation can be applied to increase SA activity in pattern I and I + II dyskinesis.

Scapular dyskinesis has been indicated to be related to musculoskeletal disorders of the shoulder complex. Altered scapular positions affect the performance of the rotator cuff significantly (Smith et al., 2002; Kibler et al., 2006; Alizadeh et al., 2009). An inadequately elevated, posteriorly tipped, or upwardly rotated scapula during arm movements may decrease the subacromial space and increase the risk of shoulder impingement (Ludewig and Cook, 2000; Kibler and Sciascia, 2010). Thus, for symptomatic subjects with scapular dyskinesis, it is important to correct scapulothoracic movements (Ludewig and Reynolds, 2009).

Conscious control of the scapula is believed to improve scapular kinematics (Cools et al., 2014). It was first mentioned by Mottram to correct movement dysfunction associated with abnormal scapular positioning and dynamic control. This method can be applied to normalize the scapular resting orientation and promote the proper 3-dimensional movement patterns of the scapula during arm movements. Evidence shows that asymptomatic people with scapular dyskinesis can achieve the corrected scapular position through conscious control of the scapula (Mottram et al., 2009; De Mey et al., 2013).

Appropriate muscle activity during movements, in addition to scapular kinematics, is important to consider for subjects with scapular dyskinesis. Previous studies have reported excessive

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activation of the upper trapezius (UT) and decreased activity of the serratus anterior (SA) and middle/lower trapezius (MT/LT) in subjects with scapular dyskinesis (Ludewig and Cook, 2000; Kibler and McMullen, 2003; Kibler and Sciascia, 2010). Thus, exercise training is focused on correcting the levels of muscle activity. Cools et al. (2007) demonstrated that four exercises, namely, side-lying flexion, side-lying external rotation, prone extension, and prone horizontal abduction with external rotation, have suitable UT/MT and UT/LT ratios in asymptomatic subjects. De Mey et al. (2013) found that conscious control of the scapular orientation combined with these exercises could alter associated muscle activations in asymptomatic subjects with scapular dyskinesis.

Although the effects of conscious control of the scapula have been demonstrated (Cools et al., 2007; Mottram et al., 2009; De Mey et al., 2013), only limited evidence exists to indicate whether symptomatic subjects with scapular dyskinesis can benefit from such control. Furthermore, there are no kinematic findings or subjects classified into different patterns in previous studies (Mottram et al., 2009; De Mey et al., 2013). The purpose of this study was to investigate whether symptomatic subjects with scapular dyskinesis can actively alter scapular orientation and associated muscle activities through conscious control of the scapula. We hypothesized that conscious control could increase scapular external rotation/posterior tipping and increase associated muscle activities in these subjects.

1. Methods

1.1. Subjects

Sixty symptomatic subjects with scapular dyskinesis participated in this study. Subjects were recruited according to the following inclusion criteria: age of 18–60 years old, and unilateral shoulder pain of less than 5 but more than 1 on a 10-point visual analog scale around the shoulder complex, including the glenohumeral joint, scapulothoracic joint, and acromioclavicular joint, during arm movements. Impingement was assessed with palpation of the pain location, speed test, Neer's impingement, Hawkins impingement, and Yergason's test. Exclusion criteria were a history of stroke, diabetes mellitus, rheumatoid arthritis, rotator cuff tear, surgical stabilization of the shoulder, osteoporosis, or malignancies in the shoulder region. Subjects who had pain or disorders of the cervical spine, elbow, wrist, or hand, who had pain radiating from the shoulder to the arm, or who could not elevate their arms to 150° were also excluded. All subjects received a written and verbal explanation of the purposes and procedures of the study.

1.2. Ethical approval statement

Subjects agreed to participate and signed informed consent forms approved by the Human Subjects Committee of University Hospital.

1.3. Instruments

The Polhemus 3Space FASTRAK system (Polhemus Inc., Colchester, VT, USA), an electromagnetic-based motion analysis system, was used for collecting 3-dimensional kinematic data of the scapula. Karduna et al. (2001) validated the scapular kinematics between skin-based sensor and bone-pinned methods and confirmed that the skin-based method is valid when arm elevation is below 120°. The details of the methodology can be found in a previous paper (Lin et al., 2005). Three sensors were placed in locations where the skin motion artifact was minimized (sternum, acromion, distal humerus). Anatomic landmarks (sternal notch, xiphoid process, seventh cervical vertebra, eighth thoracic vertebra, acromioclavicular joint, root of the spine of the scapula, inferior angle of the scapula, lateral epicondyle, and medial epicondyle) were palpated and used for subsequent receiver mounting and landmark digitization.

The sEMG assemblies included pairs of silver chloride circular (recording diameter of 10 mm) surface electrodes (The Ludlow Company LP, Chocopee, MA) with an interelectrode (center-to center) distance of 20 mm, and a Grass AC/DC amplifier (Model 15A12, Astro-Med Inc. RI, USA) with a gain of 1,000, a common mode rejection ratio of 86 dB at 60 Hz, and a bandwidth (−3 dB) of 10 to 1000 Hz. The sEMG data were collected at 1000 Hz/channel using a 16-bit analog to digital converter (Model MP 150, Biopac systems Inc., CA, USA). Surface EMG electrodes were placed on the UT (midway between the acromion and C7), MT (midway between the root of the spine of the scapula and the T3), LT (on the line between the spine of the scapula and the T7) and SA (anterior to the latissimus dorsi and posterior to the pectoralis major) of the involved shoulder. The reference electrode was placed on the ipsilateral clavicle (Huang et al., 2013; Perotto and Delagi, 1994). The maximal voluntary isometric contraction (MVIC) was tested and used to normalize the sEMG data during the task (resisted shoulder flexion 90° for UT, resisted horizontal abduction while lying prone with arm abducted to 90° for MT, resisted arm elevation while lying prone with arm abducted in line with muscle fibers for LT, and resisted arm elevation of 135° for SA) (Ludewig et al., 2004; Kendall and McCreary, 2010). The MVICs were collected for 5 s in a total of three trials, with 1 min of rest between trials.

1.4. Classification of scapular dyskinesis

Visual combined palpation was used to classify the scapular position and movement pattern (single pattern or mixed patterns) in both the raising and the lowering phases, modified by Kibler's method (2010). The 4 single patterns were inferior angle prominence (pattern I), medial border prominence (pattern II), abnormal upward rotation/elevation (pattern III), and normal movement (pattern IV). The mixed patterns were combinations of at least two single patterns. The inter-rater reliability of the classification test was moderate to substantial (κ coefficients = 0.49 and 0.57/0.64 in the raising and lowering phases, respectively) (Huang et al., 2015a,b).

1.5. Conscious control of the scapula

The subjects began the movements, which required achieving a neutral position of the scapula as judged by investigators. Verbal, auditory, and kinesthetic cues were given based on the subjects' resting positions and selected exercise-specific position (side-lying or sitting) with 1 kg load to help them achieve the neutral scapular position. A load with 1 kg was selected because it was the highest load that subject could tolerate without discomfort during the entire experimental procedure. The main instruction, "retract the scapula", was given to correct poor posture and excessive scapular internal rotation, and a supplemental instruction, "widen the chest", was given to help subjects achieve a neutral scapular position when scapular posterior tipping was lacking (Mottram et al., 2009). Participants practiced the posture exercise until satisfactory correction, as judged by the investigator, was achieved. Participants who could not correct the scapular posture satisfactorily were excluded from further investigation. Once the subjects could hold the corrected scapular position for 5 s without assistance, they performed the 3 selected exercises (arm elevation in the scapular plane, side-lying flexion, and side-lying external rotation; see Fig. 1) in a randomized order, resting for three minutes before each