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EMG biofeedback effectiveness to alter muscle activity pattern and scapular kinematics in subjects with and without shoulder impingement ☆

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ABSTRACT

Background: Muscle imbalance between serratus anterior (SA), upper trapezius (UA), middle trapezius (MT), and lower trapezius (LT) muscles has been observed in subjects with subacromial impingement syndrome (SAIS).
Objective: (1) To investigate the effect of electromyography (EMG) biofeedback training on muscle balance ratios and scapular kinematics in healthy adults and subjects with SAIS. (2) To investigate whether the effects of EMG biofeedback on muscle balance ratios are different between groups.
Design: Twelve healthy adults and 13 subjects with SAIS were recruited in this study. EMG was used to record the activity of scapular muscles. The ratios (UT/SA, UT/MT, and UT/LT) during exercises with/without EMG biofeedback were calculated. Scapular kinematics were recorded before and after exercises with/without EMG biofeedback.
Results: For the subjects with SAIS, muscle balance ratios were lower during forward flexion with EMG biofeedback than during exercise only (UT/SA: 70.3–45.2; UT/LT: 124.8–94.6). Additionally, similar results were found during side-lying external rotation (UT/MT: 58.5–36.4). For the scapular upward rotation and tipping in both groups, there were no significant differences with and without EMG biofeedback.
Conclusion: EMG biofeedback improved the scapular muscular balance during training exercises in both groups. Further clinical trials should investigate the long-term effects of EMG biofeedback.

1. Introduction

Subacromial impingement syndrome (SAIS) is defined as a mechanical compression of abrasion of the rotator cuff structure, subacromial bursa, and long head of the biceps tendon as they pass beneath the coracoacromial arch during elevation of the arm (Neer, 1983; Michener et al., 2003). SAIS accounts for 44–65% of all complaints of shoulder pain during a physician's clinical visit (Michener et al., 2003), and SAIS is the most frequent cause of shoulder pain in overarm athletes (Jobe et al., 2000).

Impaired range of motion and functional limitations have been reported in patients with SAIS (Ludewig and Cook, 2000; Kelly et al., 2010). These findings could be related to clinical symptoms in patients with SAIS, such as pain during arm elevation and limited movement (Ludewig and Cook, 2000; Kelly et al., 2010). Additionally, scapular muscle imbalance has been found in patients with neck and shoulder disorders (Cools et al., 2003). Specifically, excessive activity of the upper trapezius (UT) muscle, combined with reduced activity of the lower trapezius (LT) and serratus anterior (SA) muscles, have been observed in patients with SAIS (Cools et al., 2003; Ludewig and Cook, 2000). The imbalance of scapular muscles may result in abnormal scapular motion and may contribute to the progress of impingement (Kibler and McMullen, 2003; Ludewig and Cook, 2000). Thus, exercises for the scapular muscles in the treatment of scapulothoracic dysfunction related to SAIS should promote LT, middle trapezius (MT), and SA activation and reduce activity in the UT (Cools et al., 2003; Kibler and McMullen, 2003; Ludewig and Cook, 2000).

Exercise training can be prescribed according to kinematics mechanisms related to impingement syndrome. Decreased upward rotation and posterior tilting of the scapula in arm elevation are believed to be related to decreased subacromial space in subjects with SAIS (Ludewig and Cook, 2000; Hebert et al., 2002; McClure et al., 2006; Laudner et al., 2008). Based on the line of action, excessive activation of the UT results in excessive clavicle elevation on the thorax, which couples predominately with scapula anterior tilting. These phenomena may contribute to progression of

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impingement by decreasing the subacromial space during arm elevation (Ludewig and Cook, 2000). On the other hand, the SA and LT have the largest movement arms to produce the torque of scapular upward rotation to increase subacromial space and prevent impingement (Ludewig and Cook, 2000; McClure et al., 2006). Additionally, this prevention can be enhanced by activity of the SA, which also contributes to scapular PT. Therefore, in the treatment of patients with SAIS, it is important to consider exercises with appropriate recruitment of SA and LT for restoring proper scapular muscle balance.

Excessive activity of the UT combined with reduced activity of the LT and SA have been observed during some exercises (Cools et al., 2007; Decker et al., 1999; Ludewig et al., 2004; Tucker et al., 2010). This may lead to altered scapular kinematics. Thus, selection of exercises is important. In electromyography (EMG) biofeedback training, electronic equipment is used to reveal instantaneously certain physiological events. Subjects can be taught to control these otherwise involuntary events by manipulating the displayed signals (Basmajian, 1981). This technique is believed to allow subjects to learn how to control the activities of muscles, such as their roles as stabilizers/force couples during movements (Basmajian, 1981; Holtermann et al., 2010). According to previous studies, EMG biofeedback training can be used as a helpful tool to selectively activate muscular activity between the LT/MT/SA and UT muscles (Holtermann et al., 2009, 2010). The ratios of EMG activities between muscles of interest have been used to demonstrate the relative controlling of scapular movements (Cools et al., 2007; Ludewig et al., 2004; Decker et al., 1999; Mottram et al., 2009). However, to date, little evidence supports the use of EMG biofeedback for restoring the balance of scapular muscle and associated scapular kinematics in subjects with SAIS.

The purpose of this study was to investigate the effects of EMG biofeedback training during exercises on muscle balance ratios (UT/LT, UT/MT and UT/SA) and scapular kinematics (scapular upward/downward rotation, anterior/posterior tipping) in subjects with and without SAIS. Our first hypothesis was that exercising with EMG biofeedback would decrease muscle balance ratios and increase upward rotation/posterior tipping in subjects with and without SAIS. Our second hypothesis was that the effects of EMG biofeedback would be higher in subjects with SAIS than in those without SAIS.

2. Methods

2.1. Participants

Twelve healthy adults and 13 subjects with SAIS participated in this cross-sectional study (Table 1). Flexilevel scale of shoulder function (FLEX-SF) questionnaire was recorded for each subject (scores were recorded from 1, with the most limited function, to 50, without any limited function in the subject) (Cook et al., 2003). The average FLEX-SF score for healthy subjects and subjects with SAIS were 48.4 and 39.5 respectively. Healthy adults were recruited from the students and faculty of a university, and subjects with SAIS were recruited from a university hospital. All participants were 18–40 years of age. Subjects with SAIS were included if they demonstrated at least 2 of the following symptoms: (1) a positive Neer's impingement test; (2) a positive Hawkins-Kennedy impingement test; (3) a positive reverse impingement sign; and (4) a positive crossover impingement test. Subjects who had a history of surgery on the shoulder joint, fracture of the shoulder complex, cervical problems, or glenohumeral instability were excluded. After the aim of this study was explained to the participants, they were asked to read and sign the informed consents approved by the university hospital institutional review boards.

Table 1
Participant demographic data.

	Subjects without SAIS[a]		Subjects with SAIS[a]		Sig.
	Mean	SD	Mean	SD	
Age (yrs)	23.8	2.9	24.8	3.6	0.19
Height (cm)	168.6	9.6	174.4	8.9	0.16
Weight (kg)	61.1	7.8	71.2	8.3	0.09
Gender (male/female)	(7/5)	–	(11/2)	–	0.14
Duration of symptoms (months)	–	–	18.2	18.3	
Involved side (right/left)	(11/1)	–	(11/2)	–	0.59
Pain (VAS[b])	–	–	3.5	1.3	
FLEX-SF[c]	48.4	4.4	39.5	4.7	<0.005

[a] SAIS: Subacromial impingement syndrome.
[b] VAS: Visual analog scale.
[c] FLEX-SF: Flexilevel scale of shoulder function scale.

2.2. Instrumentation

The FASTRAK system (Pholhemus Inc., Colchester, VT, USA), an electromagnetic-based motion analysis system, was used for collecting 3-dimensional kinematic data of the scapula. The manufacturer of the FASTRACK system has reported an accuracy of 0.8 mm and 0.15°. Three sensors were attached to the bony landmarks with adhesive tape (sternum, the scapular acromial process, and the distal humerus between the lateral and medial epicondyles). A fourth sensor, attached to a stylus, was used to digitize palpated anatomical coordinates: the 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. The absolute axes defined by the sensor of the FASTRAK device were converted to anatomically defined axes derived from digitalized bony landmarks. Raw kinematic data were low-pass filtered at a 6-Hz cutoff frequency and converted into anatomically defined rotations (Lin et al., 2006; Ludewig and Cook, 2000; Karduna et al., 2001; Wu et al., 2005).

The surface electromyography (sEMG) assemblies included pairs of circular (recording diameter of 10 mm) silver chloride surface electrodes (The Ludlow Company LP, Chocopee, USA) 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 1000, a common mode rejection ratio of 86 dB at 60 Hz, and a bandwidth (−3 dB) of 10–1000 Hz. The sEMG data were collected at 1000 Hz/channel using a 16-bit analog to digital converter (Model MP150, Biopac systems Inc., CA, USA). An impedance meter (Model F-EZM5, Astro-Med Inc., RI, USA) was used to measure the impedance between the electrodes over the muscle. The impedance of each electrode was controlled to less than 10 kΩ. Full bandwidth sEMG data captured by the data acquisition software (AcqKnowledge, Biopac systems Inc., CA, USA) were reduced using a root mean square (RMS) algorithm to produce sEMG envelopes with an effective sampling rate of 50 samples per second.

2.3. Procedures

The experimental procedure is presented in Fig. 1. After signing the informed consent form, the subjects were examined by a physical therapist to establish the clinical conditions of their shoulders, including range of motion and the FLEX-SF questionnaire (Cook et al., 2003). Then scapular kinematics/EMG measurements were set up. Each subject performed arm elevations at scapular plane before and at the end of exercises with and without EMG biofeedback. The EMG and kinematics during these movements were used in the statistical analysis.