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Original article

Scapulothoracic muscle activity during elevation exercises measured with surface and fine wire EMG: A comparative study between patients with subacromial impingement syndrome and healthy controls

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ABSTRACT

Background: The quality of the scapular movement depends on the coordinated activity of the surrounding scapulothoracic muscles. Besides the well-known changes in Trapezius and Serratus Anterior (SA) activity in patients with subacromial impingement syndrome (SIS), no studies exist that have investigated the activity of the smaller less superficial muscles that attach on the scapula (Pectoralis Minor (Pm), the Levator Scapulae (LS) and the Rhomboid Major (RM)) in a population with SIS, despite the hypothesized importance of these muscles in shoulder function.
Objectives: To investigate if patients with shoulder impingement syndrome (SIS) show differences in deeper and superficial lying scapulothoracic muscle activity in comparison with a healthy control group during arm elevation tasks.
Study design: Controlled laboratory study.
Methods: Activity of the deeper lying (LS, Pm and RM) and superficial lying scapulothoracic muscles (Trapezius and SA) was investigated with fine-wire and surface electromyography (EMG) in 17 subjects with SIS and 20 healthy subjects while performing 3 elevation tasks: scaption, wall slide and elevation with external rotation. Possible differences between the groups were studied with a linear mixed model (factor “group” and “exercise”).
Results: For the Pm only, a significant main effect for “Group” was found: during the elevation exercises, the Pm was significantly more active in the SIS group in comparison with the healthy controls.
Conclusion: Patients with SIS show significantly higher Pm activity during elevation tasks in comparison with healthy controls. This study supports the idea of a possible role of the Pm in SIS.

1. Introduction

The scapula plays an important role in the function of the shoulder. During humeral elevation of the arm, a complex scapular movement of upward rotation, posterior tilt and external rotation is needed to create a stable base for the glenohumeral joint (Kibler and McMullen, 2003). The quality of this scapular movement depends on the coordinated activity of the surrounding superficial (Trapezius and Serratus anterior (SA)) and the deeper lying scapulothoracic muscles, such as Pectoralis minor (Pm), Levator Scapulae (LS) and Rhomboid Major (RM). A lack of activation or excessive activation of scapulothoracic muscles may impede optimal scapular movement. Hypothetically, excessive activation of the deeper lying muscles (Pm, LS and RM) may impede the warranted scapular movement that is necessary during humeral elevation. The LS is believed to elevate the scapula and to work together with the Rhomboids to retract and rotate the scapula downwards (Escamilla et al., 2009). The Pm is believed to move the scapula to protraction, downward rotation, anterior tilt and internal rotation (Oatis, 2004.). Normal upward rotation may be influenced by excessive activation or tension in the LS or RM (Behrsin and Maguire, 1986). Also, excessive activation of the Pm muscle may

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hinder normal posterior scapular tipping that is necessary during humeral elevation (Borstad and Ludewig, 2005).

A lack of upward rotation and anterior tilting during elevation of the arm has been related to shoulder impingement syndrome (SIS) (Ludewig and Cook, 2000; Struyf et al., 2011; Timmons et al., 2012). The term shoulder impingement was first introduced by Neer (1972), who described the phenomenon as a mechanical compression of the subacromial structures against the anterior undersurface of the acromion and coracoacromial ligament. In more recent literature, impingement has been described as a group of symptoms rather than a specific diagnosis, and has been considered to be an umbrella of a variety of shoulder conditions (Lewis, 2009). The shoulder impingement syndrome (SIS) symptoms are mostly present when the arm is elevated or when overhead activities are performed (Michener et al., 2004; Hung et al., 2010). To date, most studies that have investigated scapulothoracic muscle activity in patients with SIS have focused on the Trapezius and SA (Ludewig and Cook, 2000; Cools et al., 2004; Bandholm et al., 2006; Santos et al., 2007; Cools et al., 2007a; Moraes et al., 2008; Roy et al., 2008; Diederichsen et al., 2009; Lin et al., 2011). No studies exist that investigate the scapulothoracic activity of the smaller and less superficial muscles that attach on the scapula (such as the Pm, the LS and RM) in a population with shoulder pain, despite the hypothesized importance of these muscles in shoulder function (Cagnie et al., 2014; Cools et al., 2014).

Information from electromyographic (EMG) studies on the activity of the superficial muscles in patients with shoulder pain (Ludewig and Cook, 2000; Cools et al., 2007b; Reinold et al., 2009; Ellenbecker and Cools, 2010) has been a basis for recommendations for the choice of exercises during treatment for patients with shoulder symptoms related to scapulothoracic dysfunction. It is believed that performing exercises which address the appropriate muscles can improve the quality of the scapular movement and restore “normal” movement patterns. Although it is very important to know if patients with impingement symptoms show different activity of the deeper lying muscles, it has never been a topic of investigation. The activity of the deeper lying muscles has been studied by Castelein et al. (2016) during different commonly used rehabilitation exercises (scaption, towel wall slide, elevation with external rotation), showing different muscle activity patterns based on the specific modality of the exercise, however these investigations were performed on healthy subjects without shoulder pain. It would be interesting to know if patients with SIS would show differences during the performance of these elevation exercises, often used in clinical practice (Castelein et al., 2016).

Therefore, the objective of this study was to investigate whether the activity of the deeper lying (in particular LS, Pm and RM) and superficial lying muscles is different in a population with SIS compared to a healthy control group during various elevation tasks. This knowledge will aid clinicians in developing more targeted rehabilitation exercises.

2. Materials and methods

2.1. Subjects

Two groups of subjects were recruited: a group with shoulder impingement syndrome (SIS group, n = 17) and a matched control group without symptoms (healthy control group, n = 20). Subjects were recruited via advertisement from the local community and university. Written informed consent was obtained from all participants. The study was approved by the ethics committee of X. SIS was determined by history taking and confirmed by physical examination performed by an experienced musculoskeletal physical therapist. Patients were included in the SIS group if they reported chronic shoulder pain (>1 month during the last year, with a minimum pain intensity of 3/10 on the Numeric Rating Scale) in the anterior deltoid region of their dominant shoulder and if at least 3 of the following criteria were positive: (1) Positive Neer sign, (2) Positive Hawkins sign, (3) Positive Jobe's sign, (4) Painful Arc, and (5) Positive Resistance Test against External Rotation (Michener et al., 2009). Subjects had to be able to perform full ROM of humeral elevation in the scapular plane and this was tested by the investigator before the start of the study.

Exclusion criteria were shoulder surgery or dislocation, loss of range of motion (ROM) (i.e. capsular pattern in case of adhesive capsulitis: external rotation > abduction > internal rotation), positive spurling test, >2 cortisone injections, one cortisone injections within the last month, systemic diseases, current symptoms in the neck region, total rotator cuff rupture and upper limb training or overhead sports > 6 h/week. The in- and exclusion criteria were exclusively based upon clinical tests. Medical imaging was not a requirement for this study.

2.2. General design

EMG data was collected from 5 scapulothoracic muscles (Trapezius (UT, MT, LT) SA, LS, Pm, RM) on the dominant side of each subject during the performance of 3 different humeral elevation tasks in the scapular plane (Castelein et al., 2016): (1) scaption (elevation in the scapular plane), (2) towel wall slide and (3) elevation with external rotation component (with resistance from a Theraband®).

2.3. Test procedure

The experimental session began with a short warm-up procedure with multidirectional shoulder movements, followed by the performance of a set of five the maximum voluntary isometric contractions (MVIC) of the muscles of interest (Castelein et al., 2015), including:

1. “Abduction 90°” (sitting)
2. “Horizontal Abduction with external rotation” (prone lying)
3. “Arm raised above head in line with LT muscle fibers” (prone lying)
4. “Shoulder flexion 135°” (sitting)
5. “Arm raised above head in line with Pm muscle fibers” (supine lying)

MVIC test positions were taught to each subject by the same investigator, and sufficient practice was allowed before formal data collection. Manual pressure was always applied by the same investigator and strong and consistent verbal encouragement from the investigator was given during each MVIC to promote maximal effort. All MVICs were performed prior to the different elevation exercises, except for the MVIC “Arm raised above head in line with Pm muscle fibers”. This MVIC was always performed at the end (after the exercises) to avoid pressure on the electrodes of the dorsal muscles (due to their contact with the examination table because of the supine position). Each MVIC test position was performed 3 times (each contraction lasted for 5 s-controlled by a metronome) with at least 30 s rest between the different repetitions. There was a rest period of at least 1 min between the different test positions.

In the second part of the investigation, the subject performed three elevation tasks: (1) elevation in the scapular plane, (2) towel slide against a wall and (3) elevation with external rotation of a Theraband® (Figs. 1–3). The exercises were performed in random order (simple randomization: envelopes containing the name of