Journal of Electromyography and Kinesiology 20 (2010) 359–365

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

The use of EMG biofeedback for learning of selective activation of intra-muscular parts within the serratus anterior muscle A novel approach for rehabilitation of scapular muscle imbalance

A. Holtermann [a,*], P.J. Mork [b], L.L. Andersen [a], H.B. Olsen [a], K. Søgaard [c]

[a] National Research Centre for the Working Environment, Lersø Parkalle 105, 2100 Copenhagen, Denmark
[b] Human Movement Science Programme, Norwegian University of Science and Technology, Trondheim, Norway
[c] Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

ARTICLE INFO

Article history:
Received 1 September 2008
Received in revised form 17 February 2009
Accepted 26 February 2009

Keywords:
Neuromuscular compartment
Surface EMG
Biofeedback
Trapezius

ABSTRACT

Motor control and learning possibilities of scapular muscles are of clinical interest for restoring scapular muscle balance in patients with neck and shoulder disorders. The aim of the study was to investigate whether selective voluntary activation of intra-muscular parts within the serratus anterior can be learned with electromyographical (EMG) biofeedback, and whether the lower serratus anterior and the lower trapezius muscle comprise the lower scapula rotation force couple by synergistic activation. Nine healthy males practiced selective activation of intra-muscular parts within the serratus anterior with visual EMG biofeedback, while the activity of four parts of the serratus anterior and four parts of the trapezius muscle was recorded. One subject was able to selectively activate both the upper and the lower serratus anterior respectively. Moreover, three subjects managed to selectively activate the lower serratus anterior, and two subjects learned to selectively activate the upper serratus anterior. During selective activation of the lower serratus anterior, the activity of this muscle part was 14.4 ± 10.3 times higher than the upper serratus anterior activity ($P < 0.05$). The corresponding ratio for selective upper serratus vs. lower serratus anterior activity was 6.4 ± 1.7 ($P < 0.05$). Moreover, selective activation of the lower parts of the serratus anterior evoked 7.7 ± 8.5 times higher synergistic activity of the lower trapezius compared with the upper trapezius ($P < 0.05$). The learning of complete selective activation of both the lower and the upper serratus anterior of one subject, and selective activation of either the upper or lower serratus anterior by five subjects designates the promising clinical application of EMG biofeedback for restoring scapular muscle balance. The synergistic activation between the lower serratus anterior and the lower trapezius muscle was observed in only a few subjects, and future studies including more subjects are required before conclusions of a lower scapula rotation couple can be drawn.

1. Introduction

The high prevalence of neck and shoulder disorders (Ferrari and Russell, 2003; Hakala et al., 2002; Larsson et al., 2007) has elicited considerable scientific interest in motor control and function of scapular muscles that stabilize, move, and rotate the scapula (Cools et al., 2007b; Falla et al., 2004; Johnson and Pandyan, 2005).

The serratus anterior and trapezius muscle act to stabilize the scapula to the chest wall and are considered the primary upward rotators of the scapula (Ebaugh et al., 2005; Mottram, 1997). Due to the function of the serratus anterior and the trapezius muscle on the scapula, they have been regarded as key contributors for normal scapular control and motion for several decades (Inman et al., 1944). Accordingly, neck and shoulder disorders are observed to be associated with a deviant activation pattern of these muscles (Kibler, 1998; Lin et al., 2005, 2006; Ludewig and Cook, 2000), termed scapular muscle imbalance (Cools et al., 2007b). Specifically, excessive activity of the upper trapezius combined with reduced activity of the lower trapezius and the serratus anterior muscle is a prevalent finding among patients with neck and shoulder disorders (Cools et al., 2007a, 2004; Ludewig and Cook, 2000; Ludewig et al., 2004). Restoring normal activation of intra-muscular parts of the serratus anterior and the trapezius has therefore become a central element in rehabilitation of neck and shoulder disorders (Burkhart et al., 2003; Decker et al., 1999). The suitability of strengthening exercises for restoring the scapular muscle balance has been investigated in several studies (Cools et al., 2007a; Decker et al., 1999; Ludewig et al., 2004). In particular, establishing exercises that provide minimal activity of excessively activated intra-muscular parts (i.e. upper trapezius) and facilitate high activity of the deficiently activated intra-muscular parts (i.e. lower trapezius and serratus anterior) has been a major aim. However, restoring motor control of the scapular muscles that enable proper

* Corresponding author.
E-mail address: aho@nrcwe.dk (A. Holtermann).

1050-6411/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jelekin.2009.02.009

scapular muscle balance is considered more important for neck and shoulder function than muscle strength (Cools et al., 2004; Lin et al., 2006; Ludewig and Cook, 2000). Therefore, rehabilitation exercises that aim to restore functional motor control of the scapular muscles are considered necessary for a successful outcome (Cools et al., 2007b; Ludewig et al., 2004).

A promising and recommended approach for (re)learning of functional motor control in rehabilitation settings is electromyographical (EMG) biofeedback (Basmajian, 1981). Biofeedback is the technique of using electronic equipment to reveal instantaneously certain physiological events and teach to control these otherwise involuntary events by manipulating the displayed signals (Basmajian, 1981). The great motor learning possibilities of EMG biofeedback has previously been shown by Basmajian (1963) who demonstrated the ability to learn an extraordinary control of individual motor units within a few hours of EMG biofeedback training (Basmajian, 1963). More recently, EMG biofeedback was shown effective for learning of selective activation of intra-muscular parts within the trapezius muscle (Holtermann et al., 2009). Specifically, all subjects learned to selectively activate intra-muscular parts of the trapezius muscle (e.g. the lower) while resting other intra-muscular parts (e.g. the upper) after ~1 h with EMG biofeedback guidance (Holtermann et al., 2009). Therefore, the application of EMG biofeedback in clinical settings may be a promising approach for restoring scapular muscle balance in patients with neck and shoulder disorders.

Investigation of causes to neck and shoulder disorders has stimulated to intensive research about the control and activation pattern of the trapezius muscle (Mork and Westgaard, 2006; Palmerud et al., 1995; Veiersted et al., 1993). However, although the serratus anterior is considered as a prime mover of the scapula (Dvir and Berme, 1978), detailed knowledge of motor control abilities of this muscle is scarce. The contribution of the serratus anterior to scapular stabilization, upward rotation, posterior tilting, elevation, and protraction illustrates the remarkable functionality and need for delicate motor control of this muscle. The contribution to all these scapular actions of the serratus anterior may be mediated by a subdivisioning of the serratus anterior into different functional intra-muscular parts. Thus, appropriate motor control of intra-muscular parts of the serratus anterior may be of paramount importance for normal scapular functioning (Inman et al., 1944). Moreover, Inman et al. (1944) proposed that the lower serratus anterior and the lower trapezius muscle constitute "*the lower scapular rotary couple*". This lower scapula rotation force couple may reduce loading of the upper trapezius muscle, thereby providing a balanced control of scapular rotation. However, synergistic activation of the lower serratus anterior and the lower trapezius has to our knowledge not been shown, and the existence of a lower scapula rotation force couple remains to be documented.

The aim of this study was to investigate whether EMG biofeedback can be used to learn selective activation of intra-muscular parts within the serratus anterior, and whether the lower serratus anterior and the lower trapezius are synergistically activated and thereby constitute the lower scapula rotation force couple.

2. Materials and methods

2.1. Subjects

Nine males (27–38 years, 1.74–1.89 m stature, 70–95 kg mass) volunteered to participate in the study. None of the subjects had experienced pain or discomfort in the neck and shoulder region during the last year, and none of the subjects had previously

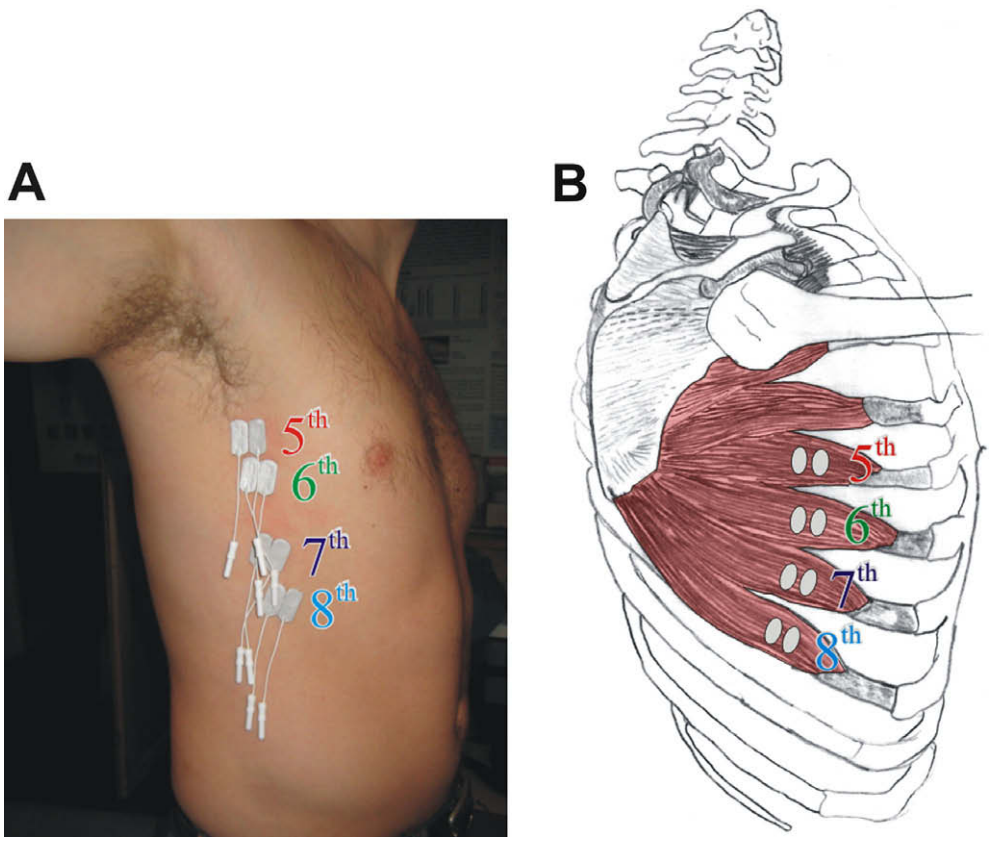

Fig. 1. Picture (A) and schematic illustration (B) of the electrode placement at the serratus anterior at the 5th–8th branch of the muscle arising from the 5th–8th rib. The reference electrode was placed at the acromion.