Journal of Electromyography and Kinesiology 24 (2014) 192–199

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

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

A comparison of cluster-based exposure variation and exposure variation analysis to detect muscular adaptation in the shoulder joint to subsequent sessions of eccentric exercise during computer work

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ARTICLE INFO

Article history:
Received 1 March 2013
Received in revised form 16 September 2013
Accepted 5 December 2013

Keywords:
Physical work load
Delay onset muscle soreness
Repeated bout effect
Muscular reorganization

ABSTRACT

The aim of this study was to compare the capability of a cluster-based exposure variation (C-EVA) with a conventional exposure variation analysis (EVA) to detect muscular adaptation in the shoulder joint to subsequent sessions of eccentric exercise (ECC). Eleven healthy subjects performed work with a computer mouse for 10 min at three instants, i.e., before, immediately after, and 24 h after ECC. The subjects repeated an identical procedure one week after the first session. Surface electromyography was recorded from descending and ascending part of the trapezius, deltoid anterior, and serratus anterior muscles. EVA and C-EVA were performed and their marginal distributions were extracted. A principal component analysis was applied to the marginal distributions of both EVA and C-EVA. Principal component difference was computed by subtraction of the corresponding principal components before the ECC from immediately after and 24 h after the ECC. The first component extracted from C-EVA revealed an interactive effect between the sessions of ECC and instants whereas this effect was absent using the conventional EVA. The current study highlights the importance of a multivariate approach to analyze the potentially important changes in muscular activity in response to the repeated bout effect.

1. Introduction

Delayed onset muscle soreness (DOMS) occurs as a result of exposure to unaccustomed high-intensity exercise (Pyne, 1994). DOMS is manifested by mechanical muscle hyperalgesia, occasional resting pain, and altered motor control (Kawczynski et al., 2012). Moreover, DOMS is mainly related to the eccentric component of exercise (Asmussen, 1953). Thus, eccentric exercises (ECC) are performed to induce DOMS in many studies of sensory-motor adaptations, e.g. (Felici, 2006; Pyne, 1994).

The symptoms related to DOMS are attenuated when the same or similar eccentric exercise has been performed days or weeks prior to the main exercise session (Clarkson et al., 1992). This seemingly adaptive or protective mechanism is called the "repetitive bout effect" (Nosaka and Clarkson, 1995). A combination of neural, mechanical, and cellular adaptations is considered the most plausible explanation of the changes observed following consecutive eccentric exercise (McHugh, 2003).

DOMS has been widely used as an endogenous muscle pain model mimicking some aspects of clinical musculoskeletal pain (Svensson and Arendt-Nielsen, 1995; Winkelstein, 2004). However, our knowledge of the repeated bout effect and motor control interaction is still limited, especially about the shoulder muscles during precision finger tasks such as computer work. Further studies along this line are warranted because physical activity and, more precisely, strength training has been reported to reduce neck-shoulder pain in office workers (Andersen et al., 2012).

Exposure variation analysis (EVA) as a computational framework has been extensively used to assess the physiological and biomechanical effects of handling physical loads on musculature in ergonomics and sports, e.g. (Abbiss et al., 2010; Ciccarelli et al., 2013; Larivière et al., 2005). EVA provides an estimate of the joint histogram of biomechanical loading level and its timing, and has mainly been applied with recordings of postures, e.g. (Bao et al., 1996; Möller et al., 2004; Straker et al., 2008), and electromyography, e.g. (Fjellman-Wiklund et al., 2004; Mathiassen and Winkel, 1996; Samani et al., 2009a).

A very distinct limitation of EVA is that it is usually applied in a univariate statistical inference (Samani et al., 2013) meaning that it addresses one outcome at a time. For instance, if a set of outcomes is correlated, a repeated application of univariate analyses for each of them may increase the risk of error in the statistical inference (Leary and Altmaier, 1980). For example, the pattern of muscular load distribution may involve the ascending trapezius, anterior

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1050-6411/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jelekin.2013.12.001

deltoid, and serratus anterior when the descending trapezius loading is decreased (Palmerud et al., 1998). Thus, such synergistic muscle recruitment needs a multivariate approach to be properly assessed.

We have previously reported a decrease in absolute electromyographic (EMG) amplitude of the descending trapezius immediately after an intense bout of eccentric exercise during computer work (Samani et al., 2009b). Thus according to that mentioned above, the load may have been redistributed to the other synergistic muscles, i.e., ascending trapezius, anterior deltoid and serratus anterior, as suggested by Palmerud et al. (1995, 1998).

In this study, we propose a cluster-based exposure variation analysis (C-EVA) allowing a multivariate inference to analyze the outcomes (Samani et al., 2013). We tested its effectiveness to detect an altered pattern of exposure compared with EVA.

In particular, we assessed the effect of repeated bouts of eccentric shoulder exercise on the pattern of the EMG activity from four muscles around the shoulder joint. Considering the multivariate approach inherent to C-EVA, we hypothesized that C-EVA will be more effective than EVA to detect muscular adaptation in response to subsequent ECC during computer work.

2. Methods

The study was conducted on 11 right-handed males (aged 25.3 ± 5.0 years; height, 177.9 ± 5.8 cm; body mass, 69.8 ± 6.4 kg; body mass index, 22.0 ± 1.3 kg m^{-2}). Informed consent was obtained from each subject. None of the participants reported pain or soreness in the shoulder region prior to the study and none had history of previous neck-shoulder disorders. All subjects maintained normal daily activity during the course of the study. The study was conducted in accordance with the declaration of Helsinki, and was approved by the local ethics committee (N-20070004).

2.1. Experimental protocol

The experiment was performed in two sessions separated by one week. Each session consisted of two consecutive days. Surface bipolar EMG was recorded from the descending and ascending parts of trapezius, deltoid anterior, and serratus anterior at three instants: before, immediately after, and 24 h after ECC. These particular muscles drew our attention for further investigation as a synergistic activity has been previously reported among these muscles (Palmerud et al., 1995, 1998). An identical procedure was performed during the second session to investigate adaptation or recovery processes. We have previously reported signs of such short time adaptation in terms of pain pressure threshold using an identical exercise protocol (Kawczynski et al., 2012). Once the participants had received the instructions concerning the experiment and the surface EMG electrodes were placed and checked, the computer workplace was individually adapted according to guidelines, e.g., seat and desk height, vision angle, glare, full arm support, and seat back rest (Kroemer et al., 2001). The recordings were sequentially performed as explained below:

(1) Reference contraction: The subjects were seated upright on a comfortable chair with their palms towards the ground looking straight forward. In this position, they were asked to perform one reference contraction consisting of bilateral arm abduction at 90° in the frontal plane for 5 s (Mathiassen et al., 1995). The mean of the root mean square (RMS) values computed over 125 ms epochs was used to define the levels of amplitude in exposure variation analysis (EVA).
(2) Computer work: 10 min of work with a computer mouse was performed each day. The standardized computer mouse work was performed as previously described (Birch et al., 2001). The computer work consisted of duplicating various graphs showing six circular targets linked to each other by straight lines including a start target (bold circle) displayed on the upper right corner of a computer screen (pixel resolution: 0.3 mm, screen resolution: 1024 × 768 pixels). Once the two graphs were identical, a new graph appeared. The time allowed for completing a graph was 8 s, after which a new graph appeared.

We have previously shown a drop in EMG amplitude immediately after an identical exercise protocol during a short computer work trial (Samani et al., 2009b). Fig. 1 shows the implemented procedure for this study.

2.2. Eccentric exercise

The subjects were seated on a chair with their back supported in an upright position. The ECC protocol used to induce DOMS consisted of 50 eccentric right shoulder elevations that were divided

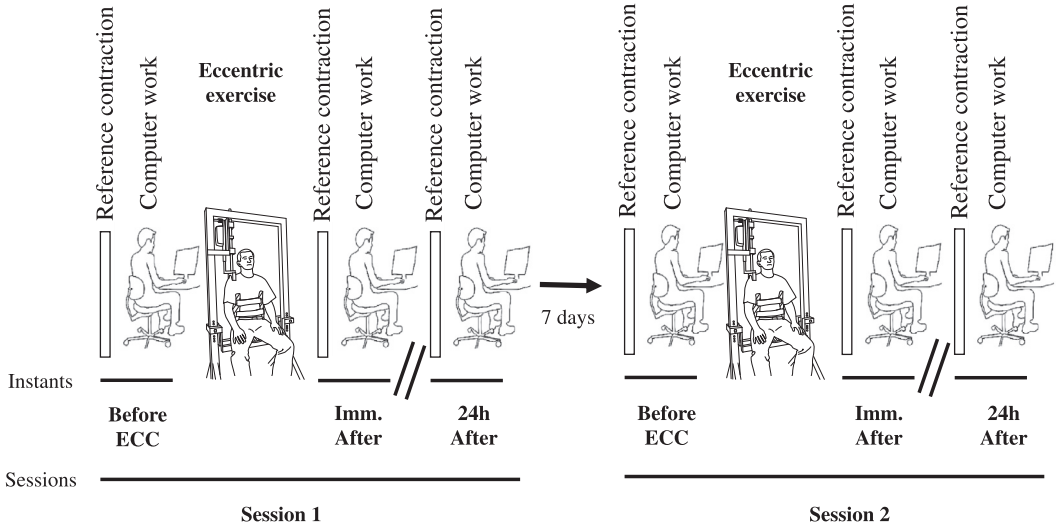

Fig. 1. Experimental protocol consisting of (i) reference contraction of bilateral arm abduction at 90° in the frontal plane with their palm toward ground for five seconds and (ii) computer work of 10 min. In each session, computer work was performed before, immediately and 24 h after eccentric exercise (ECC) over two sessions (Session 1 and 2) separated by one week.