Available online at www.sciencedirect.com
ScienceDirect
Journal of Electromyography and Kinesiology 18 (2008) 472–479
JOURNAL OF ELECTROMYOGRAPHY AND KINESIOLOGY
www.elsevier.com/locate/jelekin

# Activation of the shoulder and arm muscles during axial load exercises on a stable base of support and on a medicine ball

Anamaria Siriani de Oliveira [a,*], Marcel de Morais Carvalho [b], Daniel Pereira Cardoso de Brum [b]

[a] *Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, São Paulo University – USP, Brazil*
[b] *Av. Nicomedes Alves dos Santos, 4545 Gávea Uberlândia, MG 38411-106, Brazil*

Received 21 May 2004; received in revised form 15 August 2006; accepted 29 September 2006

**Abstract**

The purpose of this study was to compare SEMG activities during axial load exercises on a stable base of support and on a medicine ball (relatively unstable). Twelve healthy male volunteers were tested ($x = 23 \pm 7y$). Surface EMG was recorded from the biceps brachii, anterior deltoid, clavicular portion of pectoralis major, upper trapezius and serratus anterior using surface differential electrodes. All SEMG data are reported as percentage of RMS mean values obtained in maximal voluntary contractions for each muscle studied. A 3-way within factor repeated measures analysis of variance was performed to compare RMS normalized values. The RMS normalized values of the deltoid were always greater during the exercises performed on a medicine ball in relation to those performed on a stable base of support. The trapezius showed greater mean electric activation amplitude values on the wall-press exercise on a medicine ball, and the pectoralis major on the push-up. The serratus and biceps did not show significant differences of electric activation amplitude in relation to both tested bases of support. Independent of the base of support, none of the studied muscles showed significant differences of electric activation amplitude during the bench-press exercise. The results contribute to the identification of the levels of muscular activation amplitude during exercises that are common in clinical practice of rehabilitation of the shoulder and the differences in terms of type of base of support used.


*Keywords:* Shoulder; Electromyography; Closed kinetic chain; Exercises; Medicine ball

## 1. Introduction

Some studies about rehabilitation protocols of the shoulder complex have attempted to classify the exercises commonly used according to the level of electric activation of the involved musculature (Anders et al., 2004; Illyes and Kiss, 2005; Kelly et al., 2000, 2002; Ludewig et al., 2004; Townsend et al., 1991). This concern is due to the fact that the musculature has a major role in the biodynamics of the harmonious movement and on the stability of this joint (Labriola et al., 2005).

McCan et al. (1993) studied the electric activity during exercises that compose a acromioplasty rehabilitation protocol of the shoulder proposed by Hughes and Neer (1975). The specific goal of this studied program is to protect the tissues of the operated area and obtain early safe movement followed by an increase in muscular strength. The program is divided in three phases that evolve from passive exercises (Phase I) to active exercises (Phase II) and, lastly, resisted exercises (Phase III). The authors (McCan et al., 1993) point out the lowest myoelectric activity for the passive and assisted active exercises as an indication of its use

* Corresponding author.
*E-mail address:* siriani@fmrp.usp.br (A.S. de Oliveira).

1050-6411/$ - see front matter 
doi:10.1016/j.jelekin.2006.09.009

in initial phases of rehabilitation. Among the exercises studied by McCan et al. (1993), only the wall-slide may be considered an exercise performed in closed kinetic chain (Steindeler, 1955) (CKC) and it was included among the exercises that are appropriate for the initial phase of rehabilitation.

The use of exercises classified as in CKC has grown in the last years, since it is believed that they simulate biomechanical situations considered functional and promote a greater proprioceptive stimulus than the exercises in open kinetic chain (OKC) (Kibler, 1998; Wilk et al., 1996). While the scientific and clinical reason for applying exercises in CKC for the lower extremity seems obvious, the use of such exercises for the upper limb is less discussed, despite being employed during rehabilitation and training (Escamilla et al., 1998).

Uhl et al. (2003) determined the demand in the shoulder musculature during seven exercises in CKC with the discharge of body weight and the relation between the increases of this force in the activation of the shoulder's musculature. All studied exercises, frequently used in protocols for rehabilitation, were performed on a stable base of support. The authors verified that the variation of body weight discharge results in different demands of the shoulder's musculature.

Wise et al. (2004) determined the difference of the demand of the muscles from the glenohumeral joint during unsupported and supported (CKC) active range of motion (AROM) exercises, performed on vertical (short lever arm) and diagonal planes (long lever arm). The authors (Wise et al., 2004) suggest that such exercises should be introduced in protocols for shoulder rehabilitation following a sequence of supported short lever arm AROM to unsupported long lever arm AROM, based on the progressive increase of the observed electric activity.

In the attempt of systemizing a classification of exercises in relation to their clinical applicability and to the functional stages of shoulder rehabilitation, Lephart and Henry (1996) elaborated the Functional Classification System, in which the exercises in CKC are described as exercises on a fixed boundary with an external axial load. The authors (Lephart and Henry, 1995) state, as an example of such exercises, the push-up (entirely CKC) and the tripod position (one-handed push-up) on an unstable platform, which provides axial loading of the shoulder complex with the hand fixed. The last exercise is often referred to as dynamic or rhythmic stabilization exercises (Lephart and Henry, 1995).

However, although the exercises on a fixed boundary with an external axial load are indicated in early phases of rehabilitation, Wilk et al. (1996) indicate similar exercises performed on a relatively unstable base, such as a medicine ball, for more advanced phases of the rehabilitation program. This is because, according to the author, such exercises would promote a great demand of movements that need great dynamic stability. Borsa et al. (1994) affirm that the unstable base produces a series of patterns, resulting from the sudden changes of articular movement direction, while performing the exercise. These exercises stimulate both articular and mechanoreceptors for reflex joint stabilization (McMullen and Uhl, 2000).

If, ideally, the therapist will benefit from the electromyographic information to determine in which phase of rehabilitation a certain exercise may be included, there is a lack of surface electromyography (SEMG) studies about exercises on a fixed boundary with an external axial load performed on an unstable base of support.

The aim of this study was to provide a comparison of the SEMG activity recorded during different exercises accomplished with axial load on a medicine ball [relatively unstable] and stable base of support. We also described the differences of the muscles activity among the tested exercises. We tested the hypothesis that the muscle activation amplitude changes between exercises depending on the base of support used and, therefore, must be introduced in distinct phases of the rehabilitation of the shoulder complex.

## 2. Methods

### 2.1. Volunteers

Twelve healthy male subjects (mean age $\pm$ SD $= 23 \pm 7$ years, mean height $\pm$ SD $= 172 \pm 9$ cm, mean body mass $\pm$ SD $= 72 \pm 15$ kg) volunteered for this study. They were evaluated to confirm the absence of any alterations related to upper limb structures. Subjects were excluded if they had a previous history of shoulder, elbow, wrist, hand, or cervical injury or pain in the preceding six months. All subjects volunteering for this study signed an institutional review board approved consent form after the testing procedures were verbally described to them.

### 2.2. Electromyography

EMG data were collected using surface differential electrodes (two Ag–AgCl bars, $10 \times 2 \times 1$ mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and *common mode rejection ratio* of 130 dB – Lynx Electronics Ltda., São Paulo, Brazil). SEMG signals were sampled by 12 bits A/D converter board with a 2 kHz frequency, and band-pass filtered at 0.01–1.5 kHz. Raw SEMG data were digitally filtered at frequency bandwidth of 10–500 Hz and *root mean squares* (RMS) were calculated.

The skin was shaved at the electrodes' sites, gently abraded and cleaned with alcohol to reduce skin impedance, prior to the attachment of the electrodes, which were positioned in accordance with SENIAM recommendations (Hermens et al., 1999). SEMG was simultaneously recorded from the long head of biceps brachii (B), anterior portion of deltoid (D), clavicular portion of pectoralis major (P), trapezius upper fibers (T) and serratus anterior (S) muscles. No SENIAM guidelines for electrode positioning are available for clavicular portion of P and S, so the surface differential electrodes were placed between the motor point and tendinous insertion, with the bars of electrode perpendicular to the direction of the muscle fibers (Basmajian and Deluca, 1985). The electrodes were fixed using adhesive tape. The position and orientation of electrodes were confirmed by palpation of the muscle belly during monitored resisted contractions. A rectangular stainless steel electrode ($33 \times 31$ mm) was also used as a reference