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Reliability of electromyographic amplitude values of the upper limb muscles during closed kinetic chain exercises with stable and unstable surfaces

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Abstract

The purpose of the present study was to evaluate the intra and interday reliability of surface electromyographic amplitude values of the scapular girdle muscles and upper limbs during 3 isometric closed kinetic chain exercises, involving upper limbs with the fixed distal segment extremity on stable base of support and on a Swiss ball (relatively unstable). Twenty healthy adults performed the exercises *push-up*, *bench-press* and *wall-press* with different effort levels (80% and 100% maximal load). Subjects performed three maximal voluntary contractions (MVC) in muscular testing position of each muscle to obtain a reference value for *root mean square* (RMS) normalization. Individuals were instructed to randomly perform three isometric contraction series, in which each exercise lasted 6 s with a 2-min resting-period between series and exercises. Intra and interday reliabilities were calculated through the intraclass correlation coefficient (ICC 2.1), standard error of the measurement (SEM). Results indicated an excellent intraday reliability of electromyographic amplitude values (ICC $\geqslant$ 0.75). The interday reliability of normalized RMS values ranged between good and excellent (ICC 0.52–0.98). Finally, it is suggested that the reliability of normalized electromyographic amplitude values of the analyzed muscles present better values during exercises on a stable surface. However, load levels used during the exercises do not seem to have any influence on variability levels, possibly because the loads were quite similar.

Keywords: Electromyography; Reliability; Closed kinetic chain; Exercises; Swiss ball

1. Introduction

Shoulder pain and dysfunction are common orthopedic problems observed by physical therapists in individuals who practice physical activities involving upper limbs (Oliveira et al., 2006). In the search for effective rehabilitation programs, studies have aimed to asses, from a biomechanical point of view, the variables: load and muscle activation/co-activation in different exercises and motor tasks.

Closed kinetic chain (CKC) exercises have recently gained popularity and are frequently used in upper limb rehabilitation programs. The term CKC refers to tasks in which there is a task involving movement of several joints with the distal extremity fixed on a surface (Steindler, 1955).

These exercises are included in painful or unstable shoulder rehabilitation programs since they are considered biomechanically safer and more functional than Open Kinetic Chain (OKC) exercises, in which the hand moves freely with or without the presence of load. The advantages attributed to CKC exercises result from the joint

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approximation effect caused by the axial load on the limb, which increases proprioceptive stimuli and muscle co-activation, resulting in greater joint stability (Dillman et al., 1994).

When CKC exercises are performed with support over a relatively unstable surface, e.g., by supporting the hand on a medicine ball (Anderson and Behm, 2004) these exercises become more complex. The additional instability created by the support on an unstable surface increases demand over the neuromuscular system, increasing muscular co-activation (Lephart and Henry, 1996). Moreover, there is evidence that muscle reflex latency time is improved and ankle injury prevalence is reduced following the relative unstable CKC training regime (Verhagen et al., 2004). Increase in strength was another advantage attributed to unstable CKC training. This strength gains can be attributed to neural adaptations, as increase in number and in firing rate recruitment of motor units (Behm et al., 2002) and improved coordination of the agonist, antagonist, synergist and stabilizer muscles (Rutherford and Jones, 1986; Stone et al., 1998).

Several studies have suggested electromyography as a tool to evaluate muscle activity during tasks classified as closed kinetic chain (Dillman et al., 1994; Rothstein, 1985; Uhl et al., 2003). In addition, some recent studies have compared, by means of electromyographic signal analysis, the response of different muscle groups during exercises performed with the hand supported on a stable or relatively unstable surface (Anderson and Behm, 2004; Behm et al., 2002; Lear and Gross, 1998; Lehman et al., 2006).

However, so that data from electromyographic studies can be used, for instance for following the evolution of CKC protocols on an unstable surface, it is first necessary to learn about the reliability of the tool as well as the analyzed electromyographic variables. Reliability is a key element of instruments or tools used to obtain similar measures and values in two or more measurements in constant test conditions (Fagarasanu and Kumar, 2002), referring to consistency and reproducibility of such measures (Rothstein, 1985).

Surface EMG is influenced by a number of physiological properties, such as discharge frequency of motor units and muscle membrane characteristics, as well as non-physiological properties such as electrode, shape, size and placement (Farina et al., 2004; Deluca, 1997). Another factor which may affect the reliability of surface EMG values is the level of the muscle contraction (Solomonow et al., 1990). Some studies (Kollmitzer et al., 1999; Yang and Winter, 1983) have reported better levels of surface EMG amplitude reliability during sub-maximal contractions as opposed to maximal contractions. However, another studies (Kollmitzer et al., 1999; Ollivier et al., 2005) suggest similar reliability of surface EMG amplitude at maximal and sub-maximal contractions.

This information suggests that surface EMG value reliability depends on the experimental set-up. In addition, results from different studies, which assessed EMG reliability, suggest that it could differ not only among the assessed muscles, but also among the different portions of a same muscle group (Kollmitzer et al., 1999). Based on this information, the importance of studies that assess EMG reliability in different muscle groups and tasks is emphasized.

Knowing the reliability of the electromyographic amplitude recorded during CKC exercises on stable and unstable surfaces, performed by healthy individuals, at maximum and sub-maximum levels, is important in order to assess the changes following an intervention, as well as to the effect promoted by rehabilitation exercises or programs, and not simply to the lack of consistency of this data or of the methodology used.

The purpose of this study is to evaluate the reliability of EMG amplitude of the scapular girdle and arm muscles during CKC exercises on a stable and unstable surface. It was hypothesized that the EMG amplitude values recorded during CKC exercises on both surfaces present excellent intraday reliability. However, it is expected that interday values present a greater degree of variability, especially during exercises on unstable surface, due to the different displacements imposed by the Swiss ball.

2. Materials and methods

2.1. Volunteers

Twelve healthy male subjects (mean age $\pm$ SD $= 22 \pm 3$ years, mean height $\pm$ SD $= 175 \pm 0.05$ cm, mean body mass $\pm$ SD $= 68 \pm 7$ 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 previous history of shoulder, elbow, wrist, hand, or cervical injury or pain in the previous 6 months. All subjects volunteering for this study signed a consent form approved by the institutional review board after testing procedures were verbally described to them.

2.2. Tested tasks

Each volunteer randomly performed three six-second contractions in different isometric exercises, with the distal extremity fixed on stable surface and on a relatively unstable surface, such as a Swiss ball with axial load. The exercises performed were *wall-press* (Fig. 1), *bench-press* (Fig. 2) and *push-up* (Fig. 3).

2.3. Instrumentation

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).

A load cell and auditory biofeedback, both linked to auxiliary channels of the electromyographer, were used to obtain real-time values in relation to the load applied onto the ball. This also made it possible to instruct the volunteer with an audio signal regarding the amount of force produced throughout the collection time.

SEMG signals and force output were sampled by a 12-bit A/D converter board with a 4 kHz frequency, and band-pass filtered at 0.01–1.5 kHz. Raw SEMG data were digitally filtered at fre-