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On the use of EMG-ratios to assess the coordination of back muscles

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Abstract

Background. Electromyographic (EMG) amplitude ratios (EMG-ratios) have been proposed to assess back muscle coordination in chronic low back pain patients to avoid the normalization of EMG using maximal contractions. The aim of this study was to test the relevance of this type of EMG analysis.

Methods. Healthy subjects (44 men and 13 women) and patients with chronic low back pain (57 men) performed three 7 s static ramp extension contractions ranging from 0% to 100% of the maximal voluntary contraction while standing in a static dynamometer. A subgroup of 20 healthy men also performed 5 s step contractions at 10%, 20%, 40%, 60% and 80% of the maximal voluntary contraction. Finally, to assess reliability, another subgroup ($n = 20$ healthy and 20 men with chronic low back pain) performed the protocol three times, on different days. Surface EMG signals were collected from four pairs of back muscles and subcutaneous tissue thickness was measured at the corresponding electrode sites. EMG amplitude values were computed at each 5% force level from 10% to 80% of the maximal voluntary contraction. Then, EMG-ratios were computed between different electrode sites and averaged bilaterally.

Findings. All EMG-ratios were affected by the force level and the contraction type (ramp vs step contractions). Statistically significant Pearson's correlations ($r = -0.38$ to -0.57) were obtained between some EMG-ratios and their corresponding subcutaneous tissue thickness ratios. The reliability of the EMG-ratio variables ranged from moderate to excellent (intra-class correlation coefficients between 0.50 and 0.91). Comparisons between 12 men and 13 women and between 24 healthy men and 57 men with chronic low back pain showed that EMG-ratios were sensitive to sex but not to pain status. Multivariate analyses applied on the EMG-ratios identified clusters of subjects but none of the main clinical variables were able to clearly characterize these clusters.

Interpretation. Overall, even though additional research is warranted to further substantiate some important psychometric characteristics of the EMG-ratios as well as their biomechanical and clinical significance, these results support their use for assessing the coordination patterns of back muscles, provided that confounding variables such as the force level, the contraction type, and subcutaneous tissue thickness are accounted for.

Keywords: Back pain; Surface electromyography; Dynamometry; Lumbar impairment; Subcutaneous tissue thickness; Force level; Reliability

1. Introduction

Low back pain (LBP) is an increasing problem in industrialized society and the appropriate management of LBP necessitates the development of objective measures of low back status. However, the poor relationship between clinical/imaging findings and symptoms (Jensen et al., 1994) as well as the assessment of lumbar impairments through physical performance measures (range of motion, trunk muscle strength and endurance) have failed to give a clear picture of the physical condition of the LBP patient (Mellin, 1986; Newton and Waddell, 1993). One of the main reasons is probably because these latter measures rely partially on motivational factors (performance) or fear of

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injury, and consequently are not truly objective (Vlaeyen and Linton, 2000).

Surface electromyography (EMG) allows the assessment of trunk muscle activation patterns during submaximal tasks, which are thus theoretically less prone to the influence of psychological factors. It has been used extensively to study patients with chronic LBP (CLBP) (Geisser et al., 2005; van Dieen et al., 2003b) because these muscle activation patterns are likely to be altered either to correct for unstable lumbar segments (Panjabi, 1992) or, as hypothesized more recently, as a result of corrupted transducer signals from injured mechanoreceptors (Panjabi, 2006). Unfortunately, one common conclusion reached by the literature reviews on this topic is the great variability of findings (Geisser et al., 2005; van Dieen et al., 2003b), making surface EMG a limited tool for assessing and diagnosing patients with CLBP. Indeed, this variability may arise from heterogeneous patients having different pathologies and hence using different muscle recruitment patterns to deal with them. However, at least part of this variability may also be explained by (1) the lack of task standardization (posture, relative loading) and (2) by the way the EMG amplitude variables are normalized to account for variations due to electrode positioning and subcutaneous tissue thickness (STT). In both situations, maximal voluntary contractions (MVC) are mandatory because, in order to allow inter-individual comparisons, the load must be proportional to the strength, and the EMG amplitude values must be normalized to the maximal EMG reference values (EMGmax). Unfortunately, patients with CLBP are reluctant to perform MVCs because of fear of (re)injury (Vlaeyen and Linton, 2000) or other psychological factors (Hirsch et al., 1991) and possibly reflex inhibition (Stokes and Young, 1984). Different measurement strategies must thus be envisaged.

To circumvent the problem of EMG amplitude normalization, EMG amplitude ratios (hereafter called EMG-ratios) between different pairs of muscles have been proposed (Edgerton et al., 1997) to quantify asymmetric left–right (contralateral EMG-ratios) EMG imbalances (Oddsson and De Luca, 2003) or the coordination between muscles at different levels (ipsilateral EMG-ratios) of the spinal column (Reeves et al., 2006; van Dieen et al., 2003b). Unfortunately, contralateral EMG-ratios have shown poor test–retest reliability results (Lariviere et al., 2005). Ipsilateral EMG-ratios have repeatedly been shown to be sensitive to the presence of CLBP (Edgerton et al., 1997; Reeves et al., 2006; van Dieen et al., 2003a) and have revealed excellent test–retest reliability results (intra-class correlation coefficients between 0.79 and 0.95, if the standing task is disregarded) during tasks involving different static postures likely involving low force levels (Edgerton et al., 1997). Obviously, a reliability assessment would be required during tasks performed in a dynamometer. Also, unlike contralateral EMG-ratios where the STT can be assumed equivalent to be between electrode sites, ipsilateral EMG-ratios may be affected by an uneven distribution of STT between the electrode sites, and more importantly, between individuals. Consequently, it is of interest to verify the possible influence of this potential confounding factor.

An attractive property of contralateral EMG-ratios is that they are relatively independent of the force level (Lariviere et al., 2005; Oddsson and De Luca, 2003), which eliminates the problem of determining the relative load in patients with CLBP. However, to the author's knowledge, the influence of the force level has not yet been tested for ipsilateral EMG-ratios. The available data on the relative contribution of different back muscles across the force levels suggest that ipsilateral EMG-ratios would change across the force levels, at least for specific combinations of back muscles (Mayer et al., 2005; Vink et al., 1988). In fact, it has been observed that medially located muscles are more activated than more laterally located back muscles at low to moderate force levels and that the opposite occurs at higher force levels (Mayer et al., 2005; Vink et al., 1988). It would be of interest to find out which muscle combinations would produce relatively stable ipsilateral EMG-ratios across force levels. Furthermore, considering that the study of the influence of the force level can be carried out either with the use of one ramp contraction passing through different force levels or with the use of several steady step contractions (at different force levels), the possible influence of contraction type on EMG-ratios should also be studied.

The main purpose of the present study was to test the use of ipsilateral EMG-ratios of different back muscles during ramp contractions. More specifically, three test categories were used: (1) the influence of potential confounding variables such as the force level, the contraction type (ramp vs step contractions) and STT on these EMG-ratios, (2) their test–retest reliability and (3) their sensitivity to sex and CLBP status using univariate statistical analyses. Multivariate statistical analyses were also carried out to test possible presence of clusters of subjects showing similar coordination patterns.

2. Methods

This study is a secondary analysis of existing data sets from different studies that have tested other EMG parameters about the effect of force level and contraction type (ramp vs step contractions) (Lariviere et al., 2001a), their reliability (Lariviere et al., 2002) as well as their sensitivity to sex and CLBP status (Lariviere etal., 2002, 2005). These studies used exactly the same protocol regarding the measures (EMG electrode type and sites and dynamometry) and tasks (ramp contractions). Therefore, the general methodology will be presented first; additional elements specific to each study will be presented afterwards to answer different questions (contraction type, reliability).