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Controlling for out-of-plane lumbar moments during unidirectional trunk efforts: Learning and reliability issues related to trunk muscle activation estimates

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ABSTRACT

To assess the electromyographic (EMG) activation of trunk muscle during exertions performed in one primary plane (sagittal, frontal, transverse), we previously proposed a protocol allowing minimizing out-of-plane efforts (coupled moments – CMs) with the use of a static dynamometer combined with a visual feedback system. The aims of this study were to go further by testing motor learning and reliability issues related to such a protocol. Three identical sessions were conducted, where maximal voluntary contractions and submaximal ramp contractions were performed in six different directions while standing in the dynamometer. Two feedback conditions were tested, the simple 1D-feedback in the primary plane and the full 3D-feedback in all planes simultaneously. Surface EMG signals were collected from back and abdominal muscles and EMG amplitude and CMs were computed during the ramp contractions. Providing a 3D feedback to minimize CMs did not improve EMG reliability or in other words, did not reduce the within-subject variability. Providing three assessment days had practically no effect (no learning) on CMs and EMG variables. Overall, the reliability of EMG was at best moderate. However, although this limits its use on an individual basis, it still allows within- and between-group comparisons for research applications.

1. Introduction

Surface electromyography (EMG) has been used extensively to assess trunk muscle activation patterns during submaximal tasks but the great variability of findings (Dolce and Raczynski, 1985; Geisser et al., 2005; Nouwen and Bush, 1984; Traue et al., 1992; van Dieen et al., 2003b) makes surface EMG a limited tool to assess and diagnose CLBP patients. In a previous study (Lariviere et al., 2009), we hypothesized that a lack of task standardization, allowing the subject to produce efforts in more or less variable directions, may in part explain some of the variability of EMG responses of trunk muscles. We furthered hypothesized that EMG variability might decrease by using feedback from a 3D dynamometer.

The EMG assessment of trunk muscle coordination with the use of dynamometers has scarcely restricted out-of-plane (coupled) moments during efforts performed in one primary plane (sagittal, frontal, transverse). Previous results of our group provided evidence that giving a visual feedback can reduce these unwanted coupled moments (CMs) and has also a significant impact on trunk muscle activation (Lariviere et al., 2009). Using moment feedback is challenging from a motor control point of view, especially for exertions in the frontal and transverse planes (Lariviere et al., 2009), thus emphasizing the importance of motor learning.

Another source of EMG variability arises from the normalization process of the EMG signal. To allow between-day, -subject and -individual comparisons, the maximal voluntary electrical activity (MVE) values must be recorded during a maximal voluntary contraction (MVC). This allows controlling for different confounding variables such as subcutaneous tissue thickness and electrode placement (Burden, 2010). However, MVCs are difficult to generate (Allen et al., 1995) and consequently, subject to the influence of motivation and motor learning (Baratta et al., 1998), which can in turn induce variation in MVE values.

Considering that ideally motor learning should be stabilized before assessing muscle activation patterns, this has practical implications for the proposed assessment protocol. Motor learning

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has in turn an impact on the reliability of normalized EMG (NEMG). Therefore, the aim of this study was to assess motor learning and reliability issues of measures collected during (1) MVCs (peak primary moment, MVE) and (2) submaximal contractions performed in different directions, with and without controlling CMs with the use of visual feedback (CMs and NEMG of 12 trunk muscles).

2. Methods

The methodology (Lariviere et al., 2009) is summarized.

2.1. Subjects

Twenty healthy men (Age: 25, SD: 3 years) participated. The main exclusion criteria were the following: had never participated in a previous study in which this dynamometer was used; back pain in the previous year. The study and consent form were approved by the ethics committee of the *Centre de Recherche Interdisciplinaire en Réadaptation du Montréal métropolitain*.

2.2. Measurement techniques

The dynamometer measures L5/S1 moments (sampling rate: 50 Hz) in the three plane during isometric contractions (Fig. 1A, (Lariviere et al., 2001b)) while standing in a steel frame allowing stabilization of the lower body, pelvis and thorax. A software was developed to provide visual feedback of L5/S1 moments in one, two or three planes for all possible combinations and in an intuitive manner (Fig. 1B, (Lariviere et al., 2009)).

The EMG signals were collected with differential dry surface electrodes (Model DE-2.3, DelSys Inc., Wellesley, MA; bandwidth 20 ± 5 Hz to 450 ± 50 Hz, 12 dB/oct; preamplification gain: 1000; CMRR: >80 dB; noise <1.2 μV (RMS, R.T.I.)) composed of two parallel silver bars (10 mm long, 1 mm wide) spaced 10 mm apart. After the skin at the electrode sites was shaved and abraded with alcohol, the electrodes were positioned bilaterally over the multifidus at the L5 level (MU-L5, ≈3 cm from the midline of the back), iliocostalis lumborum at L3 (IL–L3, ≈ 5–6 cm from midline) and longissimus at L1 (LO–L1, ≈ 3 cm from midline), as detailed elsewhere (Lariviere et al., 2001a). The detailed procedure is in accordance with the SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) standards for back muscles electrode placement (Hermens et al., 1999). Electrodes on the abdominals were positioned bilaterally on the rectus abdominis (RA), external (EO) and internal (IO) obliques (McGill, 1991). A silver–silver chloride reference electrode (Medi-Trace model, Graphic Controls Canada Limited, Gananoque, Ont., Canada) was positioned over the C7 spinous process. For the back muscles only, a template was produced during session 1, by copying electrodes locations along with natural skin blemishes on acetate. This help to ensure the same placement of the EMG surface electrodes in sessions 2 and 3. Unfortunately, this approach is not feasible for abdominal muscles. The difficulty capturing the multifidus muscle with surface electrodes (Stokes et al., 2003) is acknowledged and therefore the validity of the electromyographic signal was assigned to the landmarked location rather than to the multifidus muscle itself. The IO electrode placement may also represent the combined activity of the internal oblique and transverses abdominis (Marshall and Murphy, 2003; McGill et al., 1996). EMG signals were bandpass-filtered between 20 and 450 Hz, A/D converted at a sampling rate of 2000 Hz (12-bits National Instruments PCI6024E card) and stored on a hard disk for later analysis.

2.3. Study design, procedures and tasks

Each subject was assessed during three sessions (same time of the day) one week apart. In each session, two submaximal ramp contractions (100 Nm in sagittal plane, 50 Nm in frontal and transverse planes) were performed in six directions (flexion, extension, left and right lateral bending and axial rotation) for warm-up and familiarization. Then, maximal voluntary contractions (MVC) were performed, with feedback provided only in the primary plane and strong verbal encouragements (Jung and Hallbeck, 2004). MVCs in the six directions (directions balanced across subjects using a

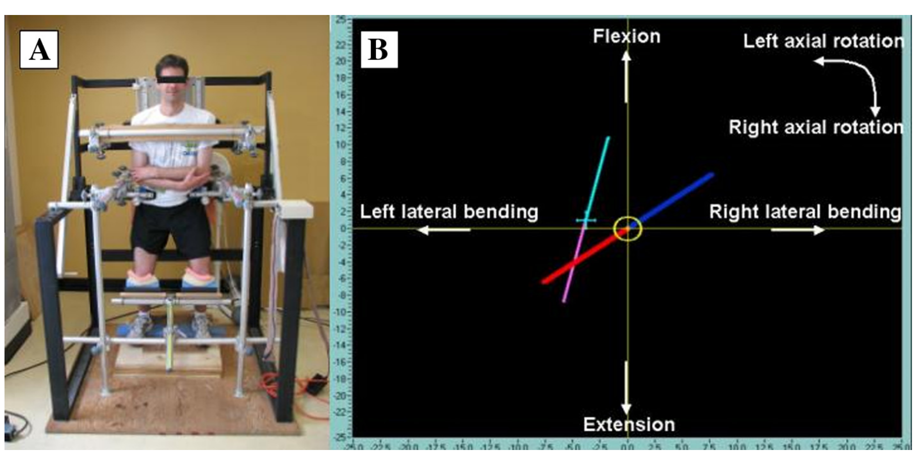

Fig. 1. Experimental setup (details in the methods – measurement techniques). (A) The triaxial dynamometer; (B) Visual feedback displayed to the subject. The white arrows and text were added only for this explanation. To use visual feedback efficiently, the subject has simply to imagine that the screen is tilted forward so that the motion of the target (circle symbol) and of the subject (+ symbol) moves in a reference system that is intuitive. Briefly, for flexion and extension moments, the circle (and +) moves forward (if the screen is tilted forward) and backward, respectively. For lateral bending to the left and to the right, the circle (and +) moves to the left and to the right, respectively. Finally, for axial rotation to the left and to the right, the lines crossing the + and the circle rotate to the left and to the right, respectively, like the hands of a clock. The color and thickness of the clock hands are also different to help the subject identify himself relative to the target. Basically, the task consists of putting the + sign (subject) into the circle (target), while simultaneously superimposing the clock hands. In the present example, the task was to produce a progressive (ramp contraction) axial rotation moment to the right. The task is completed when the blue line points downward (100% of the targeted moment). Full 3D-feedback was provided here. At this instant during the task, when looking at the hands of the clock, it is obvious that the subject was late in generating right axial rotation. Too much left lateral bending was also generated in the frontal plane, but only a small flexion moment was produced in the sagittal plane. Reprinted from Journal of Biomechanics, 42 (10), C. Lariviere, D. Gagnon, and K. Genest, Offering proper feedback to control for out-of-plane lumbar moments influences the activity of trunk muscles during unidirectional isometric trunk exertions, 1498–1505, 2009, with permission from Elsevier. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)