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Trunk stabilization estimated using pseudorandom force perturbations, a reliability study

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ABSTRACT

Measurement of the quality of trunk stabilization is of great interest to identify its role in first occurrence, recurrence or persistence of low-back pain (LBP). Our research group has developed and validated a method to quantify intrinsic and reflex contributions to trunk stabilization from the frequency response function (FRF) of thorax movement and trunk extensor EMG to perturbations applied by a linear actuator. However, the reliability of this method is still unknown. Therefore, the purpose of this study was to investigate the between-day reliability of trunk FRFs in healthy subjects and LBP patients. The test–retest ICC's in patients were substantial for both admittance and reflex gains ($ICC_{3,1} > 0.73$ and 0.67). In healthy subjects, the reliability of admittance gain was also substantial ($ICC_{3,1}$ 0.66), but the reliability of the reflexive gain was only moderate ($ICC_{3,1}$ 0.44). Although sample sizes were limited (13 healthy subjects and 18 LBP patients), these results show that trunk stabilization can be measured reliably, and represent a promising step towards using this method in further research in LBP patients.

1. Introduction

Trunk stabilization is needed to maintain control over trunk posture and movements during daily life activities (MacKinnon and Winter, 1993; van der Burg et al., 2005). Trunk stabilization is dependent on both active (muscular) and passive (osteoligamentous) structures and it has been suggested that low-back pain (LBP) might cause impaired trunk stabilization (van Dieen et al., 2003; Panjabi, 1992), which in turn might contribute to persistence or recurrence of LBP (Hodges and Moseley, 2003; MacDonald et al., 2009). It has also been suggested that poor trunk stabilization could be a predictive factor or even primary cause of LBP (Cholewicki et al., 2005). Therefore, measurement of the quality of trunk stabilization is of great interest to identify its role in the first occurrence, recurrence or persistence of LBP.

Specifically, several studies have indicated longer reflex delays after an external mechanical perturbation of trunk posture in LBP patients than in controls (Magnusson et al., 1996; Radebold et al., 2000). In apparent contrast, higher trunk stiffness, i.e. a higher mechanical resistance to such perturbations, has also been reported (Hodges et al., 2009). In fact, increased trunk intrinsic stiffness could explain the longer delays found, as with increased intrinsic stiffness the same mechanical disturbance will cause a smaller and slower deviation of trunk posture. This could result in a longer apparent reflex delay, caused by the smaller deviations in combination with thresholds of sensors signaling these deviations or even in the method detecting the responses, while the true neural delay could be unaffected.

Protocols to properly identify trunk stabilization (in terms of intrinsic stiffness and reflexive responses) must be well standardized and reliable to determine their clinical relevance and to support their use as clinical outcome measures. Many methods to measure trunk stabilization have been described in the literature, but documentation on the reliability of these methods is sparse (Maaswinkel et al., submitted for publication). Hendershot et al. (2012) performed a reliability study on a method that used pseudorandom position-controlled perturbations and found high within-day and moderate to fair between-day intraclass correlation coefficients (ICC's) for trunk stiffness (0.90 and 0.67 respectively) and reflex gain (0.85 and 0.37 respectively). A potential problem with the position controlled perturbations, is that the subject is unable to exert any influence over the resulting displacement and will therefore not be motivated to resist. It has been observed in former studies on upper extremity control that subjects reduce their efforts to resist position controlled perturbations after several seconds (de Vlugt et al., 2003a, 2003b).

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In contrast, pseudorandom force perturbations do not have this drawback and require the subject to actively resist the perturbation during the entire trial. Our research group has developed and validated a method to assess both the intrinsic and reflexive component of trunk stabilization by applying thorax perturbations with a linear actuator while subjects are restrained at the pelvis in a kneeling-seated position (van Drunen et al., 2013). However, the reliability of this method is still unknown. Reliability might be influenced by LBP because of possible variability over time in motor control impairments in LBP (Granata et al., 2004). Therefore, the purpose of this study was to investigate the between-day reliability of a pseudorandom force perturbation method to measure trunk stability in both healthy subjects and in LBP patients.

2. Methods

2.1. Subjects

Thirteen healthy subjects (5 males, age range 22–28 years, mean mass: 74 kg (±13 kg)) and 18 patients with LBP (10 males, age range 29–69 years, mean mass: 89 kg (±23 kg)) participated in this reliability study. All participants met the following inclusion and exclusion criteria; the healthy subjects did not have LBP in the year prior to the experiments. The group of patients suffered from non-specific LBP, or LBP following back surgery, for at least six weeks. Fusions, Prostheses or other operations that cause substantial anatomical changes were excluded. Subjects had no radicular pain caused by lumbar nerve root compression or a hernia nuclei pulposi, nor did they have any neurological disorders that might interfere with trunk control (e.g. Cerebro Vasculair Accident, Multiple Sclerosis or Parkinson's disease). All participants read and signed an informed consent form prior to the experiment according to the guidelines of the medical ethical committee of VU Medical Center Amsterdam.

2.2. Protocol

To assess the test–retest reliability, two separate measurements were performed following the procedure described below. The time between repeated measurements for healthy subjects was 1–3 days. Patients repeated the protocol after 1–2 weeks. This was done in order to decrease burden and to prevent influence of possible muscle-soreness after the first measurement.

The experimental setup was similar to previous studies (van Drunen et al., 2013; Maaswinkel et al., 2015). The participants were positioned in a semi-kneeling-seated posture with their pelvis restrained (Fig. 1). The subjects were blindfolded to prevent visual feedback and crossed their arms during the trials. During trials, a ventral force perturbation was applied at the T10 level of the spinous process by a magnetically driven linear actuator (Servotube STB2510S Forcer and Thrustrod TRB25-1380, Copley Controls, USA). A thermoplastic patch (4×4 cm^2) was placed between the device and the subject for comfort and better force transfer. Each subject was instructed to 'sit as still as possible' during the perturbations (resist-task). The patients performed additional trials in which they were asked to 'Relax, but sit upright' (relax-task). Each condition was repeated three times.

The same pseudorandom force perturbation signal was used for each participant and for both consecutive assessments and consisted of a pseudorandom dynamic force disturbance of ±35 N combined with a 60 N baseline preload. The dynamic disturbance was a crested multi-sine (sum of sine waves) (Pintelon and Schoukens, 2001) that contained 18 logarithmically distributed paired frequencies within a bandwidth of 0.2–15 Hz (Fig. 1). Power above 4 Hz was restricted to 40% to reduce adaptive behavior to high frequency content (Mugge et al., 2007). Each run lasted 50 s, consisting of a 3 s ramp force increase to the 60 N load level, a two second stationary load, a start-up period to reduce transient behavior (the last 5 s of the dynamic disturbance), and twice a 20 s dynamic disturbance.

After each trial, patients were asked for their momentary pain using a 10-point numeric pain rating scale (NPRS) (Freyd, 1923). Additionally, patients filled in a 7-days pain diary, using a 10-point NPRS, prior to both measurements. Both momentary pain and pain-diary scores were used for LBP-identification (NPRS-score > 0) and to assess the stability of pain between the two measurements. To correct for possible changes in severity between consecutive assessments of known prognostic factors in patients with low back pain (i.e.. illness beliefs, fear of movement, catastrophizing, depression and anxiety), the Oswestry Low Back Pain Questionnaire (Fairbank et al., 1980), Back beliefs questionnaire (Symonds et al.,

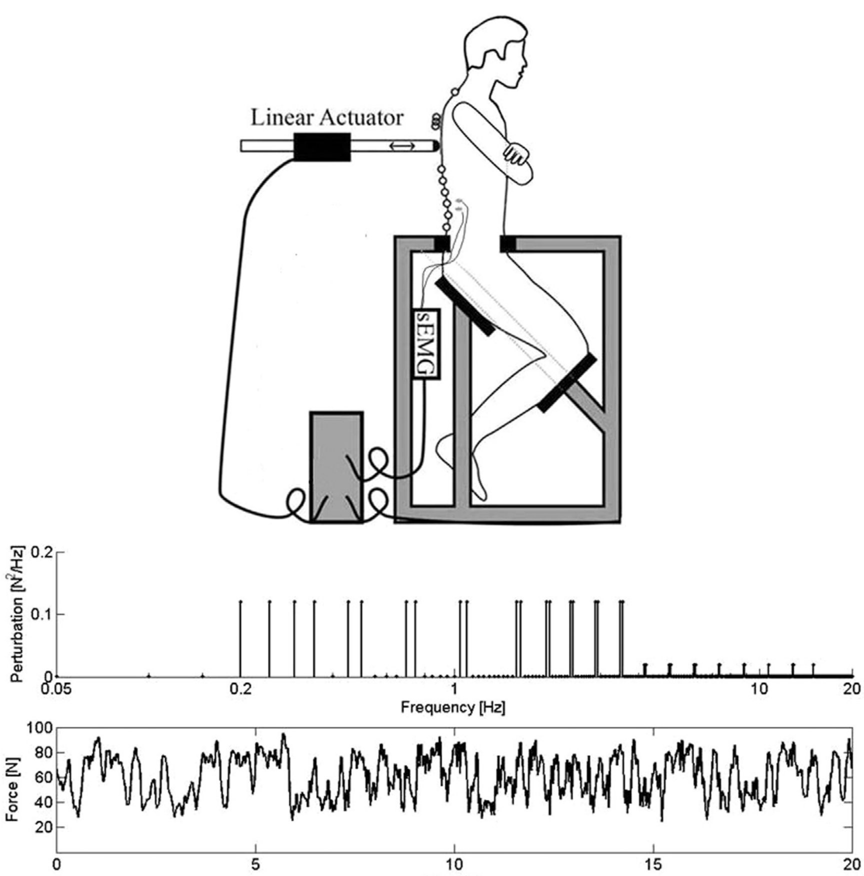

Fig. 1. The experimental setup, the power spectrum (upper) and time series (below) of the applied force perturbation.