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Center of pressure trajectories, trunk kinematics and trunk muscle activation during unstable sitting in low back pain patients

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ABSTRACT

Trunk motor behavior has been reported to be altered in low-back pain. This may be associated with impaired lumbar proprioception, which could be compensated by trunk stiffening. We assessed trunk control by measuring center-of-pressure, lumbar kinematics and trunk muscle electromyography in 20 low-back pain patients and 11 healthy individuals during a seated balancing task, in conditions with and without disturbance of lumbar proprioception and occlusion of vision. We hypothesized that low-back pain patients show larger postural sway, but smaller thoraco-lumbar movements than healthy individuals. Repeated measures analyses of variance indicated that the effects of proprioception disturbance and vision occlusion were similar between groups. Interestingly, low-back pain patients grabbed the safety rail more often, while differences between groups in sway measures were rather subtle. This suggests that low-back pain patients were more cautious. Furthermore, low-back pain patients had an about 20 degrees less flexed lumbar posture than healthy individuals, and, in contrast to our hypothesis, made larger thoraco-lumbar movements in the sagittal plane, as indicated by higher SDs of thoraco-lumbar flexion and lower (more negative) correlations between pelvis and thorax movements. Activation of the intersegmental longissimus relative to the iliocostalis muscle, which spans all lumbar segments, was lower in low-back pain patients compared to healthy individuals. This difference in muscle activation may be causal for larger thoraco-lumbar movements, and may be causative of reduced control over segmental lumbar movement, but may also reflect the need for larger corrective movements to compensate balance impairments.

1. Introduction

Differences in trunk motor behavior between low-back pain (LBP) patients and healthy control (HC) subjects have been reported in upright standing [1,2], walking [3,4] and sitting [5,6]. Findings from studies with lumbar muscle vibration, which is known to perturb proprioceptive feedback from muscle spindles [7], suggest that these differences in motor control could in part be explained by impaired proprioception in LBP-patients [8]. Consequently, to compensate for proprioceptive deficits, LBP-patients may use trunk muscle activation strategies aimed at trunk stiffening, in order to protect the painful area [9].

Seated balancing, i.e. balancing on a chair with the lower extremities supported and a hemisphere under the seat, allows studying trunk control in an implicit, challenging and natural way, while avoiding compensation by knee and ankle motion. Previous studies compared LBP-patients and HC-subjects during this task in terms of either center-of-pressure (CoP) trajectories [10,11] or trunk kinematics [12]. Radebold et al. found that balance performance in LBP-patients was lower than in HC-subjects, especially in more challenging conditions [10], while Van Dieën et al. found larger CoP-amplitudes in subjects with a recent history of LBP, but not in subjects with current LBP [11]. The latter group demonstrated lower CoP-frequencies which was in line with earlier suggestions that LBP-patients stiffen their lumbar spine [9,13,14]. However, while such a trunk stiffening strategy would result in smaller movements of the spine, Van Daele et al. reported larger pelvis and trunk movements in LBP-patients [12]. Regrettably the authors did not report lumbar spine (i.e. trunk relative to pelvis) motion. So, although seated balancing seems a convenient task for studying trunk control [15], and published data point at impaired seated balance in patients, the exact nature of differences between patients and controls, and more specifically the question whether or not patients employ a stiffening strategy, remain to be elucidated.

Therefore, our goal was to evaluate CoP-trajectories, trunk kinematics and trunk muscle activation during seated balancing in LBP-patients. In addition, we evaluated the effects of eliminating

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visual information and disturbing proprioception on postural balance. We hypothesized that LBP-patients show larger CoP-movements, coinciding with larger trunk movements, but smaller movements of the lumbar spine. In line with this, LBP-patients were hypothesized to show larger ratios of longissimus over iliocostalis, and lumbar over thoracic longissimus muscle electromyography (EMG) amplitudes, since larger ratios would reflect lumbar spine stiffening strategies. This assumption is based on differences in anatomical characteristics between muscles, i.e. the number of spinal segments crossed is larger for the iliocostalis than for the longissimus muscle and larger for the thoracic compared to the lumbar part of the longissimus muscle [16]. Model calculations indicate that preferential recruitment of muscles with multiple intersegmental insertions, over their synergist that cross more spinal segments, leads to a higher stiffness of the lumbar area [14,17,18]. Based on indications of impaired proprioception in LBP-patients, we further hypothesized that LBP-patients show larger deterioration of balance when vision is occluded and that disturbance of proprioception, through lumbar muscle vibration, degrades balance performance more in HC-subjects.

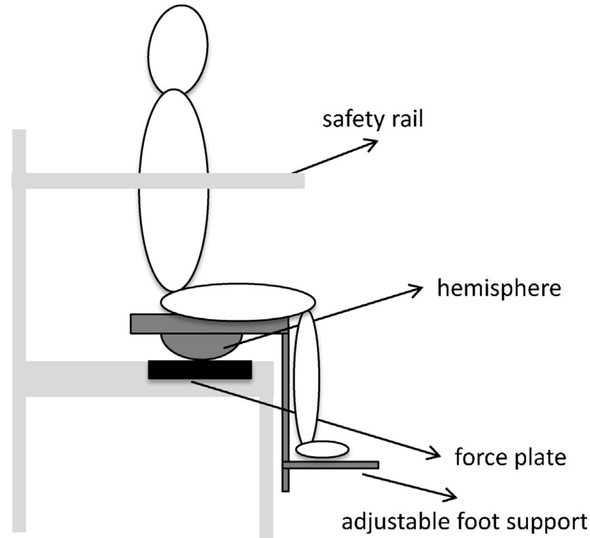

Fig. 1. Schematic representation of the experimental setup.

2. Methods

2.1. Participants

Twenty LBP-patients (9 female) and 11 HC-subjects (4 female) participated in the experiment. Subjects in the LBP-group had experienced LBP during the last 6 weeks or longer, and any specific diagnosis had been excluded by a general practitioner or physical therapist. Subjects were excluded when they had had previous surgery on the spine or scored >105 on a questionnaire identifying psychosocial risk factors [19,20]. Subjects participating in the HC-group did not experience LBP during the previous year. No differences between groups were found in age (HC: 32.6 ± 10.4, LBP: 33.4 ± 15.5 years, $p = 0.893$) and BMI (HC: 22.5 ± 2.5, LBP: 23.6 ± 3.0 kg/m^2, $p = 0.312$). LBP-patients scored 2.7 ± 1.7 on a 10 cm visual analog pain scale at the start of the measurements. The experimental protocol was approved by the local medical ethical committee and all subjects provided informed consent.

2.2. Experimental setup

An aluminum hemisphere (radius: 25 cm) was attached underneath a seat, creating instability in all directions (height of the seat relative to the lowest point of the hemisphere: 17 cm). An adjustable footplate was attached to the seat, in order to limit the influence of the lower extremities to balance control by keeping knee and angle angles fixed at 90° (Fig. 1). Three force transducers (KAP-E, AST, Germany) recorded vertical forces with 200 samples/s. A safety rail surrounded the seat, to provide security in case of balance loss. A pulse-signal was generated when subjects touched the rail.

Trunk kinematics were measured by opto-electronic markers (Optotrak 3020, Northern Digital Inc., Canada) on the spinous processes of the T1, T7, L4 and L5 vertebrae at a rate of 100 samples/s. Trunk muscle surface EMG was used to record activation of four back muscles bilaterally (Porti 17, TMS-Enschede, The Netherlands, 22-bits AD-conversion after 20× amplification, input impedance > 10^{12} Ω, CMRR > 90 dB). The skin was shaved and cleaned with alcohol. Based on a detailed anatomical study [16], we placed bipolar electrodes (Ag/AgCl) 4 cm lateral to T9, 6 cm lateral to T11 and L2, and 3 cm lateral to the midpoint between the spinous processes of L3 and L4, reflecting activation of the thoracic longissimus and iliocostalis muscles, and the lumbar iliocostalis and longissimus muscles, respectively. EMG-signals were recorded at a rate of 1000 samples/s and a pulse-signal synchronized the EMG-recordings to the opto-electronic and force-plate data.

To apply lumbar muscle vibration, we used a motor (Maxon Graphite Brushes S2326.946 driven by a 4-Q-DC Servo Control LSC30/2 in a velocity loop) rotating an eccentric mass. Vibration frequency was 90 Hz, and the vibration device was attached at the level of L3/4 by neoprene bands (Fig. 2).

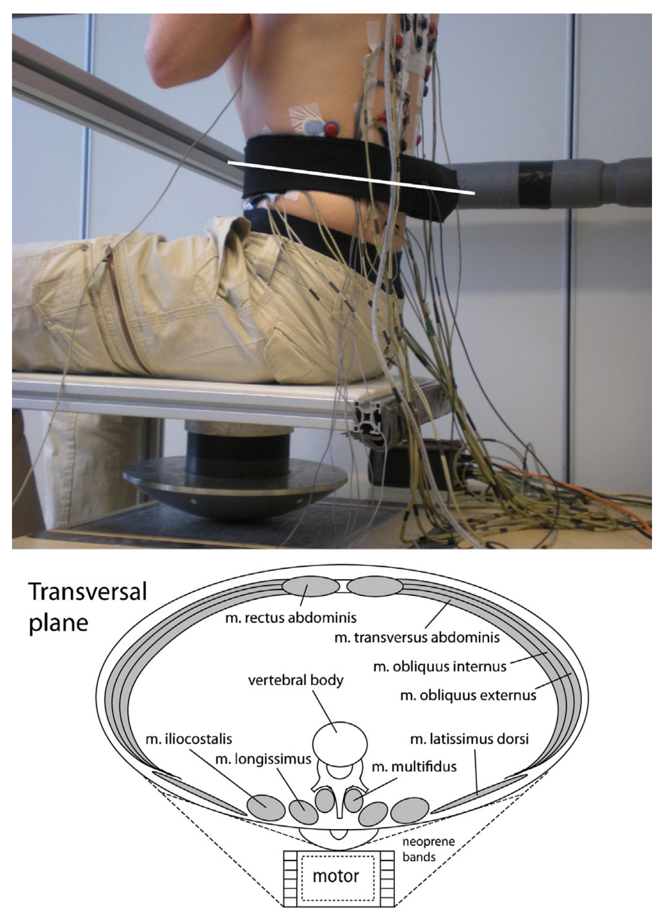

Fig. 2. Lumbar muscle vibration was applied at the level of L3/L4. A custom-made holder (shown in lower panel) ensured bilateral vibration of the paraspinal muscles, while leaving the spinous processes free.