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Multi-segment analysis of spinal kinematics during sit-to-stand in patients with chronic low back pain

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ABSTRACT

While alterations in spinal kinematics have been frequently reported in patients with chronic low back pain (CLBP), a better characterization of the kinematics during functional activities is needed to improve our understanding and therapeutic solutions for this condition. Recent studies on healthy subjects showed the value of analyzing the spine during sit-to-stand transition (STST) using multi-segment models, suggesting that additional knowledge could be gained by conducting similar assessments in CLBP patients. The objectives of this study were to characterize three dimensional kinematics at the lower lumbar (LLS), upper lumbar (ULS), lower thoracic (LTS) and upper thoracic (UTS) joints during STST, and to test the hypothesis that CLBP patients perform this movement with smaller angle and angular velocity compared to asymptomatic controls. Ten CLBP patients (with minimal to moderate disability) and 11 asymptomatic controls with comparable demographics (52% male, 37.4 $\pm$ 5.6 years old, 22.5 $\pm$ 2.8 kg/m^2) were tested using a three-dimensional camera-based system following previously proposed protocols. Characteristic patterns of movement were identified at the LLS, ULS and UTS joints in the sagittal plane only. Significant differences in the form of smaller sagittal-plane angle and smaller angular velocity in the patient group compared to the control group were observed at these three joints. This indicated a more rigid spine in the patient group and suggested that CLBP rehabilitation could potentially be enhanced by targeting movement deficits in functional activities. The results further recommended the analysis of STST kinematics using a pelvis-lumbar-thoracic model including lower and upper lumbar and thoracic segments.

1. Introduction

Chronic low back pain (CLBP) is one of the most frequent causes for limitations in daily, leisure and work related activities. Although CLBP is associated with significant decreases in quality of life and induces severe economic burden in most western countries, responses to treatments are still fairly limited (Hoy et al., 2010; Mansell et al., 2014). Better understanding kinematic alterations is critical to improve therapeutic solutions, as altered spinal kinematics is considered a possible major cause of persistence of symptoms and disability in CLBP (Dubois et al., 2014; O'Sullivan, 2005).

Several studies reported reduced range of motion and angular velocity at the lumbar spine in CLBP patients compared to asymptomatic individuals (Laird et al., 2014; Lehman, 2004). However, these studies used biomechanical models considering the lumbar spine as a single segment, whereas recent research with healthy subjects showed that the upper and lower regions of the lumbar spine move differently (Leardini et al., 2011; Mitchell et al., 2008). Specifically, rotation between the upper and lower lumbar segments were reported in the sagittal-plane during sit-to-stand transitions (Parkinson et al., 2013). Furthermore, in the study by Parkinson et al. (2013), significant differences between male and female lumbar kinematics were noticed with a multi-segment lumbar spine model, but not with a single-segment model. These observations suggest that single-segment models could hide

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important kinematic information and additional CLBP knowledge could be gained with multi-segment lumbar models. Prior research also suggests that kinematic analyses of CLBP patients should include the thoracic region. While pain in CLBP patients is mainly present in the lumbar region, alterations in thoracic kinematics were shown in this population (Crosbie et al., 2013). Therefore, there is a need to characterize the spinal kinematics of CLBP patients using a pelvis-lumbar-thoracic multi-segment model and to compare CLBP and asymptomatic subjects.

The sit-to-stand transition (STST) is a particularly relevant movement to improve our understanding of spinal kinematics in CLBP because it is a frequent daily activity (on average 60 times per day) requiring around 60% of total sagittal-plane lumbar mobility (Dall and Kerr, 2010; Hsieh and Pringle, 1994). Small, but possibly clinically relevant, rotations were also reported in the frontal and transverse planes during this movement (Baer and Ashburn, 1995; Gilleard et al., 2008; Leardini, 2011). Studying STST is further motivated by the fact that this movement is frequently described as painful by CLBP patients and is often addressed in rehabilitation (Andersson et al., 2010). Additionally, Shum and Colleagues (2005) compared this movement between patients with subacute low back pain and pain-free controls, and reported significant differences in sagittal-plane range of motion and angular velocity. Nevertheless, these results were obtained with a single-segment lumbar model. Because recent research on healthy subjects recommended differentiating the lower and upper lumbar spine regions and testing thoracic kinematics (Crosbie et al., 2013; Leardini et al., 2011; Parkinson et al., 2013), there is a strong interest to analyze CLBP patients STST using a multi-segment model.

This study aimed at comparing spinal kinematics (angle and angular velocity) between CLBP patients and asymptomatic controls during STST using a pelvis-lumbar-thoracic model with lower and upper lumbar segments. The first objectives of this work were to characterize the patterns of movement at the lower lumbar, upper lumbar, lower thoracic and upper thoracic joints to identify characteristic features that can be used to compare patient and control movements. This study then tested the hypothesis that CLBP patients perform STST with smaller angle and angular velocity than asymptomatic controls.

2. Methods

2.1. Participants

This study prospectively enrolled patients with non-specific CLBP for more than three months (Balagué et al., 2011) and with an age and body mass index (BMI) comprised between 30 and 50 years old and 18 and 27 kg/m^2, respectively. Exclusion criteria for this group were the presence of infection, rheumatological or neurological diseases, spinal fractures, any known spinal deformities, back surgery, tumors or radicular symptoms.

Healthy subjects without history of low back pain requiring medical attention during the last two years were enrolled as asymptomatic controls. Controls were selected to match the age, sex and BMI of the patient group, as these factors were shown to influence lumbar kinematics (Marras et al., 1994; Parkinson et al., 2013). General exclusion criteria for both groups were pregnancy and pain or injury in any other body parts that could compromise the evaluation of lumbar kinematics. The research was approved by the local Research Ethics Committee (protocol VD-340/14) and all participants signed an informed consent form before enrollment in the study.

2.2. Experimental procedures

Spinal kinematics was measured using a camera-based motion capture system recording marker positions at 120 Hz (VICON, Oxford Metrics, UK). Nineteen reflective markers were attached to the pelvis, lumbar spine and thoracic spine, following previously described protocols (Ebert et al., 2014; Seay et al., 2008; Wade et al., 2012). Five central markers were placed on the spinous processes of T1, T6, L1, L3 and L5 (Fig. 1). In addition, 8 lateral markers were placed between central markers on each side of the spine, at a distance of 5 cm. The 6 remaining markers were placed on the pelvis, at the posterior superior iliac spines, anterior superior iliac spines and tip of each iliac crest. The same experienced physiotherapist identified the anatomical landmarks for every participant following the same procedure.

Data collection started with the capture of a reference standing posture. Then, participants were asked to sit on a stool and STST were recorded. Participants were asked to place their feet shoulder width apart, to start the STST in their normal upright sitting posture with their arms relaxed, to stand up at their self-selected normal speed and to finish the STST in their normal upright standing posture (Parkinson et al., 2013). The height of the stool was adjusted individually in order to have participant thighs horizontal while sitting. Three STST were recorded after participants had practiced the movement. After the recording, patients were asked to evaluate the pain associated with the STST they just did using a numeric pain rating scale (NPRS) (Dworkin et al., 2005; Mannion et al., 2007). In addition to the kinematic test described above, pain during the last 24 h, disability and kinesiophobia were assessed for the CLBP patients using the Oswestry Disability Index (ODI), the NPRS and the Tampa Scale of Kinesiophobia (TSK) (Chapman et al., 2011; Fairbank and Pynsent, 2000; Vlaeyen et al.,1995).

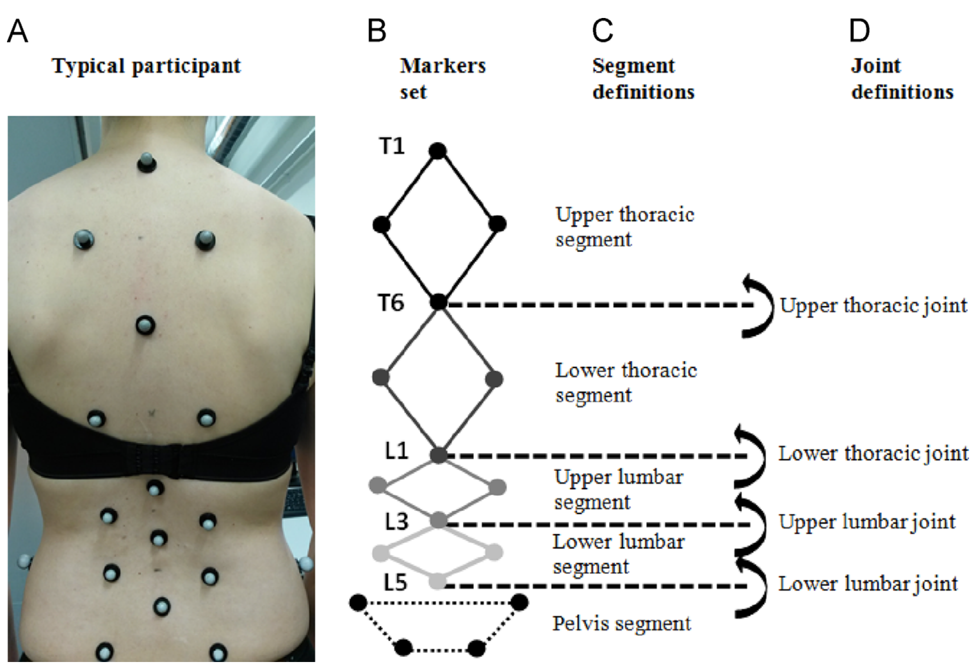

Fig. 1. Model description. (A) Picture of a typical participant with the markers, (B) markers set, (C) segment definitions, (D) joint definitions.

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