Clinical Neurophysiology 125 (2014) 1663–1668

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Deterministic accessory spinal movement in functional tasks characterizes individuals with low back pain

J.L. Dideriksen [a], L. Gizzi [b], F. Petzke [b], D. Falla [a,b,*]

[a] Department of Neurorehabilitation Engineering, Bernstein Center for Computational Neuroscience, University Medical Center Göttingen, Georg-August University, Göttingen, Germany
[b] Pain Clinic, Center for Anesthesiology, Emergency and Intensive Care Medicine, University Hospital Göttingen, Göttingen, Germany

ARTICLE INFO

Article history:
Accepted 27 November 2013
Available online 18 December 2013

Keywords:
Low back pain
Movement analysis
Recurrence quantification analysis

HIGHLIGHTS

- Spinal angles were recorded during a functional lifting task in subjects suffering from low back pain (LBP) and in healthy controls.
- Recurrence quantification analysis revealed that the structure of the variability of spinal angular movement was more deterministic (less random) for the LBP group.
- This method offers a new approach to detect movement impairment in LBP.

ABSTRACT

Objectives: To apply a novel method to assess the characteristics of spinal movement in subjects with low back pain (LBP) in a functional task.
Methods: 17 subjects suffering from chronic non-specific LBP (average pain intensity: 1.8 ± 1.6), and 17 age and gender matched controls performed a repetitive lifting task. Spinal movement was recorded using a novel sensor strip with 12 angle sensors recording the spinal dynamics in evenly spaced (25 mm) locations along the spine. Recurrence quantification analysis was applied to different components of the angles to assess the structure of its variability.
Results: Mechanically, the LBP and control group performed the task similarly. Reported pain increased in the LBP group, yet task-related angular movement was not different. However, the percentage of determinism for the accessory angular movement (movement variability not directly related to task execution) was significantly higher for the LBP group, indicating a more deterministic (less random) structure of the muscle activation pattern variability.
Conclusion: The structure of the variability of spinal movement differs in subjects with chronic non-specific LBP.
Significance: The determinism of accessory spinal movement may be a useful measure for evaluation of movement impairment in LBP and for monitoring rehabilitation effects.

1. Introduction

Low back pain (LBP) is a common disorder affecting the majority of people during their lifetime (Dunn and Croft, 2004; Kent and Keating, 2005; Hoy et al., 2010). The chance of recurrence is high, and in many cases the pain is never fully resolved (Kent and Keating, 2005; Hoy et al., 2010). Thus LBP implies functional impairment for a large proportion of the population and imposes large demands on health and social systems (Dunn and Croft, 2004).

People with chronic LBP display a variety of biomechanical disturbances. Such disturbances include altered hip-trunk coordination (Lamoth et al., 2002; Shum et al., 2007), decreased spinal range of motion (Shum et al., 2007; Silfies et al., 2009), and longer time to regain stability following perturbations (Mok et al., 2011). These biomechanical differences may in part be attributed to abnormal muscle recruitment patterns (Roy et al., 1997; Hodges and Richardson, 1999; Humphrey et al., 2005) and decreased ability to modulate proprioceptive feedback gain according to task requirements (Claeys et al., 2011). The influence of LBP on the

* Corresponding author. Address: Department of Neurorehabilitation Engineering, Bernstein Center for Computational Neuroscience, University Medical Center Göttingen, Georg-August University, Von-Siebold-Str. 6, 37075 Göttingen, Germany. Tel.: + 49 (0) 551 3920109; fax: +49 (0) 551 3920110.
E-mail address: deborah.falla@bccn.uni-goettingen.de (D. Falla).

1388-2457/$36.00
http://dx.doi.org/10.1016/j.clinph.2013.11.037

magnitude of movement variability, however, is less clear. For example, trunk movement in gait has been reported to increase (Vogt et al., 2001) and to decrease (Lamoth et al., 2008; Van Den Hoorn et al., 2011). Furthermore, postural sway has been reported to be higher (Leinonen et al., 2003), unchanged (Van Dieën et al., 2010), and to either de- or increase depending on the stability of the support (Claeys et al., 2011). Finally, the onset of trunk muscle activity in repetitive arm movements is less variable for persons with LBP (Jacobs et al., 2009), whereas the trunk muscle EMG activity displays higher variability during gait (Lamoth et al., 2006). In particular during slow movements, little difference has been found between persons with and without LBP (Hodges and Richardson, 1999; Lamoth et al., 2006).

Instead, recent studies have suggested that the mechanical differences related to LBP may reside in the intrinsic structure of the variability, rather than in its magnitude (Lamoth et al., 2006; Silfies et al., 2009). For example, using principal component analysis, Lamoth and colleagues (2006) showed that lumbar spine movement was less coordinated in persons with LBP than in healthy controls.

In this study, we investigated the variability of spinal movements during a repetitive functional task using novel angle sensor strips that allowed measurement of angular trajectories in 12 evenly spaced locations along the spine (Consmüller et al., 2012). With this method, the spinal dynamics could be analyzed in greater detail than has previously been possible. For each of the spinal angles, the variability was analyzed with respect to the dynamics related to the execution of the task as well as to the accessory dynamics reflecting the random variability occurring during the movements. Recurrence Quantification Analysis (RQA), a methodology allowing quantification of recurrent patterns in non-stationary data (Eckmann et al., 1987), was employed for the analysis of the structure of the variability. RQA has previously been applied within biomechanical analyses (Riley et al., 1999; Labini et al., 2012). We hypothesized that the differences between the LBP group and the controls would be found not in the magnitude of variability by which the task was executed, but instead in the structure of this variability.

2. Methods

2.1. Subjects

Seventeen subjects with chronic non-specific LBP aged between 18 and 45 years were recruited for the study through referral from a Pain Clinic, general practitioners or through general advertising in the popular press. Subjects were considered for the study if they were suffering from non-specific episodic LBP lasting longer than three months with periods of symptom aggravation and remission in the last six months. Each episode of LBP should have lasted at least one week with sufficient intensity to limit function.

Seventeen age and gender matched healthy subjects were recruited to act as the control group. These pain-free subjects were included if they had no relevant history of back or lower limb pain or injury that limited their function and/or required treatment from a health professional. Patients and control subjects had to have the capacity to give their consent at their own will.

Participants were excluded from both groups if they had any major circulatory, neurological, or respiratory disorders, recent or current pregnancies, previous spinal surgery, current treatment for LBP from health care providers, or participation in specific trunk muscle exercise in the past 3 months. Subjects were also excluded from both groups if they were taking any medication such as opioids, anticonvulsants, or antidepressants. Patients taking non-steroidal anti-inflammatory drugs (NSAIDs) on a regular basis were also excluded and patients were asked not to take any NSAID or simple analgesics on the day of the experiment. Initial screening was conducted over the telephone and eligible persons attended a baseline evaluation appointment.

Ethical approval for the study was granted by the local Ethics Committee and the procedures were conducted according to the Declaration of Helsinki. The study was performed at the Department of Neurorehabilitation Engineering, Göttingen, Germany where all data was collected. The raw data was extracted and provided by Epionics Medical GmbH (Potsdam, Germany). All further analysis and writing of the manuscript were performed by the authors.

2.2. Questionnaires

A questionnaire was administered to obtain information on subject demographics, history, duration of pain, average intensity of pain and localization of pain in the LBP group. Patients completed the German version (Nigbur et al., 2009) of the Tampa Scale for Kinesiophobia (17 items; (Vlaeyen et al., 1995)), a measure to assess fear-avoidance behavior and fear-avoidance beliefs and the German version (Meyer et al., 2008) of the Pain Catastrophizing Scale (PCS), a measure of catastrophic thinking related to pain. The PCS is a 13-item questionnaire in which respondents rate the frequency with which they experience different thoughts and feelings when in pain (Osman et al., 1997). The German Oswestry Disability Index (ODI) (Mannion et al., 2006)was used to assess pain-related disability specifically related to LBP (10 items; (Fairbank and Pynsent, 2000)). Finally, the LBP group completed the German version of the Short Form of the Spielberger State-Trait Anxiety Inventory (SF-STAI) (Laux et al., 1981). It is a six-item questionnaire that has been shown to be a reliable and sensitive measure of anxiety (Spielberger et al., 1970). All subjects completed the German version (Bullinger, 1995) of the SF-36 Health Survey (Brazier et al., 1992), a measure of general health status.

Finally, the activity-related pain was monitored during the repetitive task. For this, subjects of both groups were asked to verbally rate their level of perceived pain intensity on an 11 point numerical rating scale (NRS) anchored with “no pain” (0) and “the worst possible pain imaginable” (10) at rest and every 40 s during the lifting task. Pain intensity was also noted 3 min after completion of the task.

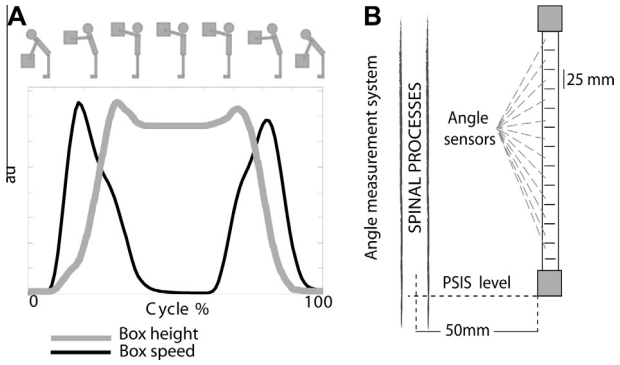

Fig. 1. The functional task consisted of lifting a box containing a 5 kg weight between two shelves represented by box height and speed during the 8 s duration (A). The Epionics SPINE sensor system consists of two sensor strips each with 12 evenly spaced angle sensors (25 mm apart from one another). Due to the purely sagittal nature of the task the right one was considered representative. The bottom of the strip was located at the posterior superior iliac spine (PSIS).