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Standardized activities of daily living in presence of sub-acute low-back pain: A pilot study

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ABSTRACT

The aim of this pilot study was to investigate how sub-acute low-back pain (LBP) patients differed with respect to control in movements and muscle activation during standardized tasks representing daily living activities, and explore relationships between cognition and measured motor performance. Linear and nonlinear parameters were computed from kinetics, kinematics and muscle activity recorded for 12 sub-acute patients and 12 healthy matched controls during trunk flexion, sit-to-stand from a chair and lifting a box. Cognitive variables were collected to explore relationships with biomechanical parameters. For trunk flexion, left external abdominal oblique muscle activity level was lower for patients compared with controls ($p < 0.05$), whereas sample entropy (complexity) was higher ($p < 0.05$). Normalized mutual information was lower for patients compared with controls for left and right erector spinae ($p < 0.05$). Level of activity of left external abdominal oblique correlated negatively with cognitive ignoring and positively with catastrophizing ($p \leqslant 0.05$), and catastrophizing also correlated positively with functional connectivity of abdominal muscles ($p < 0.05$). Signs of reorganization in muscle activation pointed towards different synergistic actions in trunk muscles in sub-acute LBP patients compared with controls. The interplay with maladaptive cognition suggested that in the subacute stage of LBP, both biomechanical and cognitive factors should be taken into account.

1. Introduction

Low-back pain (LBP) is a widespread burden upon society, with a monthly prevalence up to 40% in the working population (Nachemson, 2004). LBP interferes with daily life activities at acute, sub-acute (Verbunt et al., 2005) and chronic LBP stages (Spenkelink et al., 2002). Stability of tasks involving postural control has shown to be decreased in LBP patients in both static (Brumagne et al., 2008) and active tasks (Claeys et al., 2011). During daily living activities, Shum et al. (2005, 2007a) found reduced trunk and hip motion for LBP patients in a sit–stand and stand–sit test, and also in a task with bending down and picking up an object (Shum et al., 2007b). In trunk flexion, LBP patients are also reported to have an altered movement pattern compared with controls (Esola et al., 1996). It is hypothesized that dysfunctional trunk muscle recruitment is related to this limitation of physical function (Hodges and Richardson, 1996). Dysfunctional trunk muscle recruitment is reflected in an increased use of antagonist muscles to stabilize the lumbar spine (van Dieen et al., 2003) and in the changes in the recruitment synergies of trunk muscles (Hodges, 2001; Mehta et al., 2010).

Supplementary tools for the classic assessment of motor control are useful to understand the motor control in activities of daily living tasks. Interestingly, the sole use of linear measure to describe the motor performance does not delineate the dynamic changes in motor variability, and it is suggested that linear variability measures in motor control studies are insufficient for these situations (Madeleine et al., 2011a; van Emmerik and van Wegen, 2002, which calls for e.g. nonlinear tools to reveal complex structures inherent in the biomechanical variability (Harbourne and Stergiou, 2009). Nonlinear approaches, describing the complexity of task performance, have been introduced in movement analysis, and as an addition to linear measures they can be used to reveal motor control strategies (Latash et al., 2002; Morrison et al., 2007). In painful or pathophysiological condition, a decrease in complexity is observed during static contractions following the loss of complexity hypothesis (Lipsitz and Goldberger, 1992; Madeleine et al., 2011a; van Emmerik and van Wegen, 2002) whereas an

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increase in complexity has been proposed during dynamic exercise (Vaillancourt and Newell, 2002). For patients with chronic low-back pain, a few recent studies have reported lower complexity of muscle activity in comparison with controls (Sung et al., 2005, 2007). However, our knowledge about patients in acute and transitional stages is very sparse, and activities of daily living are merely studied in these pain stages. Thus, combining linear and nonlinear tools should enable a better understanding of the relationship between sub-acute pain and motor control by focusing on both the size and the structure of variability.

In addition, biomechanical studies often omit the influence of cognitive aspects in the development of e.g. chronic LBP whereas the sole assessment of physical measures like muscle activity and trunk movement variability underexposes the influence of cognitive factors (Descarreaux et al., 2007; Grotle et al., 2004). Fear-avoidance beliefs and coping strategies, assessable using questionnaires (Hasenbring, 2000; Vlaeyen et al., 1995), actually provide genuine information of the cognitive status of patients with sub-acute LBP that may give important clues about the chronification of LBP. Furthermore, information that encompasses biomechanical and cognitive aspects is also vital for the development of treatment regimens for LBP patients.

The aims of this study were to investigate how patients with sub-acute LBP differed with respect to controls in movements and muscle activation during standardized tasks representing daily living activities, as well as to explore the relationship between cognitive aspects and the measures of motor performance. The motor tasks were trunk flexion, sit-to-stand from a chair and lifting a box.

2. Methods and materials

2.1. Subjects

In this study, 12 LBP patients and 12 matched healthy controls participated. The LBP patients were recruited from the rheumatologic department at Aalborg Hospital, Denmark. The inclusion criteria for the patients were: age between 18 and 55, non-specific LBP for a period of 0–6 months, free of any known psychiatric disturbances, and non-pregnant. Besides the inclusion criteria, LBP patients had to be able to conduct normal daily life routines. Rheumatologists examined the LBP patients to ensure that they met the inclusion criteria. Controls were matched to the participating LBP patients by age, sex and body mass index. Anthropometric data for the LBP and control group are reported in Table 1. The study was approved by the local ethics committee (N-20100006) and conducted in conformity with the Declaration of Helsinki. Written informed consent was obtained from the participants of the study.

2.2. Experimental procedures

After recruitment, LBP patients were asked to complete the fear avoidance belief questionnaire (FABQ) and the coping strategy questionnaire (CSQ). Questionnaire items were answered by a 7-point Likert scale ranging from 0 to 6. Pain was rated at arrival to the laboratory on a numeric scale ranging from 0 to 10 where 0 was anchored "no pain" and 10 "worst imaginable pain".

Table 1
Anthropometric data from the LBP and matched control groups (mean (SD)).

	Subjects with LBP (n = 12)	Healthy matched controlled subjects (n = 12)
Age (years)	38.6 (9.8)	37.5 (9.7)
Height (cm)	177.8 (11.5)	178.3 (9.9)
Body mass (kg)	79.8 (15.5)	75.2 (10.7)
Body mass index (kg/m^2)	25.1 (3.2)	23.6 (2.1)
Gender	9 males, 3 females	9 males, 3 females

Mean (SD).

The experiment consisted of a static reference contraction where subjects were instructed to maintain a static erected posture for 30 s. Afterwards, three different dynamic tasks representing activities of daily living (ADL) were carried out: (i) a repeated stand-to-sit task, (ii) a repeated trunk flexion task, and (iii) a continuous box lifting task. All tasks were performed with the subjects standing on a force plate (AMTI, Watertown, MA, USA). After each task was initiated, subjects performed the given task for 30 s. During the task surface electromyography (SEMG) was recorded from four muscles at the trunk and lumbar area with bipolar surface electrodes (Neuroline 720, Ambu, Denmark). The selected muscles for SEMG recording were left and right external abdominal oblique (EAO), and left and right erector spinae (ES). At EAO, electrodes were located approx. 15 cm lateral to the umbilicus, and at ES approx. 3 cm lateral from the midline at L3 level on the largest muscle mass found by palpation. Electrodes were aligned on the selected muscles on abraded ethanol-cleaned skin along the muscle fibers. Three-dimensional kinematic of the tasks was recorded by an 8-camera motion capture system (Oqus system, Qualisys AB, Sweden). In total 35 reflective markers were placed on anatomical landmarks on feet, legs, hips and back to record body motions.

2.2.1. Stand-to-sit task

Subjects were instructed to sit on a chair from standing position and then return to the original standing position. This task was performed for 30 s (3–6 stand–sit cycles).

2.2.2. Trunk flexion task

Subjects were instructed to flex the trunk as much as possible, without bending the knees and then return to their upright position. The task was continued for 30 s (4–8 trunk flexions).

2.2.3. Box-lifting task

Subjects were instructed to lift a box from a shelf (40 cm above the floor) to their upright position while maintaining elbows flexed at 90° angle, and then to replace the box on the shelf. The subjects were instructed not to flex the trunk, but to bend down at the knees. The box weighed 5 kg. After the box had been placed on the shelf and the subjects were back to their upright position, they were instructed to continue the task for a 30 s period (3–6 box lift cycles).

The order of the three ADL tasks was randomized between patients and executed with approximately 5 min breaks in between.

2.3. Data analyses

From the questionnaires different subscales of fear-avoidance and coping strategy were selected. FABQ questionnaire items were used for two subscales (fear avoidance during physical activity and work). CSQ questionnaire items were used for six subscales (diverting attention, reinterpreting pain sensations, coping self-statements, ignoring pain sensations, increasing activities, praying and hoping, and catastrophizing). From the 7-point Likert scale in the questionnaire, the maximum score for the subscale of fear avoidance beliefs during physical activity would be 24 (four items), and during work 42 (seven items). In the CSQ subscales maximum values would be 36 (six items in each subscale). For internal reliability test, Cronbach's α was calculated within each subscale (Cronbach, 1951). Only subscales with $\alpha > 0.7$ were considered reliable and were reported to describe the LBP patient group's fear-avoidance beliefs and coping strategies.

Ground reaction forces and moments from the force plate and SEMG signals were sampled at 2000 Hz, while 3D kinematics were