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Postural strategy and trunk muscle activation during prolonged standing in chronic low back pain patients

Inge Ringheim [a,b,*], Helene Austein [a,b], Aage Indahl [b], Karin Roeleveld [a]

[a] Department of Neuroscience, Norwegian University of Science and Technology, Trondheim, Norway
[b] Clinic Physical Medicine and Rehabilitation, Vestfold Hospital Trust, Stavern Norway

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ABSTRACT

Prolonged standing has been associated with development and aggravation of low back pain (LBP). However, the underlying mechanisms are not well known. The aim of the present study was to investigate postural control and muscle activation during and as a result of prolonged standing in chronic LBP (cLBP) patients compared to healthy controls (HCs). Body weight shifts and trunk and hip muscle activity was measured during 15 min standing. Prior and after the standing trial, strength, postural sway, reposition error (RE), flexion relaxation ratio (FRR), and pain were assessed and after the prolonged standing, ratings of perceived exertion. During prolonged standing, the cLBP patients performed significantly more body weight shifts ($p < .01$) with more activated back and abdominal muscles ($p = .01$) and similar temporal variability in muscle activation compared to HCs, while the cLBP patients reported more pain and perceived exertion at the end of prolonged standing. Moreover, both groups had a similar change in strength, postural sway, RE and FRR from before to after prolonged standing, where changes in HC were towards pre-standing values of cLBP patients. Thus, despite a more variable postural strategy, the cLBP patients did not have higher muscle activation variability, but a general increased muscle activation level. This may indicate a reduced ability to individually deactivate trunk muscles. Plausibly, due to the increased variable postural strategy, the cLBP patients could compensate for the relatively high muscle activation level, resulting in normal variation in muscle activation and normal reduction in strength, RE and FRR after prolonged standing.

1. Introduction

During periods of prolonged standing we change postural position more or less frequent, usually by shifting body weight from one leg to the other. The individuals perception of muscle fatigue, musculoskeletal discomfort and pain in the postural control system are believed to initiate these changes [1]. In fact, variation in muscle activation causing and resulting from these postural changes may be directly related to a delay in muscle fatigue, discomfort and decrease in pressure over joint tissues.

Patients with chronic low back pain (cLBP) often experience increased symptoms due to sustained low-load activities such as prolonged sitting and standing [2], and the perception of discomfort associated with prolonged standing is commonly assessed in LBP disability questionnaires [3].

A complex network, of almost 70 muscles of varying size, makes up the lumbar-spine musculature. Each one is capable of several possible tasks and exerts various forces and actions on the spinal motion segments [4]. Collectively they provide a pool of possible motor actions during load distribution, load transfer and control of spinal movement. Reasonably strong evidence exists for altered neuromuscular function and stiffened movement patterns in cLBP patients during walking, trunk flexion and unstable sitting [5–7]. Such stiffened postural control can then be seen as the cause of these muscular pain problems, or at least a factor that might explain the continuation of them.

During short periods of quiet standing (typical 60 s duration), both in cLBP patients and healthy persons, postural control has frequently been investigated through the assessment of postural sway, measured by changes in the location of the center of pressure (COP) on the supporting surface by means of a force platform.

* Corresponding author at: Clinic Physical Medicine and Rehabilitation, Vestfold Hospital Trust, Stavern, Norway.
E-mail address: inge.ringheim@siv.no (I. Ringheim).

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However, few studies have addressed postural- and motor control strategies in cLBP patients during prolonged standing, despite its known relation to LBP. The nature of sway in prolonged standing is not the same as in quiet standing, where sway is interpreted as 'noise' in the postural control system (i.e. deficiency in balance). Large sway during prolonged standing is rather due to postural changes in terms of voluntary movements performed periodically as effective responses of the postural control system to complete the task with minimal effort [8]. To the authors' knowledge only one study included cLBP patients [2], and they solely investigated postural control. Findings from this study by Lafond et al. suggest that cLBP patients have a stiffer posture with fewer postural changes during prolonged standing compared to healthy controls (HCs), in contrast to increased displacement during quiet standing [2]. Moreover, they seem to be more affected by prolonged standing, suggesting an altered postural control system [2].

The aim of the present study was to investigate muscle activation level and variability in addition to postural control during 15 min of prolonged standing in cLBP patients compared to HCs and differences between the cLBP patients and HCs in the effect of prolonged standing on neuromuscular control, proprioception, postural sway, strength, pain and perceived effort. In line with the findings of Lafond et al. [2], we hypothesized that cLBP patients would have a postural strategy with reduced movement accompanied by increased and less variable muscle activation compared to HCs. Further we hypothesized that cLBP patients would be more affected by prolonged standing.

2. Methods

2.1. Subjects

Seventeen patients (7 male, 10 female) with cLBP and 21 HCs (8 male, 13 female) with no LBP in the previous year or LBP lasting longer than one week in the previous 3 years in the age range 31–50 were included in the study (Table 1). The cLBP patients were recruited from the outpatient clinic at Vestfold Hospital Trust. All eligible patients, diagnosed with cLBP for more than 3 months, were invited to participate. Exclusion criteria were anamnesis of medical or drug abuse, surgery on the musculoskeletal system of the trunk, known congenital malformation of the spine or scoliosis, systemic-neurological-degenerative disease, history of stroke, psychiatric disorder, pregnancy and abnormal blood pressure. Patients were asked not to use any medications except for Paracetamol or Ibuprofen preparations one week before examination and not to perform any back-straining exercises 48 h prior to examination.

All subjects signed an informed consent before enrolment, approved by the Regional Committee for Medical and Health Research Ethics (2012/1158/REK).

2.2. Participant characteristics

The height, weight, body mass index (BMI) and waist-hip ratio were obtained. A questionnaire was employed to collect the participants' age, duration of pain, average pain intensity last week and localization of pain. The Oswestry Disability Index was used to assess pain-related disability specifically related to LBP [3]. The Tampa Scale of Kinesiophobia was employed to assess fear of movement and/or (re)injury [9].

2.3. Equipment

Surface electromyography (sEMG) signals were detected with pairs of disposable sEMG electrodes (Ambu Blue Sensor M-00-S/50, 20 mm IED) bilaterally from the erector spinae (ES), gluteus medius (GM), rectus abdominis (RA) and external oblique (EO) muscles. A reference electrode was placed on S1 level. The skin at the electrode sites was shaved and abraded with alcohol, subsequently the bipolar sEMG electrodes were placed aligned with the muscle fibre direction and in accordance with European guidelines for sEMG (SENIAM) [10]. Before data collection, the signal quality was checked by visual inspection of the EMG signal during muscle contractions against light manual resistance.

A force sensor (Interface, Inc. Scottsdale, Arizona), attached horizontally to a non-elastic polyester band around the subjects torso at T6-T8 level and the wall, was used to measure the force during maximal voluntary contraction (MVC) of trunk flexion and extension, while the subject was standing in a modified "Cybex 6000 back extension module".

Ground reaction forces were recorded for each foot separately using two force plates during all tasks except for MVC (AMTI, USA; model BP400600-1000).

All data were sampled with 1500 Hz. The sEMG and force sensor data were collected with TeleMyo 2400 (Noraxon Inc., USA). Prior to digitalization, all channels were filtered with an 8th-order Butterworth low-pass filter (500 Hz), and sEMG leads were filtered with a 1st-order high-pass filter at 10 Hz. sEMG channel hardware gain was 500. Analogue output from the Noraxon system was synchronised with force plate data and stored in Qualisys Track Manager (Qualisys Medical AB, Sweden, version 2.7) and exported to Matlab R2011a (The Mathworks Inc., USA) for post processing and analyses.

2.4. Procedure

Three standing tests were performed in the following order; 60 s quiet standing, 15 min prolonged standing and 60 s quiet standing. Participants wore socks during all standing tests. During quiet standing, the participants were blindfolded and stood as still as possible with one foot on each force plate with their feet approximately at pelvis width, looking straight ahead and keeping

Table 1
Characteristics of the cLBP and healthy controls (HC). BMI: body mass index.

Characteristic	HC $n=20$		cLBP $n=17$		t (p)
	Mean (SD)	Range	Mean (SD)	Range	
Age (years)	40.2 (5.4)	31–50	39.0 (5.4)	31–48	.65 (.52)
Height (cm)	174.6 (8.9)	162–191	177.5 (6.5)	163–188	−1.1 (.26)
Weight (kg)	77.5 (16.7)	56–120	81.7 (15.7)	57–113	−.78 (.44)
BMI (kg/m^2)	25.2 (3.7)	20–33	25.9 (4.7)	18–38	−.48 (.64)
Waist–hip ratio	0.9 (0.1)	0.7–1.0	0.9 (0.1)	0.8–1.1	−1.6 (.11)
Duration of pain (months)			139 (119)	6–360	
Average pain last week (0–10)			5 (1.7)	3–8	
Tampa (13–54)			23.8 (8.6)	13–41	
Oswestry (%)			21.1 (7.8)	10–42	