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Low back pain and postural control, effects of task difficulty on centre of pressure and spinal kinematics

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ABSTRACT

Association of low back pain and standing postural control (PC) deficits are reported inconsistently. Demands on PC adaptation strategies are increased by restraining the input of visual or somatosensory senses. The objectives of the current study are, to investigate whether PC adaptations of the spine, hip and the centre of pressure (COP) differ between patients reporting non-specific low back pain (NSLBP) and asymptomatic controls. The PC adaption strategies of the thoracic and lumbar spine, the hip and the COP were measured in fifty-seven NSLBP patients and 22 asymptomatic controls. We tested three "feet together" conditions with increasing demands on PC strategies, using inertial measurement units (IMUs) on the spine and a Wii balance board for centre of pressure (COP) parameters. The differences between NSLBP patients and controls were most apparent when the participants were blindfolded, but remaining on a firm surface. While NSLBP patients had larger thoracic and lumbar spine mean absolute deviations of position (MADpos) in the frontal plane, the same parameters decreased in control subjects (relative change (RC): 0.23, 95% confidence interval: 0.03 to 0.45 and 0.03 to 0.48). The Mean absolute deviation of velocity (MADvel) of the thoracic spine in the frontal plane showed a similar and significant effect (RC: 0.12 95% CI: 0.01 to 0.25). Gender, age and pain during the measurements affected some parameters significantly. PC adaptions differ between NSLBP patients and asymptomatic controls. The differences are most apparent for the thoracic and lumbar parameters of MADpos, in the frontal plane and while the visual condition was removed.

1. Introduction

Postural control (PC) of the trunk when standing is regarded essential to keep or regain one's body position for stability and orientation, within challenging environments [1]. Postural control strategies are described as a feedback mechanism derived by the interaction of sensory input and adapted motor output [1]. Postural control strategies on firm ground with open eyes predominantly use peripheral or ankle strategies for the sagittal plane [2,3]. In contrast the frontal plane control-mechanisms are described as proximal or hip loading/unloading strategies [3]. In a recent review changes in postural control sway excursions in patients with non-specific low back pain (NSLBP) compared to asymptomatic controls were inconsistently reported in previous studies [4]. Some studies showed impaired postural control in the presence of LBP with increased body sway, sway velocity and loss of balance [5,6] others did not find any differences in body sway or sway velocity [7,8]. Possible reasons for these contradictory reports are the differences in tasks and conditions used in those studies [7,9,10]. Most studies evaluate centre of pressure (COP) movements using force plate technology [5,8,11]. However, range and velocity of segmental adaptations in thoracic, lumbar and hip segments cannot be described by COP variables, as only kinematic models can adequately account for segmental and directional strategies [6,9,10,12–15]. One recent study used additional kinematic measurements to evaluate hip and trunk control strategies in the sagittal plane while standing [5,8]. Two electrogoniometers were placed over the first thoracic vertebra and the second sacral vertebra. They assessed sagittal plane kinematics and the mean position of the trunk. They found, that patients with

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LBP have larger forward trunk inclination during demanding PC tasks. Further kinematic measurements of body segments might even better discern differences in PC strategies of LBP patients and asymptomatic controls.

To date, no research evaluated movements of the thoracic and lumbar spine and the hip in the frontal and sagittal plane parallel with COP measurements during standing PC tasks.

Therefore the aim of this study was to examine the sway of the thoracic and lumbar spine, the hip and COP during three standing tasks conditions with increasing PC requirements in patients with NSLBP and asymptomatic controls. The research questions were (a) does the presence of LBP affects sway and sway velocity and are PC strategies different in asymptomatic controls and those with NSLBP, (b) how does changing the task difficulty in terms of visual and surface condition influences sway and sway velocity of the thoracic and lumbar spine, the hip and COP.

2. Method

2.1. Subjects

Participants between 18 and 65 years were recruited at physiotherapy-practices, the university campus and by newspaper advertisements. Included were patients with NSLBP for longer than 4 weeks with at least moderate disability, defined as an Oswestry-disability-index (ODI) >8% and a low level of having biopsychosocial risk factors defined with less than 4 points in the STarT Back Screening tool [16,17]. Excluded were subjects with specific LBP, vertigo or disturbance of the equilibrium, systemic diseases (diabetes, tumours), pain in other areas of the body (neck, head, thoracic spine, or arms), complaints, injury, or surgery of the legs (hips to feet) within the last six months, medication affecting postural control (e.g. anti-depressants) and pregnancy. The exclusion criteria for healthy controls were the same as for the LBP-group, and additional no current, and no LBP during the preceding 3 months. The study was approved by the local ethical committee. All participants signed informed consent prior to the study.

2.2. Measurement systems

Movements of the spine and hip were measured using four inertial measurement units (IMUs), ValedoSensors, Hocoma, Volketswil, Switzerland) at a sampling frequency of 200 Hz. The system's validity has been shown before [18]. Sensors were placed on the right thigh (RTH), the sacrum (S2), the lower back (L1) and the upper back (T1). The RTH sensor was placed on the line connecting the lateral epicondyle of the femur and the trochanter major. Sensors on the back were placed following the method described by Ernst and colleagues [19]. The COP was measured with a Wii-balance board (WBB, Nintendo Incorporation, Kyoto, Japan) sampling with 200 Hz. The WBB is valid for COP measurements [20].

2.3. Procedure

Descriptive data and covariates were recorded before assessing the postural control tasks. All participants had to fill in a questionnaire about their physical activity, their physical and mental stress at work and their education level [21]. LBP patients additionally filled in the Oswestry disability index (ODI) [16].

Subjects were asked to stand stable, arms crossed in front of the chest, in three different conditions in a fixed order of increasing requirements on PC adaptation:

1. feet together on firm surface, eyes open = Open-Firm
2. feet together on firm surface, blindfolded = Blind-Firm
3. feet together on foam, blindfolded = Blind-Foam

Standing tasks lasted for 1 min and were repeated three times, for each condition. Pain intensity was recorded after each condition using a numeric rating scale (NRS) from 0 (no pain) to 10 (maximal pain).

2.4. Data processing and analysis

The IMU sensors consist of an accelerometer, a gyroscope and a magnetometer. Data acquisition was undertaken with the Valedo Research Software (Hocoma, Volketswil, Switzerland). Further calculation and analysis were done using MATLAB (The MathWorks, Inc, Natick, MA, US, Version R2012a). The scaled data from the sensors were converted into quaternions according to Madgwick et al. [22]. Data were then filtered using a fourth-order zero-phase low-pass Butterworth filter with a cut-off frequency of 1 Hz. The filtered data were transformed into rotation matrices and then into Tilt-Twist angles, according to Crawford et al. [23]. The hip angle was defined as the differential signal between RTH and S2 (hip), the lower back angle as the differential signal between S2 and L1 (lumbar spine) and the thorax angle as the differential signal between L1 and T1 (thoracic spine).

The following quantities were calculated: the mean absolute deviation (MAD) of the sway position, MADpos, and the mean absolute deviation of sway velocity, MADvel, the MAD was computed by

$$\mathrm{MAD} = \frac{1}{T}\sum_{i=1}^{T}|x_i - \bar{x}|,$$

with x_i representing the ith sampled signal, $\bar{x}$ the mean signal and T the number of samples.

It was decided to take the MAD instead of a root mean square (RMS), as big evasion movement have less influence on the variable. The variables were calculated for the angular movement of each segment and for the COP excursion in the sagittal and frontal plane. The mean value of the three repetitions was taken for the statistical analysis.

2.5. Statistical analysis

For each MAD, a linear mixed model was fitted to the data with condition (Open-Firm, Blind-Firm, and Blind-Foam), group (LBP or control) and the interaction (condition × group) as fixed effects. Reference levels were "Female" for gender, "Open-Firm" for condition and "Control" for group. "Subject" was included as a random intercept. It was adjusted for gender, BMI, age, pain during the tests, physical and mental stress at work. A stepwise model selection procedure with optimisation of the AIC-criterion was used to eliminate covariates. Random intercept models are equivalent to repeated measures ANOVA and take into account the correlation between repeated measurements. Residual analysis was performed to check the model assumptions. Based on residual analysis, the logs of the outcomes were modelled. The model for observation Y_{ijk} (outcome for condition i, group j, subject k nested in group j) was (without other between-group variables)

$$\log Y_{ijk} = \mu + \alpha_i + \beta_i + (\alpha\beta)_{ij} + U_{kj} + \in_{ijk}, \quad i = 1,2,3; j = 1,2; k = 1,\ldots,n_j,$$