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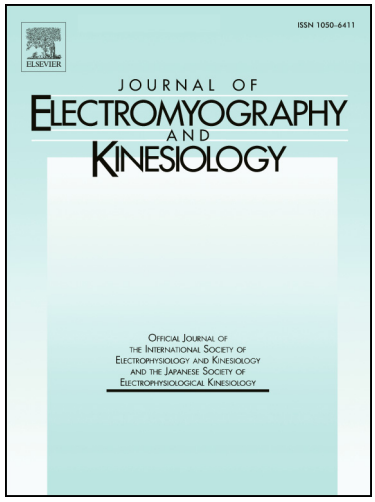


Pain intensity attenuates movement control of the lumbar spine in low back pain

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# Pain intensity attenuates movement control of the lumbar spine in low back pain

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## Abstract

### Introduction

Pain intensity attenuates muscular activity, proprioception, and tactile acuity, with consequent changes of joint kinematics. People suffering from low back pain (LBP) frequently show movement control impairments of the lumbar spine in sagittal plane. This cross-sectional, observational study investigated if the intensity of LBP attenuates lumbar movement control. The hypothesis was that lumbar movement control becomes more limited with increased pain intensity.

### Methods

The effect of LBP intensity, measured with a numeric rating scale (NRS), on lumbar movement control was tested using three movement control tests. The lumbar range of motion (ROM), the ratio of lumbar and hip ROM as indicators of direction specific movement control, and the recurrence and determinism of repetitive lumbar movement patterns were assessed in ninety-four persons suffering from LBP of different intensity and measured with an inertial measurement unit system. Generalized linear models were fitted for each outcome.

### Results

Lumbar ROM (+0.03°, p=0.24) and ratio of lumbar and hip ROM (0.01, p=0.84) were unaffected by LBP intensity. Each one point increase on the NRS resulted in a decrease of recurrence and determinism of lumbar movement patterns (-3.11 to -0.06, p≤0.05).

### Discussion

Our results indicate changes in movement control in people suffering from LBP. Whether decreased recurrence and determinism of lumbar movement patterns are intensifiers of LBP intensity or a consequence thereof should be addressed in a future prospective study.

Keywords: Low back pain; Movement Disorders; Biomechanical Phenomena; Recurrence Quantification Analysis

# 1. Introduction

Low back pain (LBP) is a common disorder with a lifetime prevalence as high as 84%, and a high probability of recurrence (Airaksinen et al.,2006). In many cases the cause of pain is never fully resolved (Hoy et al.,2010). LBP causes functional impairment in everyday life for a large proportion of the population and thus imposes large demands on healthcare and social systems (Dunn and Croft,2004). Contemporary LBP classification systems propose that there is a large group of patients who present with movement control impairments (MCI), which are a relevant and provocative factor for ongoing pain (O'Sullivan,2005). Typically 50% of patients with a MCI demonstrate changes in the sagittal plane (Vibe Fersum et al.,2009). These impairments may be the consequence of decreased tactile acuity (Luomajoki and Moseley,2011), decreased ability to modulate task specific proprioceptive feedback (Claeys et al.,2011) or altered muscle recruitment patterns (Humphrey et al.,2005).

Tests of direction specific movement control (DSMC) assess the ability of a person to stabilize the lumbar spine during active movement of the hip and or knee. They are based on visual observation and use a dichotomous rating, have substantial reliability, and have been shown to differentiate between asymptomatic persons and patients with LBP (Luomajoki et al.,2007, Luomajoki et al.,2008). However, objective, quantitative data on the severity of MCI assessed by DSMC tests in people suffering from LBP are currently lacking. Repetitive movements (RM) can demonstrate changes in lumbar spine kinematics which are not observed when analysing purely the range of motion or magnitude of MCI (Lamoth et al.,2006, Silfies et al.,2009). Less variable movement patterns of lumbar spine were observed in persons with chronic LBP when they repetitively picked up a box (Dideriksen et al.,2014) or performed repeated trunk movements (Asgari et.al.,2015). Persons with chronic LBP also demonstrated less variable recruitment patterns of lumbar erector muscles during lifting tasks (Falla et al., 2014).

The effect of LBP on lumbar movement may be more pronounced in higher order kinematics (Aluko et al.,2013, Bourigua et al.,2014, Marras et al.,1993, Marras et al.,1995). Participants with chronic LBP showed smaller lumbar angular velocity and acceleration during a repeated trunk flexion-extension task, compared to pain free participants. These group differences were less pronounced when analysing purely their angular displacement (Marras et al.,1995). Increased lumbar angular

velocity and acceleration during lifting tasks had a greater odds ratio for future low back pain episodes when compared to changes in angular displacement (Marras et al.,1993). Chronic LBP patients showed lower angular velocity during trunk flexion at self-selected and fast movement speeds (Bourigua et al,.2014). Lumbar acceleration increased after a six weeks exercise intervention that reduced LBP intensity (Aluko et al,.2013).

Previous cross-sectional studies often do not report the relationship between LBP intensity and MCI, and do not consider that pain differently attenuates motor planning and diminishes proprioception, and that tactile acuity depends up on its intensity (Catley et al.,2014, Matre et al.,2002, Ervilha et al.,2004). The purpose of this study is to investigate the effect of LBP intensity on MCI using two DSMC tests, and one RM test. The emphasis is on reduced control of active movement (Luomajoki et al.,2008, O'Sullivan,2005) and on repetitive task movement control (Dideriksen et al.,2014). It is hypothesised that lumbar movement control deteriorates with increased LBP intensity. Anthropometric factors such as age, gender, or body mass index (BMI) influence lumbar kinematics (Consmuller et al.,2012). Persons engaging in heavy manual labour have a higher risk of developing LBP (Hoozemans et al.,2002). These factors should be controlled for when investigating the relationship between lumbar kinematics and LBP.

# 2. Methods

## 2.1 Design

Cross-sectional, observational study

## 2.2 Participants

Sixty-three participants with sub-acute or chronic LBP and 31 asymptomatic participants, aged between 18-65 years were recruited from physiotherapy practice, the university campus and through newspaper advertisements. Participants with LBP were included if their current episode of LBP persisted for four weeks or longer, and if they reported at least moderate disability, defined as an Oswestry-disability-index (ODI) >8% and a low level of psychosocial risk factors defined with less than four points on the subscale of the STarT Back screening tool (Mannion et al.,2006). Exclusion criteria were 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 asymptomatic participants were the same as for the LBP participants, and additionally no current LBP episodes or episodes during the preceding three months. The study was conducted according to the declaration of Helsinki, and approved by

the local ethics committee (KEK-ZH-2011-0522). Participants provided their written informed consent.

## 2.3 Movement Analysis

### 2.3.1 Sensor placement and data processing

Trunk movements were measured by an inertial measurement unit (IMU) system, with multiple IMUs placed above the right thigh, sacrum and at the level of L1, (Ernst et al.,2013, Schelldorfer et al.,2015) (Figure 1). The IMU system has been shown to provide concurrently valid estimates of spinal kinematics (Bauer et al.,2015).

The sensors of the IMU system (ValedoMotion, Hocoma AG, Volketswil, Switzerland) include a tri-axial gyroscope, magnetometer, and accelerometer. Movement data were recorded with a sampling frequency of 200 Hz (Valedo®Research, Hocoma AG). The raw data from the IMUs were transformed into quaternions to prevent rotational singularities (Madgwick et al.,2010) . Segmental kinematics were calculated using the tilt/twist formulation (Crawford et al.,1999) with sagittal and frontal planes defined by the global coordinate system. All outcome variables were derived from the flexion/extension angle, where flexion is positive and extension is negative. An angle of zero degrees is defined as alignment of two IMUs. A second-order zero-phase low-pass Butterworth filter (1Hz cut-off frequency) was applied on the angular displacement data since angular velocity and acceleration required smoothing to obtain interpretable estimates. Angular velocity and acceleration were calculated using the first and second derivative of the filtered angular displacement data. A complete description of the data processing from raw data to tilt/twist angles is described elsewhere (Bauer et al.,2015).

### 2.3.2 Movement Tests

Participants attended one measurement session and performed two DSMC tests: “Sitting Knee Extension”, and “Waiters Bow”; and one RM test: “Pick Up a Box”(Figure 2) (Bauer et al.,2015). Prior to each test the participants received standardized oral instructions by one of the examiners and visual instructions in a video. In case of poor initial performance these instructions were repeated up to three times and the test was demonstrated by one examiner. If the participant was still performing the test incorrectly it was omitted.

During “Sitting Knee Extension” the participants sat upright and were asked to stabilize their lumbar spine whilst extending their right knee. They were instructed to stop extending their knee before they perceived movement of their lumbar spine, without giving a target range for knee extension or target duration for the test. In “Waiters Bow” they were instructed to stand upright and then flex their hips as far as possible whilst keeping their lumbar spine stable. They were instructed to stop

flexing their hips before they perceived movement of their lumbar spine, without giving a target range for hip flexion or target duration for the test. The participants were allowed to perform the DSMC tests at their own preferred speed.

The "Pick Up a Box" test consisted of ten cycles, of four seconds duration, starting in upright standing. During each cycle the participants were asked to pick up the box from the ground and put it back down again. They were guided with a metronome set at 60bpm. The box was loaded to ten percent of their body weight and placed at a standardized distance in front of the participants.

The order of the tests was randomized between participants. The DSMC tests were repeated three times and the participants were allowed to choose their rest time between repetitions, whereas the RM test was performed one time.

### 2.3.3 Outcomes

For "Sitting Knee Extension" the range of motion at the lumbar spine $ROM\ LS$ was calculated between the sacrum and L1 sensors. For "Waiters Bow" the ratio between the range of motion of the lumbar spine and the hip was calculated and is later denoted with $\frac{LS}{Hip}ROM$. For both outcomes, the mean of the three repetitions was used for further analysis. For the "Pick Up a Box" test recurrence quantification analysis was performed on the angular displacement, velocity, and acceleration data. This method has been described previously and is only briefly summarized here (Webber and Zbilut,1994). In recurrence quantification analysis, movement data are projected into a phase space by taking time-delayed samples from the movement data. The time-delayed samples represent movement patterns which can be visualized as points in the phase-space plot. Similar movement patterns are located close to each other, and form a cluster of recurrent points ($R_{i,j}$). In this study, the phase-space reconstruction was undertaken separately for angular displacement, velocity, and acceleration data by using the set of parameters specified in Table 1. All $R_{i,j}$:s were subsequently transferred into a *N*x*N*-sized recurrence plot (RP) with N being the number of measurement points. Two measures were then calculated: the recurrence rate (*REC*) and the determinism (*DET*). *REC* is a measure of the density of the recurrent points in the RP. It measures the probability of recurrence of movement patterns and is expressed as:

$$REC = \frac{1}{N^2}\sum_{i,j=1}^{N} R_{i,j} * 10^2$$

*DET* is the amount of $R_{i,j}$ that form diagonal lines (i.e. are sequential to each other in time) of a prespecified minimal length (*lmin*) given in Table 1. The DET is a measure of the stochasticity of the movement data and expressed as:

$$DET = \frac{\sum_{l=lmin}^{lmax} l * P(l)}{\sum_{l=1}^{lmax} l * P(l)} * 10^2$$

with *l* being the length of the diagonal lines, *lmax* the maximal possible length of the diagonal lines, and *P(l)* being the number of diagonal lines of length *l*. All data processing and calculations were done using Matlab 2012b® (Mathworks, USA), with code from University of Potsdam, Germany (Marwan and Kurths,2002). *REC* and *DET* were calculated for angular displacement (REC AD and DET AD), velocity (REC AV and DET AV), and acceleration (REC AA and DET AA). In a previous study the reliability of all outcomes, using the current test setup, was found to be high (Bauer et al.,2015).

## 2.4 Covariates

For each of the participants, LBP intensity, age, gender, BMI, and the amount of physical stress at work (PS) were recorded. All participants rated their LBP intensity, defined as the mean level of LBP pain during the past four weeks, using a 11 point numerical rating scale (NRS) anchored with "no pain" (0) through to "the worst possible pain imaginable" (10). Following this the participants were allocated into eight groups, according to their perceived LBP intensity (0-7). PS was measured with a five point Likert scale; ranging from "almost no physical stress" (1) to "maximal physical stress" (5) (Galati-Petrecca,2008).

## 2.5 Statistical Analysis

For each outcome a linear model was fitted to the data with LBP intensity as the covariate of interest. In a first model, we adjusted for gender, age, BMI, PS and all the two-way interactions between these covariates with LBP intensity. A stepwise model selection procedure with backwards optimisation by the Akaike-Information-criterion was used to determine the final model. The aim of this procedure was to choose a parsimonious model in order to prevent overfitting of the data. This procedure ensured that the model is optimized for prediction, that is, for future data.

Therefore the model for each observation of the outcome $Y_i$ was

$$Y_i = \beta_0 + \beta_1 NRS_i + \beta_2 Gender_i + \beta_3 Age_i + \beta_4 BMI_i + \beta_5 PS_i + \beta_6 NRSxGender_i + \beta_7 NSRxAge_i + \beta_8 NRSxBMI_i + \beta_9 NRSxPS_i + \varepsilon_i$$

with $\beta_0$ representing the intercept, $\beta_k$ the effect of the k-covariate and $\varepsilon_i$ the independent and normal distributed errors $\varepsilon_i \sim N(0, \sigma^2)$.

Residual analysis was performed to check the models assumptions. Therefore the log-transformed ratio $\frac{LS}{Hip} ROM$ was modelled since the residuals did not have a normal distribution. Point and interval estimations were performed for each covariate. The alpha-level was set at 0.05. Statistical analysis was done using R (R Foundation for statistical computing, Austria).

## 3. Results

Sixty three persons with LBP and thirty one pain-free persons were included. The distribution of LBP intensity and the descriptive data of the covariates and outcomes are shown in Table 2. Figure 3 depicts the DSMC and RM angular displacement, velocity, and acceleration trajectories of one representative participant with high movement control and one participant with low movement control. The parameter estimates for the final model for each outcome are shown in Table 3. Depending upon the presence of interaction terms, the observed effect of a one point increase of LBP intensity ($\widehat{\omega}$) can be a function of age, BMI and gender, but not of PS (Table 3).

### Sitting Knee Extension:

$\widehat{\omega}$ for $ROM\ LS$ was

$$\widehat{\omega}_{ROM\ LS} = 0.3° - 0.5° * \mathbf{1}_{Gender=Female}$$

with **1** being the indicator function, indicating a 0.3° increase in males, but a -0.2° decrease in females. This means that LBP intensity had no significant effect on $ROM\ LS$.

### Waiters Bow:

$\widehat{\omega}$ for $\frac{LS}{Hip} ROM$ was

$$\widehat{\omega}_{\frac{LS}{Hip}ROM} = 0.0 + 0.1 * \mathbf{1}_{Gender=Female}$$

This indicates a 0.1 increase for females on the log scale and no changes for males. This means that LBP intensity had no significant effect on $\frac{LS}{Hip} ROM$.

### Pick Up a Box:

$\widehat{\omega}$ for *REC AD* and *DET AD* were

$$\widehat{\omega}_{REC\ AD} = 0.11$$
$$\widehat{\omega}_{DET\ AD} = -0.06$$

Due to the absence of interactions, these effects were independent of age, BMI and gender. This means that $DET\ AD$ significantly decreased with increasing LBP intensity (p=0.01).

$\widehat{\omega}$ for *REC AV and DET AV* were

$$\widehat{\omega}_{REC\ AV} = -0.25$$
$$\widehat{\omega}_{DET\ AV} = -3.11 + 0.11 * BMI$$

$\widehat{\omega}_{REC\ AV}$ was independent of age, gender or BMI. $\widehat{\omega}_{DET\ AV}$ was dependent on BMI. For example, the effect of a one point increase in LBP intensity for a person with a BMI of 19.0 is -1.02 while for a

person with a BMI of 23 is -0.58. The main effect of LBP were statistically significant (p=0.03 and p=0.05) while the interaction of LBP with BMI was not.

$\widehat{\omega}$ for *REC AA* was

$$\widehat{\omega}_{REC\ AA} = -2.03 + 1.14 * \mathbf{1}_{Gender=Female} + 0.03 * Age$$

and thus a function of age and gender. For example, the effect of a one point increase in LBP intensity for a 20 year old female is -0.29; while for a 50 year old female it is 0.61. The main effect of LBP and the interaction of LBP with gender were statistically significant (p=0.03 and p=0.02), while the interaction of LBP with age was not. This means that *REC AA* either increased or decreased with increasing LBP intensity, depending on the age of the participant.

$\widehat{\omega}$ for *DET AA* was

$$\widehat{\omega}_{DET\ AA} = -0.86$$

This means that $DET\ AD$ significantly decreased with increasing LBP intensity (p=0.05).

In summary the results show a statistically significant effect of LBP intensity on *REC* and *DET*. REC AV and *DET* decrease with increasing LBP intensity whilst *REC AA* either increases or decreases, depending on the age of the participant.

## Discussion

This study examined if the intensity of LBP affects movement control of the lumbar spine during two DSMC tests and one RM test. LBP intensity had no effect on DSMC, which is unexpected since previous research demonstrated reduced DSMC in patients with LBP (Luomajoki et al.,2008) . This can be explained by methodological differences regarding the group allocation, study population, and measurement systems. In our study, participants were allocated into eight groups according to their LBP intensity, while Luomajoki and colleagues (2008) summarized chronic LBP patients with varying degrees of pain intensity into one group, which hampers comparability between the results. Dichotomization of the participants might have increased the contrast between the two groups. However, using a quantitative approach leads to a more detailed insight into the relation between MCI and LBP.

Observed group differences might be further increased by the selection of the study subjects. Luomajoki and colleagues (2008) recruited LBP patients that were referred from physicians and treated by physiotherapists. Conversely, not all participants with LBP recruited for the present study perceived their condition serious enough to seek treatment, indicating a lower burden of disease, with less impairment due to LBP. Luomajoki and colleagues (2008) used a dichotomous rating of

movement control by observation of lumbar spine flexion, while in the present study an IMU system was used and movement control was measured continuously.

These findings raise the possibility that i) a relation between severity of DSMC impairment and LBP intensity exists, ii) DSMC is a clinically relevant feature, but iii) DSMC impairment becomes clinically relevant only after it exceeds a certain magnitude or cut-off point. It is possible that only a smaller subgroup of patients with LBP show a DSMC impairment that manifests in “Waiters Bow” and “Sitting Knee Extension”. The link between performance in DSMC tests and LBP intensity is based upon investigations of tactile acuity tests (Cately et al.,2014, Luomajoki and Mosely 2011). However our results do not validate this link.

Recurrence and determinism of lumbar movement patterns were significantly affected by LBP intensity. More variable lumbar movement patterns, indicated by reduced recurrence and determinism, were found with increasing levels of LBP and this effect was more pronounced in angular velocity and acceleration data. Silfies et al. (Silfies et al.,2009) found that the variability of lumbar movement during a repetitive reaching task was increased in LBP patients, when compared to those without pain indicating impaired movement control (Silfies et al.,2009). Lamoth and colleagues (2006) revealed that lumbar angular velocity patterns during gait were more variable in LBP patients, compared to no pain, and found these changes to be related to poor coordination of lumbar erector spinae muscles (Lamoth et al.,2006). These findings are in line with the results of the present study, although both studies used a different methodology, regarding task and calculation of variability of lumbar movement.

Falla and colleagues (2014) examined lumbar muscular activation patterns during a RM test and found less variability in LBP. To maintain constant movement patterns during repetitive activities an adaptive muscular activation is necessary, leading to a greater variability of muscular activity and less variability of movement patterns. Thus, stereotyped movement may be accompanied by variable electromyography patterns, while this may be reversed in painful conditions such as LBP (Falla et al.,2014).

Contrary to our findings one study reported less variability using a similar RM test (Dideriksen et al.,2014). Differences in the data processing may explain this contradiction, as Dideriksen and colleagues used a notch filter to smooth out the frequencies related to the RM, without affecting other frequency components. In this way only the deviation from the target movement was investigated (Dideriksen et al.,2014), while the present study investigated the target movement.

Participants in the present study were asked to perform the repetitive movement with a predetermined, fast speed, possibly overriding any protective feedforward strategy of movement

control. This contrasts findings from two studies (Arzi et al.,2014, Uri et al.,2015) who showed that patients after shoulder surgery had less variable kinematics of the shoulder joint when moving at self-selected slow and fast speed. To test this hypothesis the repetitive "Pick up a box" task should be performed at self-selected preferred, slow, and fast speed.

In summary the results indicate that there is an effect of perceived intensity of LBP on lumbar movement control. This effect manifests in the variability of lumbar movement patterns, but not in DSMC. RM tests, in contrast to DSMC tests, might better reflect lumbar movement control in activities of daily living, which in turn might be of greater relevance in the development, persistence and intensity of LBP (O'Sullivan,2005).

The final models show that covariates such as gender and BMI, significantly affect movement control. Their effect was not consistent across all measures of movement control, and sometimes exceeded that of LBP intensity. Consequently it is recommended to consider these covariates in future research on movement control. Other covariates, such as the frequency and duration of the current LBP episode, physical stress during leisure time, might also be related to MCI. Furthermore anthropometric factors, such as a participants arm length, might impact performance during a repeated lifting test and should be controlled for in future research. The models and subsequent interpretations were based on the assumption of a linear relationship between perceived LBP intensity and MCI, which was confirmed by partial-residual plots. Backwards selection of covariates enabled us to test the effect of two-way interactions before testing main effects, and to exclude redundant covariates from the final models. Perceived LBP intensity was measured using a NRS and may not have ratio qualities (Price et al.,1994). Therefore a one point increase in mild pain intensity may not have the same meaning as in high pain intensity. In addition, two participants with similar pain might not rate their pain equally.

The number of participants was unevenly distributed across the levels of perceived LBP intensity, with a small number that rated their perceived LBP higher than five. However, the distribution of an outcome does not affect the models validity, provided that the residuals follow a normal distribution, verified by residual analysis. Exclusion criteria were asserted using patient history interviews and questionnaires. To improve validity of patient selection, ascertainment should be accompanied by anamnestic interviews, physical examination, imaging techniques or other instruments.

This study investigated sagittal plane MCI as this was found to be an important subgroup of MCI (Vibe Fersum et al.,2009). Future studies should expand on this research and address control of combined movements since LBP and injury might occur while combining rotational torques and sagittal or lateral rotations. The IMU system provides valid and reliable estimates of lumbar movement control in the sagittal plane (Bauer et al.,2015), while validity and reliability of combined

movements have not been addressed until now. Choosing an appropriate filtering technique is a compromise between loss of information and noise allowed through. While significant associations between LBP intensity and MCI were found following our procedure, we might have missed small fragmentations of movement related to LBP (Dideriksen et al,2014). Future studies should address options that might conserve such information.

## Conclusion

The effect of perceived LBP intensity on lumbar movement control was analysed and controlled for the effect of age, gender, BMI and PS. A linear effect of LBP intensity on variability of lumbar movement patterns was found, but not on DSMC. The variability of lumbar movement patterns increased with greater LBP intensity, measured with a repetitive Pick up the box test and recurrence quantification analysis.

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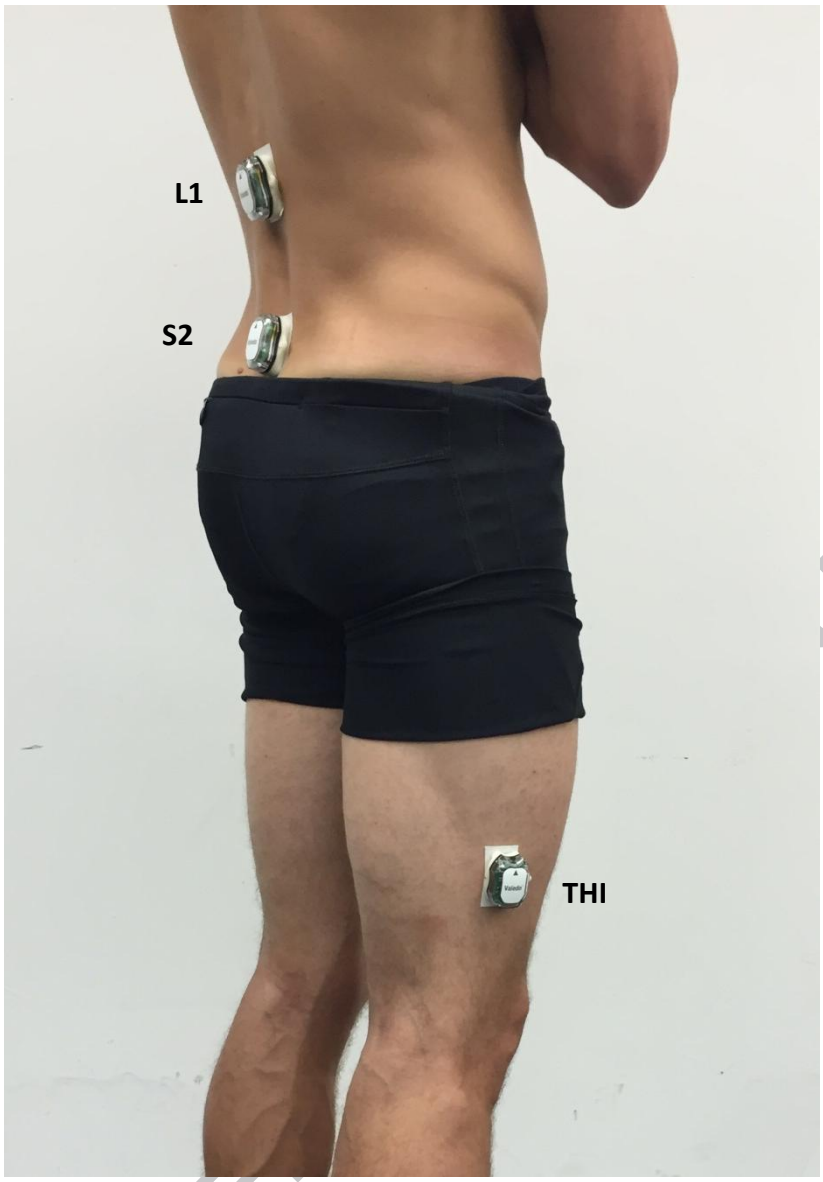



**Fig 1.**
Experimental setup: IMUs were placed on the right thigh (THI), and level of sacrum (S2), and L1 (L1).

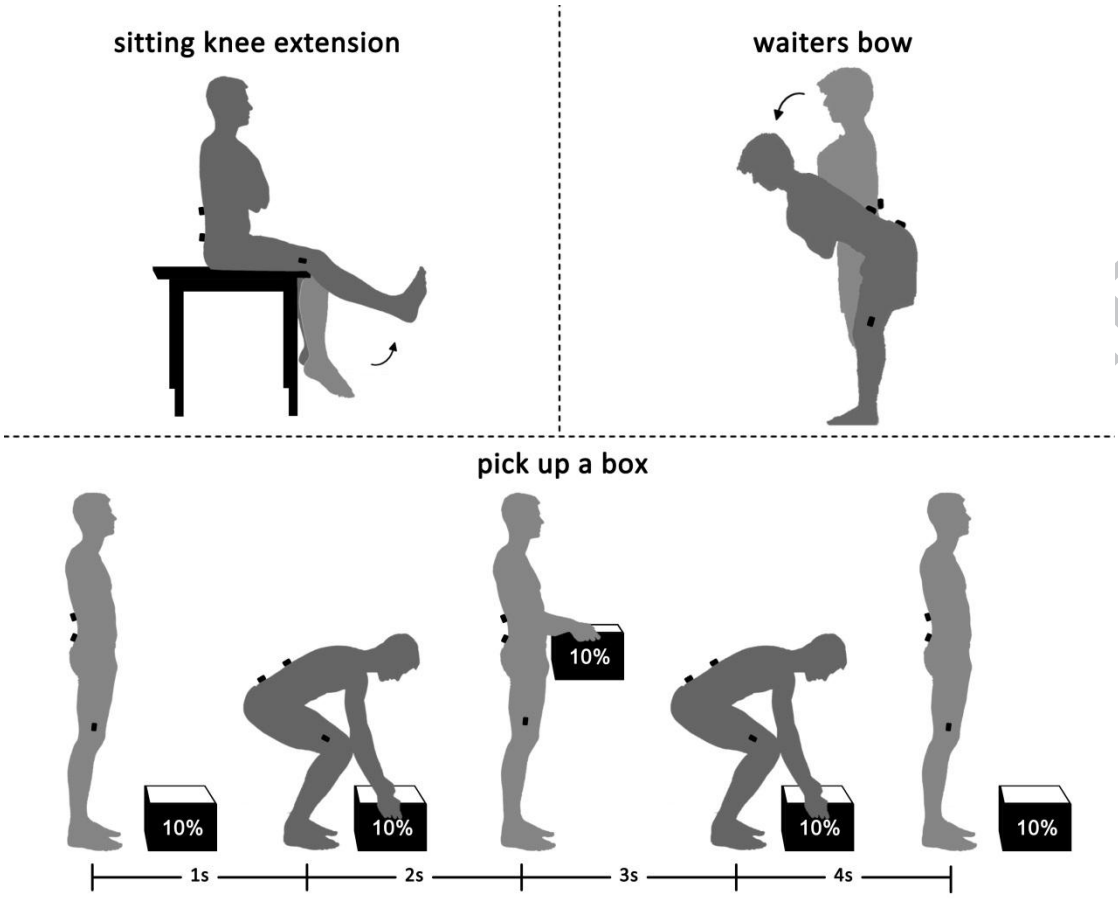
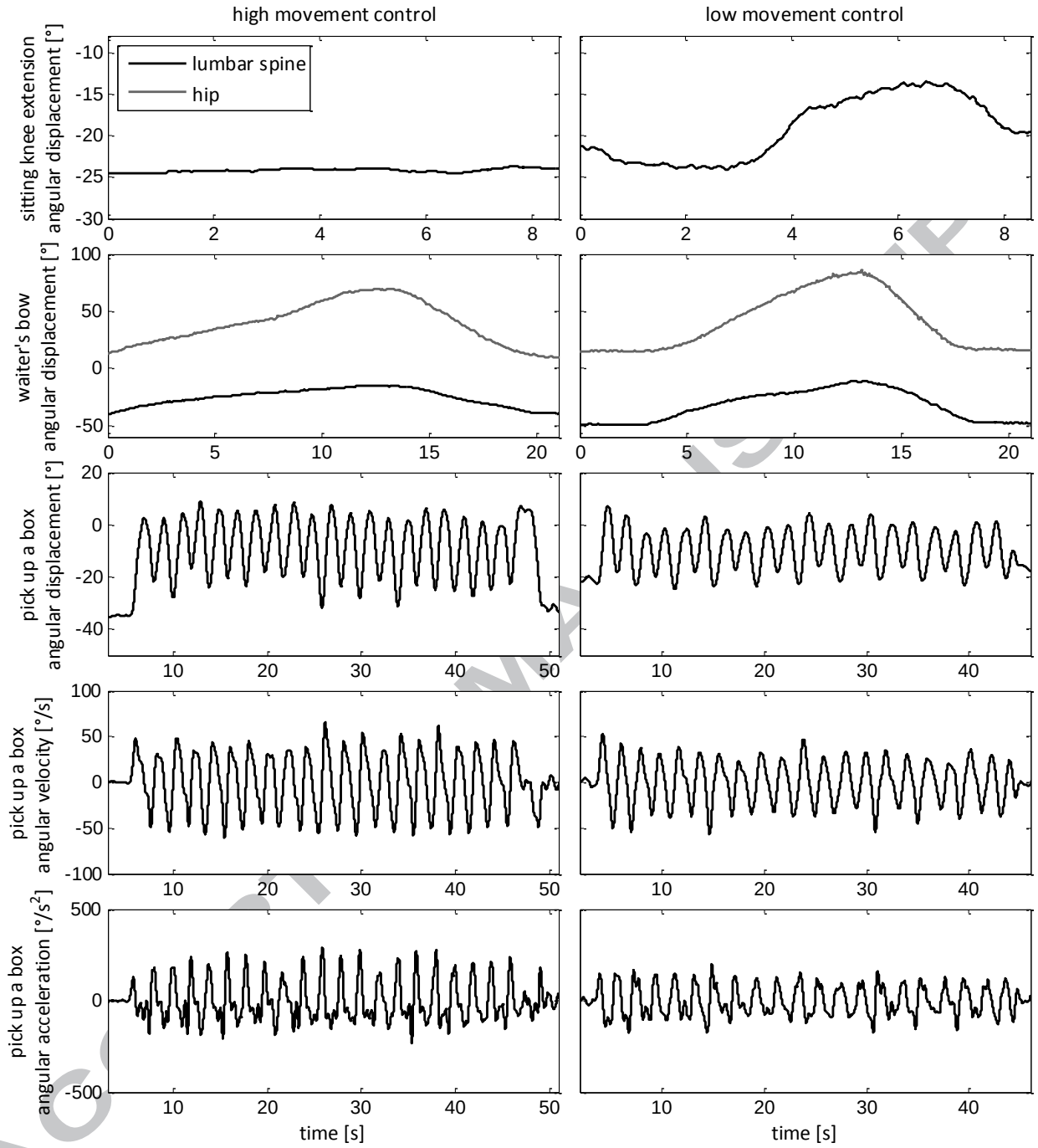



**Fig 2.**

Test procedure “Sitting Knee Extension”, “Waiters Bow” and “Pick Up a Box”




## Fig 3. Comparison of movement control

The left column shows a participant without low back pain and high movement control, the right column a participant with high intensity low back pain and low movement control.

Table 1. Input parameters used in recurrence quantification analysis.

| Picking Up a Box | Delay | Embedding Dimension | Distance | lmin | Size of Neighbourhood |
|---|---|---|---|---|---|
| Angular Displacement | 37 | 2 | Euclidian | 20 | 1.3 |
| Angular Velocity | 16 | 2 | Euclidian | 50 | 1.3 |
| Angular Acceleration | 9 | 2 | Euclidian | 20 | 1.3 |

lmin - minimal length of diagonal line

The delays were estimated using mutual information analysis. The first minimum of mutual information was defined as the optimal delay. The embedding dimensions were estimated by calculating the correlation dimension with different embedding dimensions. The optimal value of embedding dimension was chosen as the starting point where the correlation dimension did not increase significantly although increasing the embedding dimension.

Table 2. Descriptive Statistics.

| LBP NRS | n | Gender m/f | Age years | BMI ($kg/m^2$) | PS | Sitting Knee Extension ROM LS (°) | Waiters Bow Ratio LS/hip ROM | Picking Up a Box REC AD | DET AD | REC AV | DET AV | REC AA | DET AA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 31 | 14/17 | 40.1(±12.1) | 22.7(±2.9) | 1(1-4) | 2.6(±3.7) | 0.3(±0.2) | 41.0(±1.3) | 98.7(±0.4) | 43.5(±2.0) | 94.0(±3.5) | 39.2(±5.1) | 58.3(±9.3) |
| 1 | 4 | 3/1 | 49.8(±10.6) | 26.9(±2.8) | 1(1-2) | 1.2(±3.8) | 0.5(±0.4) | 40.1(±0.4) | 98.4(±0.4) | 42.2(±3.4) | 87.1(±9.6) | 39.8(±5.9) | 55.4(±11.8) |
| 2 | 19 | 11/8 | 43.8(±13.2) | 24.9(±3.7) | 1(1-3) | 2.2(±3.0) | 0.2(±0.1) | 41.7(±2.3) | 98.1(±0.5) | 43.7(±2.5) | 89.6(±6.0) | 37.4(±1.9) | 52.4(±6.4) |
| 3 | 13 | 7/6 | 35.2(±10.8) | 24.1(±4.8) | 1(1-4) | 2.5(±2.7) | 0.5(±0.5) | 41.4(±1.3) | 98.3(±0.4) | 42.9(±1.9) | 93.2(±3.7) | 37.9(±2.6) | 54.4(±6.3) |
| 4 | 15 | 7/8 | 34.6(±11.0) | 22.8(±3.2) | 2(1-4) | 3.3(±4.0) | 0.3(±0.2) | 41.9(±1.3) | 98.4(±0.3) | 42.5(±1.9) | 90.6(±3.7) | 38.5(±2.6) | 52.8(±7.6) |
| 5 | 5 | 2/3 | 38.0(±15.8) | 23.8(±2.9) | 1(1-2) | 1.1(±2.7) | 0.8(±0.7) | 40.9(±0.6) | 98.3(±0.2) | 41.5(±1.9) | 89.4(±4.0) | 38.7(±2.8) | 53.8(±5.5) |
| 6 | 4 | 1/3 | 45.0(±11.6) | 26.5(±7.3) | 2(1-5) | 2.4(±2.7) | 0.7(±0.7) | 41.4(±1.4) | 98.2(±0.3) | 42.6(±1.7) | 90.4(±3.4) | 38.7(±4.4) | 51.2(±9.3) |
| 7 | 3 | 1/2 | 30.0(±4.0) | 21.9(±1.2) | 2(2- | 1.3(±3.5) | 0.4(±0.2) | 41.9(±1.6) | 98.1(±0.3) | 41.6(±1.3) | 86.7(±6.9) | 35.7(±1.4) | 49.9(±4.8) |

5)

AA – angular acceleration; AD – angular displacement; AV – angular velocity; BMI – body mass index; DET – determinism; LBP – mean low back pain in the past four weeks; LS – lumbar spine; NRS – numeric pain rating scale; PS – physical stress at work; REC – recurrence rate; ROM – range of motion;

Results are provided as median (range) or mean (±standard deviation)

Table 3. Final model of each outcome.

| Test & Variable | Covariate | Point Estimation | 95% CI LB | 95% CI UB | p-value |
|---|---|---|---|---|---|
| Sitting Knee Extension | | | | | |
| ROM LS (°) | LBP | 0.3 | -0.2 | 0.9 | 0.24 |
| | Gender(Female) | 0.8 | -1.3 | 2.9 | 0.44 |
| | BMI | -0.2 | -0.4 | 0.0 | 0.05* |
| | LBP:Gender(Female) | -0.5 | -1.3 | 0.2 | 0.14 |
| Waiters Bow | | | | | |
| Log Ratio LS/Hip | | | | | |
| ROM | LBP | 0.0 | -0.1 | 0.2 | 0.84 |
| | Gender(Female) | -0.1 | -0.6 | 0.5 | 0.78 |
| | BMI | 0.1 | 0.0 | 0.1 | 0.03* |
| | PS | -0.4 | -0.7 | 0.0 | 0.04* |
| | LBP:Gender(Female) | 0.1 | -0.1 | -0.1 | 0.16 |
| Pick Up the Box | | | | | |
| REC AD | LBP | 0.11 | -0.05 | 0.26 | 0.18 |
| DET AD | LBP | -0.06 | -0.11 | -0.02 | 0.01* |
| | Age | -0.01 | -0.01 | 0.00 | 0.11 |
| REC AV | LBP | -0.25 | -0.46 | -0.03 | 0.03* |
| DET AV | LBP | -3.31 | -6.21 | -0.01 | 0.05* |
| | Gender(Female) | -2.22 | -4.25 | .-0.02 | 0.03* |

| | | | | | |
|---|---|---|---|---|---|
| | BMI | -0.66 | -1.11 | -0.25 | 0.45 |
| | NRS:BMI | 0.11 | -0.02 | 0.24 | 0.11 |
| REC AA | LBP | -2.03 | -3.87 | -0.20 | 0.03* |
| | Gender(Female) | -2.35 | -5.10 | 0.47 | 0.09 |
| | Age | -0.05 | -0.16 | 0.06 | 0.40 |
| | LBP:Gender(Female) | 1.14 | 0.17 | 2.12 | 0.02* |
| | LBP:Age | 0.03 | -0.01 | 0.07 | 0.14 |
| DET AA | LBP | -0.86 | -1.73 | 0.00 | 0.05* |
| | BMI | -0.59 | -1.06 | -0.13 | 0.01* |

Abbreviations: 95% CI – 95 % confidence interval; AA – angular acceleration; AD – angular displacement; AV – angular velocity; BMI – body mass index; DET – determinism ; LB – lower bound; LBP – low back pain intensity; LS – lumbar spine; PS – physical stress at work; REC – recurrence rate; ROM – range of motion; UB – upper bound

The reference level for gender was defined as female. The point estimation for each covariate is the effect of a one point increase of the respective covariate on the variable. For gender it represents the effect of being female.

*indicates $p \leq 0.05$

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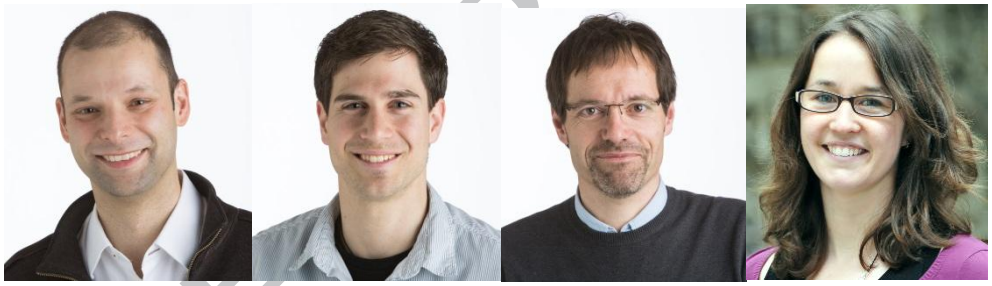

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