SDU
University of Southern Denmark

Postural sway does not differentiate individuals with chronic low back pain, single and multisite chronic musculoskeletal pain, or pain-free controls

a cross-sectional study of 229 subjects

Mikkonen, Jani; Leinonen, Ville; Kaski, Diego; Hartvigsen, Jan; Luomajoki, Hannu; Selander, Tuomas; Airaksinen, Olavi

Published in:
The Spine Journal

DOI:
10.1016/j.spinee.2022.04.013

Publication date:
2022

Document version:
Final published version

Document license:
CC BY

Citation for pulished version (APA):
Mikkonen, J., Leinonen, V., Kaski, D., Hartvigsen, J., Luomajoki, H., Selander, T., & Airaksinen, O. (2022). Postural sway does not differentiate individuals with chronic low back pain, single and multisite chronic musculoskeletal pain, or pain-free controls: a cross-sectional study of 229 subjects. *The Spine Journal*, *22*(9), 1523-1534. https://doi.org/10.1016/j.spinee.2022.04.013

Go to publication entry in University of Southern Denmark's Research Portal

Terms of use
This work is brought to you by the University of Southern Denmark.
Unless otherwise specified it has been shared according to the terms for self-archiving.
If no other license is stated, these terms apply:

- You may download this work for personal use only.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying this open access version

If you believe that this document breaches copyright please contact us providing details and we will investigate your claim.
Please direct all enquiries to puresupport@bib.sdu.dk

Download date: 17. Sep. 2023

The Spine Journal 22 (2022) 1523–1534

Clinical Study

Postural sway does not differentiate individuals with chronic low back pain, single and multisite chronic musculoskeletal pain, or pain-free controls: a cross-sectional study of 229 subjects

Jani Mikkonen, DC, BSc (Hons)[a,b,*], Ville Leinonen, MD, PhD[c,d], Diego Kaski, MBBS, BSc, PhD, FRCP[e], Jan Hartvigsen, DC, PhD[f,g], Hannu Luomajoki, PT, MSc, PhD[h], Tuomas Selander, MSc[i], Olavi Airaksinen, MD, PhD[b,j]

[a] *Private Practice, Mikonkatu 11 D TT1, 00100 helsinki, Finland*
[b] *Department of Surgery (Incl. Physiatry), Institute of Clinical Medicine, University of Eastern Finland, 70211 Kuopio, Finland*
[c] *Institute of Clinical Medicine-Neurosurgery, University of Eastern Finland, Kuopio, 70211, Finland*
[d] *Department of Neurosurgery, Kuopio University Hospital, Kuopio, 70211, Finland*
[e] *Department of Clinical and Movement Neurosciences, University College London, London WC1E 6BT, UK*
[f] *Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, DK-6400, Denmark*
[g] *Chiropractic Knowledge Hub, Odense, DK-6400, Denmark*
[h] *ZHAW School of Health Professions, Zurich University of Applied Sciences, Winterthur, CH-8401, Switzerland*
[i] *Science Service Center, Kuopio University Hospital, Kuopio, 70211, Finland*
[j] *Department of Physical and Rehabilitation Medicine, Kuopio University Hospital, Kuopio, 70211, Finland*

Received 25 November 2021; revised 16 March 2022; accepted 26 April 2022

Abstract

BACKGROUND CONTEXT: Physical activity in its various forms are the most recommended prevention and treatment strategy for chronic low back pain (CLBP). Standing postural stability is a prerequisite for many types of physical activities. Systematic reviews have investigated the evidence for an association between CLBP and postural stability but results remain inconclusive.

PURPOSE: Our primary objective was to compare postural stability between pain-free controls and subjects with CLBP with or without leg pain and single and multisite chronic musculoskeletal pain subjects. The secondary objectives were to evaluate the association between postural stability with CLBP intensity and duration, demographics, physical characteristics and validated health and pain-related patient-reported outcome measures (PROMs).

STUDY DESIGN/SETTING: Cross-sectional study in a private chiropractic clinic setting

PATIENT SAMPLE: Subjects included 42 pain-free controls and 187 patients with chronic musculoskeletal pain divided into CLBP with or without leg pain and single and multisite pain groups.

OUTCOME MEASURES: Pain intensity was measured using the numerical pain rating scale, PROMs Central Sensitization Inventory, Tampa Scale of Kinesiophobia, The Depression Scale, EuroQol-5D, Roland-Morris Disability Questionnaire, and Pain and Sleep Questionnaire Three-Item Index disability. Group differences were measured using area and velocity of sway on the force plate.

METHODS: Postural stability was assessed using a force plate on four 60-second bipedal quiet stance tests: eyes open on a stable surface, eyes closed on a stable surface, eyes open on an unstable foam surface, eyes closed on an unstable foam surface. Following the clinic visit, subjects completed an online web-based data entry detailing pain history, demographic data, physical characteristics, pain intensity via the numerical pain rating scale, and PROMS.

FDA device/drug status: Not applicable

Author disclosure: ***JM:*** Nothing to disclose. ***VL***: Nothing to disclose. ***DK***: Nothing to disclose. ***JH***: Nothing to disclose. ***HL***: Nothing to disclose. ***TS***: Nothing to disclose ***OA***: Nothing to disclose.

*Corresponding author. Private Practice, Mikonkatu 11 D TT1, 00100 helsinki, Finland

E-mail address: jani@selkakuntoutus.fi (J. Mikkonen).

https://doi.org/10.1016/j.spinee.2022.04.013

1529-9430/© 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

RESULTS: Postural sway parameters did not differ between pain-free controls and subjects with CLBP with or without leg pain and single and multisite chronic musculoskeletal pain subjects. Furthermore, severity and duration of CLBP pain in addition to central sensitization, kinesiophobia, depression, quality of life, disability, and effect of pain on sleep only had very weak associations with postural stability.

CONCLUSIONS: Chronic musculoskeletal pain appears not to influence bipedal postural stability. © 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

Keywords: Central sensitization; Chronic low back pain; Chronic musculoskeletal pain; Demographics; Pain duration; Pain intensity; Physical characteristics; Postural control; Postural stability; Kinesiophobia

Introduction

Chronic low back pain (CLBP) is a worldwide leading cause of disability and the most prevalent chronic musculoskeletal pain syndrome [1]. Chronic musculoskeletal pain syndromes are complex multifactorial biopsychosocial disorders, where it is seldom possible to draw any definite conclusion of causality of single factors leading to persistent and disabling pain [1,2]. According to the clinical presentation, chronic pain can be categorized into single or multisite pain [1,3]. Patients with multisite pain have more comorbid biopsychosocial health issues and poorer long-term prognosis [3].

Standing postural stability is one of the most fundamental human functions and is a prerequisite for locomotion. Physical activity across the domains of daily activities and physical exercises are the most recommended prevention and treatment strategies for CLBP [2,4,5]. Because postural stability is an integral part of physical activity, its association with CLBP and different chronic musculoskeletal pain syndromes have gained a considerable amount of research during the last decades [6,7]. Previous studies have proposed that adaptation to musculoskeletal pain has short-term benefits in relation to the protection of injury or threat of injury but, in the long-term, may have detrimental due to low-order muscle-specific effects through to higher-order neural and behavioral maladaptations [6,8,9]. The most used postural stability measurement is standing bipedal postural sway on the force plate [10−13]. The force plate measures displacement of the center of pressure (CoP) and records a range of sway parameters. The most studied CoP parameters among CLBP patients are sway velocity and area of sway [14]. Systematic reviews studying postural sway CoP displacement between pain-free controls and subjects with CLBP have shown inconsistent results, but with a trend towards poorer postural stability in subjects with CLBP. Such poorer postural stability becomes especially evident in the more challenging postural conditions (ie, eyes closed and on an unstable surface) [10−13]. Notably, however, the higher the methodological quality of the individual studies, the weaker the observed association in experimental findings [11−13].

The primary objective of this large cross-sectional study was to determine if postural stability differs between pain-free controls and subjects with CLBP with or without leg pain and single and multisite chronic musculoskeletal pain subjects. The secondary objectives were to evaluate the association between postural stability and low back pain intensity and duration, age and gender, physical characteristics (height, weight, and body mass index (BMI), and multiple well-established pain-related factors with patient-reported outcome measures (PROMs) including central sensitization, kinesiophobia, depression, quality of life, disability, and effect of pain on sleep.

Materials and methods

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Research Ethics Committee of the Northern Savo Hospital District with identification number 1106/13.02.00/2018. Written informed consent was obtained from all subjects before the study. The study was conducted in accordance with the declaration of Helsinki. STROBE statement for guidelines for reporting cross-sectional studies [15] was adhered to in this study.

Setting and study subjects

Data were collected from a single Chiropractic private practice setting in Helsinki, Finland, between May 2019 and March 2020. A total of 237 subjects agreed to participate and booked clinical appointments through an online booking system. Subjects were recruited using online advertisements and via social media for a range of national Finnish musculoskeletal pain and spine-related organizations and healthcare colleagues. All 18 to 65 years old subjects from the general population meeting the study inclusion and exclusion criteria were invited to participate, whether they suffered pain or not. Inclusion criteria were; (1) age between 18 and 65 years (2) proficiency in written and spoken Finnish. Exclusion criteria were; (1) history of malignant tumor, (2) history of diagnosed trauma negatively affecting the central nervous system, including whiplash or mild traumatic brain injury, (3) history of diagnosed disease negatively affecting the central nervous system, including multiple sclerosis, Parkinson's disease, Alzheimer's disease or other dementia, (4) positive Slump

test, (5) acute dizziness symptoms on the interview before postural stability tests, (6) unable to perform movement control and/or postural sway clinical tests in a safe manner indicating possible undiagnosed neurological conditions affecting the central nervous system.

Data collection

Postural stability data were collected using a force plate during the routine clinic visit on Thursdays between 8 $_{AM}$and 12 $_{AM}$, at which point the clinical interview and movement control assessments were also performed. A structured interview was done during the clinic visit before the force plate measurement regarding subjects' dizziness status. During the clinic visit, a Slump test was carried out to exclude subjects with symptomatic lumbar disc herniation (30).

None of the study subjects reported acute dizziness during the interview before postural stability tests or had a positive Slump test for acute sciatica thus excluding symptomatic intervertebral disc herniation. Five subjects were excluded due to clinical features suggestive of underlying neurological disorders identified during the prescreening assessment with low back movement control tests described by Luomajoki et al. [16], and/or markedly abnormal postural stability on the force plate. Such tests were interrupted when subjects experienced falls or were deemed to be at high risk of falls and subjects were excluded from the study. Three further subjects were excluded as they did not complete the study questionnaires at the time of their clinical appointments. After the exclusions, the total number of participants in the study was 229 (see Fig. 1 for a study flow chart).

Following the clinic visit, subjects were asked to complete an online web-based data entry detailing demographic information (age, gender, height, weight, and pain history) and PROMs at home. BMI was calculated using subject-reported height and weight data.

Variables

Clinical tests of postural control on the force plate

Postural control was measured with a force plate (four-channel portable computerized force plate (BT4; HUR Labs Oy, Tampere, Finland). Because the subjects completed the questionnaires after the clinic visit, the assessor and the first author (JM) were blinded from the participants' pain history and questionnaire scores. Postural control measurements included velocity and area of sway, which are the most commonly used outcomes for postural control in CLBP cohorts in previous studies [10,14].

The force plate was calibrated before each individual's measurement. Subjects were given the standardized instructions: to stand barefoot, feet as close together as comfortably as possible, to look straight ahead, and keep balancing in a relaxed manner keeping their arms at their sides. If subjects found foot stance as close as possible unnatural, they were instructed to bring their feet slightly further apart to create a more stable and natural feeling standing stance. Minor changes in the stance of feet should not have a considerable effect on the results [17] and results are more reliable when subjects can do slight adaptations to have their natural stance [18]. There was no clear fixation point for gaze, and the opposite wall was more than 3 meters away. The tests were carried out in the same room with identical conditions for each subject, including distance to the opposite wall and light in the room.

Four different postural control tests were carried out. Each test lasted 60 seconds, which was identical to the time measurement in previous studies on CLBP patients with a similar testing protocol [10]. A 60-second test time is also used on a very similar and well-validated postural control test protocol in a vestibular disorder population [19]. A 5-second prephase period occurred before the actual COP measurement of 60 seconds. The sampling frequency was set to 50 Hz, which was recommended by the manufacturer to balance consistent data acquisition and manageable data size. Four CoP displacement quiet stance measurements in respective order were:

- Eyes open on a stable surface (EOS).
- Eyes closed on a stable surface (ECS).
- Eyes open on an unstable foam surface (EOU).
- Eyes closed on an unstable foam surface (ECU).

Two postural sway parameters were studied on each test: (1) Mean velocity of the sway [mm/s] and (2) Area of the sway [mm^2]. A rectangular high density (50 kg/m^3) closed-cell Airex Balance Pad (delivered by a manufacturer with the force plate) was used for all tests requiring a calibrated foam surface in order to provide an unstable surface. All measurements were carried out once, in similar (nonrandomized) order, and there was no designated resting period between tests other than breaks, when subjects stepped off from the force plate while taking Airex Balance Pad on and off between EOS-ECS and EOU-ECU tests. The force plate protocol was identical to a routine clinical postural sway assessment to ensure direct clinical translation.

Subject-reported pain history questions

All subjects completed a structured web-based pain history assessment with binary questions (yes/no), including presence of chronic low back pain, referral to leg (if yes to CLBP), the experience of other ongoing chronic musculoskeletal pain, and presence of chronic headache. Subjects with CLBP were also asked to rate the severity of pain on a numerical pain rating scale (NPRS) from 0 to 10 and to indicate the duration of the pain as a function of the number of months with pain. CLBP was defined as pain present for more than 3 months and for more than 3 days per week [20,21].

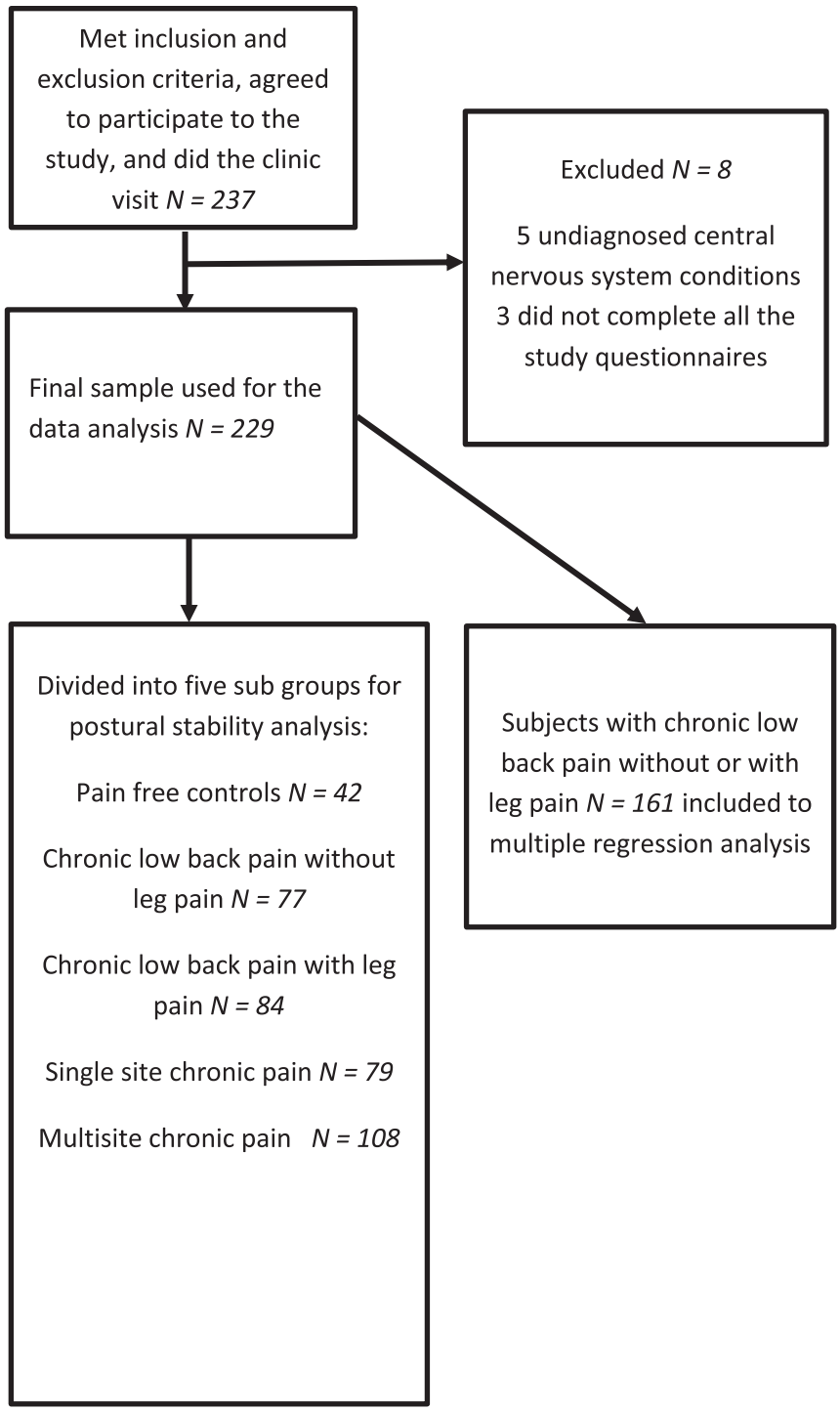


Fig. 1. Flow chart of subjects.

Patient-reported outcome measurements

Numerical pain rating scale (NPRS) measures subjective pain on 11-point numerical scale. The scale is composed of 0 (no pain at all) to 10 (worst imaginable pain) [22].

Central Sensitization Inventory (CSI) was developed to be a screening tool for central Sensitization [23]. CSI is a two-part questionnaire where Part A includes 25 questions about CS-related symptomology. The total score range is "0" to "100" on Likert scale options: 0=never, 1=rarely, 2=sometimes, 3=often, and 4=always. Part B asks with "No/Yes, and year diagnosed" possible previously diagnosed Central Sensitization syndromes and related disorders. CSI part B is only for information and is not scored [24]. CSI has been translated and validated in a Finnish population [25]. Fibromyalgia [26,27], temporomandibular joint disorder [28], migraine, or tension headaches [29,30]

from CSI part B is known to have an effect on postural stability. Therefore, these previous diagnoses on CSI part B were taken into account when comparing subjects with CLBP and pain-free controls.

Tampa scale of Kinesiophobia (TSK) evaluates kinesiophobia (fear of movement). TSK is a 17-item questionnaire used to assess subjective kinesiophobia on Likert scale options: 1=strongly disagree 2=disagree 3=agree 4=strongly agree. The range of scores is from 17 to 68. Higher scores indicate an increasing degree of kinesiophobia [31]. TSK has been translated into Finnish and validated in the Finnish population [32].

Depression Scale (DEPS) is a 10-item questionnaire used to assess depressive symptoms on Likert scale options: 0=not at all, 1=a little, 2=quite a lot and 3=extremely. Higher scores indicate a higher possibility of a Major Depressive Disorder diagnosis [33]. The DEPS has excellent structural validity for screening depressive symptoms among patients with low back pain [34].

EuroQol (EQ-5D-5L) assesses health related quality of life in the five dimensions [35]. The dimensions are mobility, self-care, usual activities, pain/discomfort, and anxiety / depression. Each dimension has five response levels: 0=no problems, 1=slight problems, 2=moderate problems, 3=severe problems, 4=unable to/extreme problems. A second part of the EQ-5D-5L is the EQ visual analogue scale (EQ VAS) [35]. Because there is currently no Finnish standard value set available, a value set from Denmark was used to calculate the index value as recommended by the EuroQol EQ-5D-5L User Guide [36].

Roland-Morris Disability Questionnaire (RMDQ) evaluates disability related to chronic low back pain. RMDQ is a 24-item questionnaire of disability in chronic low back pain populations [37]. The RMDQ is scored by adding up the number of items checked “yes” on different low back pain-related daily activity disabilities. Total scores range from 0 to 24, with higher scores indicating a higher level of disability related to low back pain [38].

Pain and Sleep Questionnaire Three-Item Index (PSQ-3) assesses the impact of pain on sleep. PSQ-3 is a three-item sleep questionnaire designed to measure the impact of chronic pain on sleep during the past week [39]. PSQ-3 measures effect of pain on sleep on a numerical 11-point rating scale from 0 to 10. Zero indicates “never” and 10 indicates “always.” Thus, the final score is ranged from 0 to 30. PSQ-3 is translated and validated in Finnish [40].

Statistical methods

Statistical analysis was performed using SPSS version 25 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Statistical significance was defined as $p<.05$. The normality of the data was checked by Shapiro-Wilks tests. Demographics data were shown as percentages or means with standard deviations or medians with ranges depending on the distribution of the variables. Pearson’s correlation coefficient was calculated between demographics, physical characteristics, PROMs, and postural stability variables. Strengths of the correlations were interpreted as: no to weak correlation ($0>r\leq0.25$), weak to moderate correlation ($0.25>r\leq0.50$), moderate to strong correlation ($0.50>r\leq0.75$), and strong to perfect correlation ($0.75>r\leq1$) [41].

The minimum required sample size was calculated with average means and estimated standard deviation from the review comparing pain-free controls and subjects with low back pain [10]. The two-tailed hypotheses were calculated on two independent study groups with 0.05 probability of type I error, 0.80 effect size, and 0.8 statistical power. The calculation revealed that at least 25 subjects had to be included in each group.

Normally distributed variables were compared by independent samples *t* test or One-Way ANOVA with post hoc comparison of Least Significant Difference (LSD). Skewed distributed data were tested by Mann-Whitney *U* test. Categorical variables were compared by chi-square or Fisher’s exact tests. The scatter plots were used to visualize and further investigate some of the key findings of the data.

A multivariable linear regression was calculated to evaluate associations of postural stability with demographics and PROMs by postural stability with eyes closed on unstable surface as dependent variable and gender, age, weight, height, NPRS, pain duration, CSI, TSK, DEPS, EQ-5D-5L, RMDQ, and PSQ-3 as independent variables. BMI was not included in this analysis as a variable because of potential multicollinearity effects between highly correlated variables of BMI and height and weight. Only subjects with CLBP were included in the multiple regression calculation. Sway velocity with eyes closed on unstable surface was chosen as the dependent variable, as sway velocity is considered to be the most accurate parameter of postural sway and previous studies report greatest abnormalities on postural stability in subjects with CLBP on the more challenging test conditions (ie, eyes closed and on unstable surface) [10−13,42].

Results

We enrolled 229 subjects, which consisted of 162 females and 67 males with mean age of 44.5±11.8 years, height 171.2±9.3 cm, weight 75.4±16.9 kg, and BMI 25.6±4.8. Subjects were grouped into a pain-free control group and group with CLBP with or without leg pain and single and multisite chronic musculoskeletal pain groups, based upon self-reported pain symptoms. Of the 229 total sample, 42 (18.3%) comprised the control group (reported no pain). Specifically, the pain-free controls reported no CLBP, no leg pain, pain scale 0/10, pain history 0 months, no other chronic musculoskeletal pain, and no chronic headaches. The remaining 187 subjects (81.3%) reported chronic pain, of which 77 (41.2%) reported CLBP without leg pain and 84 (44.9%) with leg pain, 79 (34.5%) reported pain in a single body area (one of the following: CLBP

group with or without leg referral, other chronic musculoskeletal pain or chronic headache), and 108 (47.2%) reported multisite chronic pain (two or more of the following: CLBP with or without leg referral, other chronic musculoskeletal pain and/or chronic headache).

Of the total study cohort, only five subjects reported previous fibromyalgia diagnosis (1% in the pain-free control vs. 3% in CLBP groups), 32 temporomandibular joint disorder diagnoses (17% in the pain-free control vs 16% in CLBP groups), and 24 migraine or tension headache diagnoses (4% in the pain-free control vs 15% in CLBP groups).

The pain-free controls and chronic pain subjects were not statistically significantly different in gender, height, weight, or BMI. Demographics between pain-free controls and single and multiple site pain subgroups differed with respect to age. On average, the chronic pain groups were about 4 and 6 years older, showing statistically significant differences between controls vs CLBP with leg pain, single body area pain, and multisite pain groups. There were more males in the single pain group than the multisite pain group.

Pain intensity, duration and all pain-related PROMs measuring disability, central sensitization, kinesiophobia, quality of life and quality of sleep showed clear differences between all five group comparisons (pain-free control vs CLBP without leg pain, pain-free control vs CLBP with leg pain, pain-free control vs single site pain, pain-free control vs multisite pain, single-site pain vs multisite pain). There was a group difference in three of five comparisons in depression. Table 1.

There were only 2 significant differences of 40 comparisons (2/40, 5%) in postural stability parameters. The two differences were between pain-free controls and CLBP with leg pain and between pain-free controls and chronic multisite pain groups on eyes open unstable surface test on an area of sway parameter. Postural stability did not differentiate groups of single and multisite pain on any parameter. Overall, the pain-free control group showed marginally poorer postural stability on the most challenging test than the four chronic pain groups. Table 2.

Postural stability parameters showed only weak correlations with age, height, weight, and BMI. Table 3.

Postural stability parameters correlated very weakly and even weaker than demographics and physical characteristics with CLBP and its intensity and duration and with PROMs of central sensitization, kinesiophobia, depression, quality of life, disability, and effect of pain on sleep. Table 4.

Central sensitization and kinesiophobia, well-established chronic musculoskeletal pain-related factors showed very weak associations between individual scores and performance on the velocity of postural sway tests. Two of four eyes closed tests showed a negative association with central sensitization. Fig. 2.

The results of the multivariable linear regression indicated that the model explained 12.1% of the variance and that the model was a significant predictor of postural stability performance F(3.61), p=.001. Age was the only factor which contributed significantly to the model

Table 1
Demographics among pain-free controls and chronic pain groups

Variables	Pain-free control group N=42	CLBP without leg pain N=77	CLBP with leg pain N=84	Chronic pain in a single body area N=79	Multisite pain in two or more chronic pain locations N=108
Subjects with CLBP	0 (0%)	77 (100%)*	84 (100%)†	56 (71%)‡	105 (97%)§,‖
Age	40.2 (36.9-43.4)	43.8 (41.1-46.5)	46.6 (44.0-49.1)†	44.5 (41.9-47.3)‡	46.1 (43.9-48.4)§
Height	171.3 (168.7-173.8)	172.4 (170.2-174.6)	169.8 (168.0-171.6)	172.6 (170.4-174.8)	170.1 (168.3-171.8)
Weight	76.6 (71.6-81.5)	75.9 (72.7-79.2)	73.8 (70.1-77.6)	76.1 (71.8-80.4)	74.4 (71.5-77.3)
BMI	26.0 (24.5-27.5)	25.5 (24.6-26.5)	25.5 (24.4-26.7)	25.2 (24.1-26.3)	25.7 (24.8-26.6)
Gender Female N (%)	29 (69%)	51 (66%)	64 (76%)	48 (61%)	85 (78%)‖
NPRS	0±0 (0.0-0.0)	4.4 (4.0-4.9)*	5.4 (5.0-5.8)†	3.8 (3.0-4.3)‡	4.7 (4.3-5.1)§,‖
Duration	0±0 (0.0-0.0)	69.5 (50.2-88.8)*	69.2 (52.4-86.0)†	39.7 (22.0-51.3)‡	76.7 (60.7-92.6) §,‖
CSI	28.0 (24.7-31.3)	34.7 (32.0-37.4)*	39.8 (37.2-42.4)†	31.8 (29.5-34.1)‡	40.7 (38.5-43.0) §,‖
TSK	25.8 (24.3-27.3)	31.4 (29.5-33.2)*	32.8 (31.2-34.4)†	30.2 (28.7-31.7)‡	33.0 (31.5-34.5) §,‖
DEPS	5.4 (4.0-6.7)	5.6 (4.6-6.5)	7.2 (6.0-8.4)†	4.8 (3.9-5.6)	7.3 (6.2-8.3) §,‖
EQ-5D-5L	0.85 (0.82-0.88)	0.77 (0.74-0.79)*	0.74 (0.71-0.77)†	0.79 (0.77-0.81)‡	0.74 (0.71-0.76) §,‖
RMDQ	0.4 (0.15-0.71)	3.7 (2.9-4.5)*	4.6 (3.8-5.4)†	2.6 (1.9-3.3)‡	4.4 (3.7-5.2) §,‖
PSQ-3	2.0 (0.87-3.1)	7.0 (5.5-8.5)*	9.6 (8.0-11.2)†	6.2 (4.7-7.6)‡	9.3 (7.9-10.7) §,‖

Chronic low back duration in months (duration), CLBP, Chronic low back pain; CSI, Central Sensitization Inventory; DEPS, The Depression scale; EQ-5D-5L, EuroQol 5-level EQ-5D version; NPRS, Numerical Pain Scale; PSQ-3, Pain and Sleep Questionnaire Three-Item Index; RMDQ, Roland-Morris Disability Questionnaire; TSK, Tampa scale of kinesiophobia. Mann-Whitney tests. One-Way ANOVA post hoc comparison of Fisher's Least Significant Difference (LSD).

Data presented as mean (95% Confidence interval lower and upper bound) or N (%). Comparison between controls without pain and chronic low back pain (CLBP) group without leg pain.

* Between controls and CLBP group with leg pain.

† Between controls and chronic single body area pain.

‡ Between controls and multisite pain.

§ And between single body area pain and multisite pain.

‖ With statistical significance p<.05.

Table 2
Postural stability between pain-free controls and chronic pain groups and between single and multisite pain groups

Variables	Pain-free controls N=42	CLBP without leg pain N=77	CLBP with leg pain N=84	Chronic single body area pain N=79	Chronic multisite pain N=108
Test 1. Eyes open stable surface (EOS)					
Area of sway [mm^2]	252 (204- 299)	267 (235-298)	299 (261-338)	270 (238-302)	301 (268-335)
Velocity of sway [mm/s]	9.2 (8.5.-10.0)	9.2 (8.5-9.8)	9.9 (9.2-10.5)	9.4 (8.7-10.1)	9.7 (9.1-10.2)
Test 2. Eyes closed stable surface (ECS)					
Area of sway [mm^2]	363 (309-417)	443 (359-527)	469 (390-549)	363 (361-529)	459 (392-525)
Velocity of sway [mm/s]	15.2 (13.5-16.8)	15.0 (13.1-17.0)	15.5 (14.3-16.7)	15.2 (13.5-17.4)	15.2 (14.2-16.2)
Test 3. Eyes open on unstable surface (EOU)					
Area of sway [mm^2]	416 (350-482)	471 (421-522)	502 (448-557)†	476 (429-536)	502 (453-551)§
Velocity of sway [mm/s]	13.9 (12.7-15.1)	13.9 (13.1-14.7)	14.8 (14.0-15.7)	13.9 (13.2-15.2)	14.4 (13.9-15.3)
Test 4. Eyes closed on unstable surface (ECU)					
Area of sway [mm^2]	1112 (922-1304)	1098 (958-1238)	1097 (976-1219)	1112 (955-1253)	1096 (988-1204)
Velocity of sway [mm/s]	31.3 (28.3-34.1)	29.8 (27.1-32.4)	29.9 (27.6-32.4)	31.2 (27.6-33.2)	29.4 (27.6-31.3)

CLBP = Chronic low back pain. Presented as mean (95% Confidence interval lower and upper bound). Mann-Whitney tests.
*Comparison between controls without pain and chronic low back pain (CLBP) group without leg pain.
† Between controls and CLBP group with leg pain.‡Between controls and chronic single body area pain.
§ Between controls and multisite pain.‖And between single body area pain and multisite pain with statistical significance p<.05.

B=0.297. Table 5. Multivariable linear regression using the velocity of way parameter and other three postural stability tests of EOS, ECS, or EOU as a dependent variable with same independent variables provided essentially very similar results.

Discussion

We show that there are only very small and clinically unimportant differences in postural stability between pain-free controls and subjects with CLBP with or without leg pain, nor in subjects with single or multisite chronic musculoskeletal pain. Hence, the results suggest that neither isolated nor widespread chronic musculoskeletal pain are associated with greater postural instability. Only 2 parameters of 40 total parameters showed a statistically significant intergroup difference, thus confirming that our results are robust and consistent.

Very small and clinically unimportant postural stability differences cannot be explained by demographics or physical characteristics, because the only group difference was age. Indeed, aging has been shown to be a strong indicator of poorer postural stability [43]. All four chronic pain groups included average of older subjects and hence should have led to more evident group differences between control groups. Moreover, age was the only significantly contributing factor for postural stability on multivariable linear regression analysis in our cohort.

The primary results are perhaps surprisingly unambiguous given previous findings showing differences in postural stability between subjects with and without CLBP. Systematic reviews in fact support the notion that methodological quality

Table 3
Correlations of demographics and postural stability parameters (N=229)

	Age	Gender	Height	Weight	BMI	EOS Area	EOS Velocity	ECS Area	ECS Velocity	EOU Area	EOU Velocity	ECU Area
Gender	-0.41											
Height	0.13	-0.66*										
Weight	0.09	-0.45*	0.56*									
BMI	0.11	-0.12	0.69	0.86*								
EOS Area	0.24*	-0.13*	0.24*	0.11	0.01							
EOS Velocity	0.34*	-0.24*	0.25*	0.21*	0.10	0.54*						
ECS Area	0.21*	-0.17*	0.26*	0.13	0.01	0.6*	0.57*					
ECS Velocity	0.26*	-0.26*	0.21*	0.20*	0.10	0.33*	0.74*	0.71*				
EOU Area	0.26*	-0.22*	0.32*	0.20*	0.04	0.71*	0.42*	0.64*	0.33*			
EOU Velocity	0.36*	-0.18*	0.15	0.22*	0.16	0.41*	0.75*	0.53*	0.65*	0.55*		
ECU Area	0.21*	-0.25*	0.27*	0.21*	0.08	0.51*	0.55*	0.71*	0.62*	0.64*	0.65*	
ECU Velocity	0.30*	-0.18*	0.16	0.21*	0.15	0.28*	0.62*	0.52*	0.76*	0.34*	0.73*	0.81*

ECS, eyes closed on a stable surface; ECU, eyes closed on an unstable foam surface; EOS, Eyes open on a stable surface; EOU, eyes open on an unstable foam surface.
Pearson's correlation coefficient.
* Statistical significance p<.05. With reference to gender, the negative correlation indicates better postural stability on women.

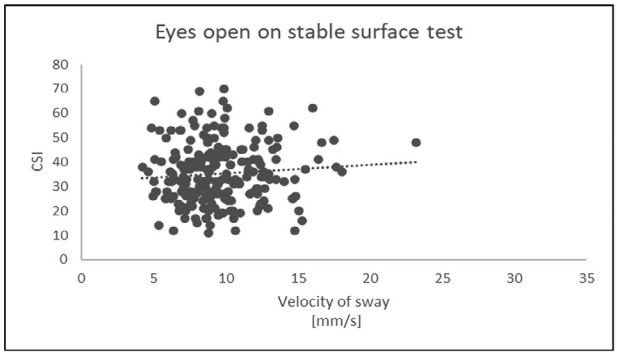
Table 4
Correlations between chronic low back pain (CLBP), pain intensity and duration, patient-reported outcome measures and postural stability parameters (N=229)

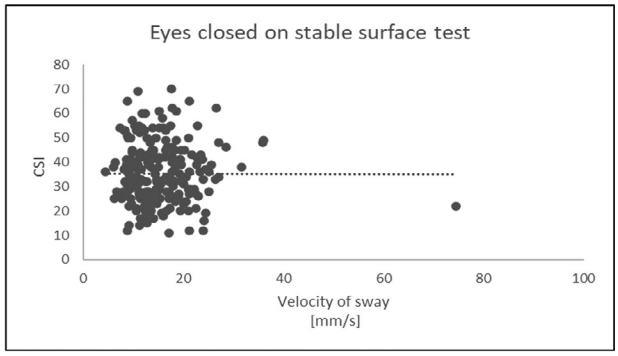
	CLBP	NRPS	Pain duration	CSI	TSK	DEPS	Euro Qol (EQ-5D-5L)	RMDQ	PSQ-3	EOS Area	EOS Velocity	ECS Area	ECS Velocity	EOU Area	EOU Velocity	ECU Area
NPRS	0.81*															
Pain duration	0.42*	0.34*														
CSI	0.23*	0.28*	0.18*													
TSK	0.28*	0.32*	0.21*	0.46*												
DEPS	0.10*	0.13	0.11	0.65*	0.39*											
EQ-5D-5L	-0.26*	-0.39*	-0.12*	-0.50*	-0.45*	-0.49*										
RMDQ	0.50*	0.59*	0.32*	0.32*	0.46*	0.30*	-0.49*									
PSQ-3	0.34*	0.46*	0.15*	0.48*	0.34*	0.30*	-0.33*	0.45*								
EOS Area	0.02	0.06	0.14	0.17*	0.22*	0.10	-0.10*	0.15	0.13							
EOS Velocity	-0.08	0.05	0.15	0.08	0.07	0.13	-0.14	0.17	0.13	0.54*						
ECS Area	0.06	0.09	0.10	0.14	0.18*	0.13	-0.17	0.22*	0.20*	0.62*	0.57*					
ECS Velocity	-0.01	0.01	0.09	0.01	0.06	0.11	-0.10	0.15	0.07	0.33*	0.74*	0.71*				
EOU Area	-0.02	0.09	0.08	0.15	0.22*	0.08	-0.10	0.16	0.19*	0.71*	0.42*	0.64*	0.33*			
EOU Velocity	-0.02	0.01	0.10	0.12	0.12	0.16	-0.16	0.14	0.12	0.41*	0.75*	0.53*	0.65*	0.33*		
ECU Area	-0.03	0.01	0.11	0.02	0.14	0.06	-0.07	0.09	0.14	0.51*	0.55*	0.71*	0.62*	0.64*	0.65*	
ECU Velocity	-0.05	-0.05	0.09	-0.04	0.07	0.07	-0.06	0.07	0.02	0.28*	0.62*	0.52*	0.76*	0.34*	0.73*	0.81*

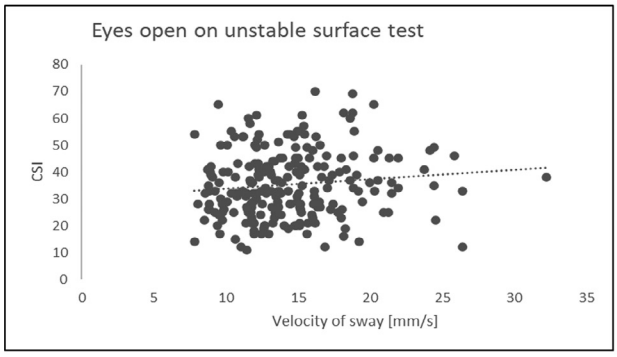
CSI, Central Sensitization Inventory; DEPS, The Depression scale; EQ-5D-5L, EuroQol 5-level EQ-5D version; ECS, eyes closed on a stable surface; ; ECU, eyes closed on an unstable foam surface; EOS, Eyes open on a stable surface; EOU, eyes open on an unstable foam surface; NRPS, Numerical Pain Scale; PSQ-3, Pain and Sleep Questionnaire Three-Item Index; RMDQ, Roland-Morris Disability Questionnaire; TSK, Tampa scale of kinesiophobia.

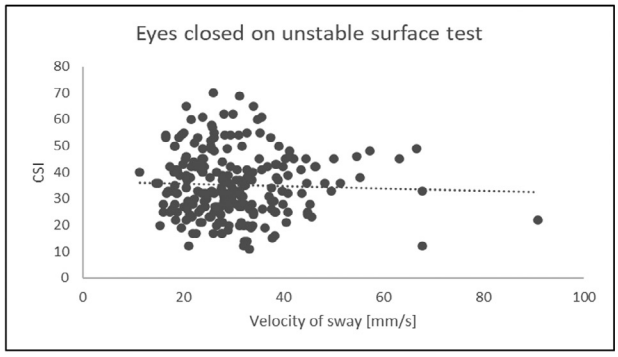
Pearson's correlation coefficient.

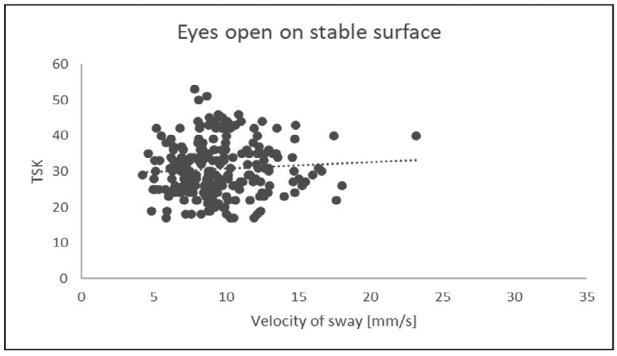
* Statistical significance $p<.05$.

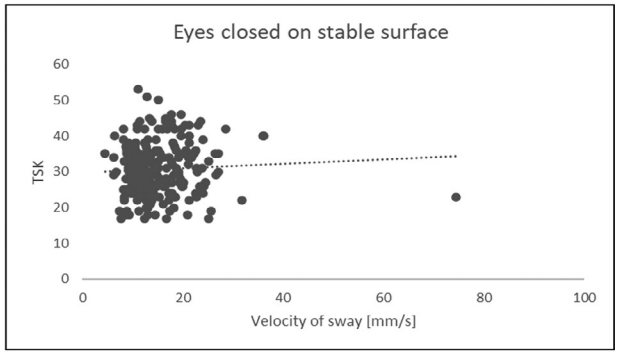


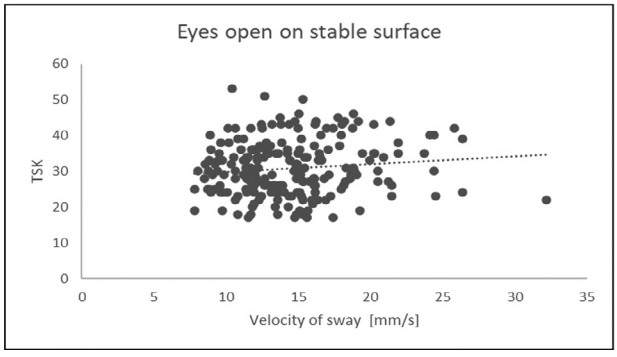












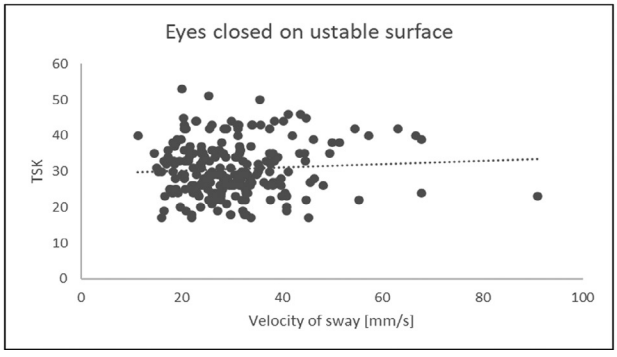


Fig. 2. Scatter plots of Central Sensitization Inventory (CSI) and Tampa Scale of Kinesiophobia (TSK) scores versus velocity of sway.

Table 5
Multivariable linear regression model independent variables (N=161)

	Standardized Beta	Mean (CI95%)
Age	0.297*	45.3 (43.5-47.1)
Gender	-0.70	1.71 (1.64-1.78)
Height	0.18	171.1 (169.7-172.6)
Weight	0.12	75.0 (72.5-77.5)
Low back pain intensity (NPRS 0-10)	-0.14	5.0 (4.7-5.3)
Low back duration pain in months	0.05	69.4 (56.8-82.0)
Central Sensitization Inventory	-0.14	37.2 (35.3-39.0)
Tampa Scale of Kinesiophobia	0.08	32.0 (30.9-33.2)
The Depression scale	0.14	6.4 (5.6-7.1)
EuroQol (EQ-5D-5L)	-0.26	0.76 (0.74-0.77)
Roland-Morris Disability Questionnaire	0.04	4.2 (3.7-4.8)
Pain and Sleep Questionnaire Three-Item Index	-0.12	8.4 (7.3-9.6)

BMI, body mass index. NRPS= Numerical Pain Rating Scale.

Presented as mean (95% Confidence interval lower and upper bound). Dependent variable velocity on eyes closed on an unstable foam surface test.

* Statistical significance p<.05. With reference to gender, the negative regression coefficient indicates better postural stability in women.

affects study findings, with studies of greater quality being more likely to find no difference between subjects with CLBP and pain-free controls [11−13]. Indeed, we sought to address many of the methodological limitations of the previous studies including small sample sizes [11,13], lack of detailed reporting of measurement protocol [12,13], lack of adequate inclusion and exclusion criteria and physical testing [10,12], and lack of reporting of subjects' baseline demographics and physical characteristics [13,14]. Also, overlapping other pain-related conditions affecting postural stability did not explain findings, because there were no unforeseen underlying diagnoses in the pain-free control group.

Several previous studies have found that differences between subjects with CLBP and controls are more obvious on eyes closed conditions [10−13] due to impaired proprioception in patients with CLBP and therefore being less able to rely on this sense for balance when vision is denied [10,11]. We did not observe any differences between eyes open and eyes closed test conditions between groups, although we did see a normal trend of increased instability on eyes closed and on unstable surface tests within groups. Moreover, the control group showed marginally poorer postural stability than the pain groups on the most challenging test.

Neither pain intensity and duration nor multiple well-established chronic pain-related PROMs were related to poorer postural stability, and these findings were consistent across the dataset. Previous studies have shown inconclusive associations between postural stability and pain intensity and duration [12−14,44] and with central sensitization, disability, kinesiophobia, and quality of sleep [25,45−48]. In our results, demographic, and physical characteristics showed a higher correlation with postural stability than pain-related variables.

From a clinical perspective, we would argue that bipedal standing postural sway is not a reliable clinical test to understand the effects of pain upon balance function, particularly in the context of CLBP. Given the substantial burden of CLBP on the individual, and society [1,49] we would advise caution in performing unnecessary, time-consuming, and costly high-tech investigations measuring postural sway. Consistent with this, we are aware of a pilot randomized controlled trial evaluating the effect of an exercise training program on postural stability compared to sham treatment in CLBP subjects, where results showed only a small and clinically nonsignificant effect size [50].

Strengths and limitations

Strengths

The major strengths of this study were the large cohort with well-defined study groups, strict inclusion and exclusion criteria including physical examination and interview, detailed clinically applicable test protocol, and use of multiple well-established measures. Moreover, this study was the first study to note clinically important pain distribution differences, which was not studied on previous research comparing controls with subjects with CLBP.

Limitations

We did not include a detailed history of exercise and physical activity in our baseline assessment and therefore cannot comment on whether baseline activity may influence postural stability. Moreover, whilst our physical examination for low back pain included the Slump test, inclusion of advanced imaging of the lower back and clinical tests such as active and passive leg raise and lower extremity sensory and motor clinical testing could have enabled classification of subjects with CLBP into specific etiological categories, which cannot be done with the Slump test alone [51].

Conclusion

We found only very small and clinically unimportant differences in postural stability between pain-free controls and subjects with CLBP with or without leg pain, and subjects with single or multisite chronic musculoskeletal pain. Moreover, postural stability did not reveal an association with leg more widespread distribution of pain or its intensity or duration or indeed correlate with central sensitization, kinesiophobia, depression, quality of life, disability, and effect of pain on sleep. Overall, chronic musculoskeletal pain, especially chronic low back pain, and well-established related factors do not appear to influence static postural stability.

Declaration of Competing Interest

There are no financial conflicts of interest to disclose.

Acknowledgments

The authors would like to thank all of the study participants who volunteered to participate in this study. The authors would like to thank Pauli Ohukainen, Jon Haglund, Tuomo Ahola, Kristian Ekström, and Mia Jokiniva for their contributions to data collection.

References

[1] Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. What low back pain is and why we need to pay attention. Lancet 2018;391(10137):2356–67.
[2] Booth J, Moseley GL, Schiltenwolf M, Cashin A, Davies M, Hübscher M. Exercise for chronic musculoskeletal pain: a biopsychosocial approach. Musculoskeletal Care 2017;15(4):413–21.
[3] Aili K, Campbell P, Michaleff ZA, Strauss VY, Jordan KP, Bremander A, et al. Long-term trajectories of chronic musculoskeletal pain: a 21-year prospective cohort latent class analysis. Pain 2021;162(5):1511–20.
[4] Foster NE, Anema JR, Cherkin D, Chou R, Cohen SP, Gross DP, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet 2018;391(10137):2368–83.
[5] Kongsted A, Ris I, Kjaer P, Hartvigsen J. Self-management at the core of back pain care: 10 key points for clinicians. Braz J Phys Ther 2021;25(4):396–406.
[6] Meier ML, Vrana A, Schweinhardt P. Low back pain: the potential contribution of supraspinal motor control and proprioception. Neuroscientist 2019;25(6):583–96.
[7] Ruhe A, Fejer R, Walker B. Altered postural sway in patients suffering from non-specific neck pain and whiplash associated disorder - a systematic review of the literature. Chiropr Man Therap 2011;19(1):13.
[8] Hodges PW. Pain and motor control: from the laboratory to rehabilitation. J Electromyogr Kinesiol 2011;21(2):220–8.
[9] Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. Fifth edition. Philadelphia: Wolters Kluwer; 2017. p. 660.
[10] Ruhe A, Fejer R, Walker B. Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: a systematic review of the literature. Eur Spine J 2011;20(3):358–68.
[11] Mazaheri M, Coenen P, Parnianpour M, Kiers H, van Dieën JH. Low back pain and postural sway during quiet standing with and without sensory manipulation: a systematic review. Gait Posture 2013;37(1):12–22.
[12] Berenshteyn Y, Gibson K, Hackett GC, Trem AB, Wilhelm M. Is standing balance altered in individuals with chronic low back pain? A systematic review. Disabil Rehabil 2019;41(13):1514–23.
[13] Koch C, Hänsel F. Non-specific low back pain and postural control during quiet standing-a systematic review. Front Psychol 2019;10:586.
[14] Ruhe A, Fejer R, Walker B. The test-retest reliability of centre of pressure measures in bipedal static task conditions−a systematic review of the literature. Gait Posture 2010;32(4):436–45.
[15] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61(4):344–9.
[16] Luomajoki H, Kool J, de Bruin ED, Airaksinen O. Reliability of movement control tests in the lumbar spine. BMC Musculoskelet Disord 2007;8:90.
[17] Wrisley DM, Whitney SL. The effect of foot position on the modified clinical test of sensory interaction and balance. Arch Phys Med Rehabil 2004;85(2):335–8.
[18] Chen B, Liu P, Xiao F, Liu Z, Wang Y. Review of the upright balance assessment based on the force plate. Int J Environ Res Public Health 2021;18(5). https://www.mdpi.com/1660-4601/18/5/2696.
[19] Horn LB, Rice T, Stoskus JL, Lambert KH, Dannenbaum E, Scherer MR. Measurement Characteristics and Clinical Utility of the Clinical Test of Sensory Interaction on Balance (CTSIB) and modified CTSIB in individuals with vestibular dysfunction. Arch Phys Med Rehabil 2015;96(9):1747–8.
[20] Hoy D, March L, Brooks P, Blyth F, Woolf A, Bain C, et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis 2014;73(6):968–74.
[21] Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ 2006;332(7555):1430–4.
[22] Haefeli M, Elfering A. Pain assessment. Eur Spine J 2006;15(Suppl 1):S17–24.
[23] Mayer TG, Neblett R, Cohen H, Howard KJ, Choi YH, Williams MJ, et al. The development and psychometric validation of the central sensitization inventory. Pain Pract 2012;12(4):276–85.
[24] Neblett R. The central sensitization inventory: a user's manual. J Appl Behav Res 2018.
[25] Luomajoki H, Airaksinen O, Neblett R, Selander T, Leinonen V. Cross-cultural adaptation and validation of the Finnish version of the central sensitization inventory and its relationship with dizziness and postural control. BMC Neurol 2021;21(1):141.
[26] Núñez-Fuentes D, Obrero-Gaitán E, Zagalaz-Anula N, Ibáñez-Vera AJ, Achalandabaso-Ochoa A, López-Ruiz MDC, et al. Alteration of postural balance in patients with fibromyalgia syndrome-a systematic review and meta-analysis. Diagnostics (Basel) 2021;11(1).
[27] Peinado-Rubia A, Osuna-Pérez MC, Rodríguez-Almagro D, Zagalaz-Anula N, López-Ruiz MC, Lomas-Vega R. Impaired balance in patients with fibromyalgia syndrome: predictors of the impact of this disorder and balance confidence. Int J Environ Res Public Health 2020;17(9).
[28] Nota A, Tecco S, Ehsani S, Padulo J, Baldini A. Postural stability in subjects with temporomandibular disorders and healthy controls: a comparative assessment. J Electromyogr Kinesiol 2017;37:21–4.
[29] Balaban CD, Black RD, Silberstein SD. Vestibular neuroscience for the headache specialist. Headache 2019;59(7):1109–27.
[30] Sremakaew M, Sungkarat S, Treleaven J, Uthaikhup S. Impaired standing balance in Individuals with cervicogenic headache and migraine. J Oral Facial Pain Headache 2018;32(3):321–8.
[31] Miller RP, Kori SH, Todd DD. The Tampa scale. A measure of Kinesiophobia. Clin J Pain 1991;7(1).
[32] Koho P, Borodulin K, Kautiainen H, Kujala U, Pohjolainen T, Hurri H. Finnish version of the Tampa Scale of Kinesiophobia: reference values in the Finnish general population and associations with leisure-time physical activity. J Rehabil Med 2015;47(3):249–55.
[33] Poutanen O, Koivisto AM, Kääriä S, Salokangas RK. The validity of the Depression Scale (DEPS) to assess the severity of depression in primary care patients. Fam Pract 2010;27(5):527–34.
[34] Kyrölä K, Häkkinen AH, Ylinen J, Repo JP. Rasch validation of the Depression Scale among patients with low back pain. J Back Musculoskelet Rehabil 2020;34(2):261–7.
[35] Janssen MF, Pickard AS, Golicki D, Gudex C, Niewada M, Scalone L, et al. Measurement properties of the EQ-5D-5L compared to the EQ-5D-3L across eight patient groups: a multi-country study. Qual Life Res 2013;22(7):1717–27.
[36] van Hout B, Janssen MF, Feng YS, Kohlmann T, Busschbach J, Golicki D, et al. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. Value Health 2012;15(5):708–15.
[37] Stevens ML, Lin CC, Maher CG. The roland morris disability questionnaire. J Physiother 2016;62(2):116.

[38] Roland M, Fairbank J. The roland-morris disability questionnaire and the oswestry disability questionnaire. Spine (Phila Pa 1976 2000;25 (24):3115–24.

[39] Ayearst L, Harsanyi Z, Michalko KJ. The Pain and Sleep Questionnaire three-item index (PSQ-3): a reliable and valid measure of the impact of pain on sleep in chronic nonmalignant pain of various etiologies. Pain Res Manag 2012;17(4):281–90.

[40] Mikkonen J, Leinonen V, Luomajoki H, Kaski D, Kupari S, Tarvainen M, et al. Cross-cultural adaptation, reliability, and psychophysical validation of the pain and sleep questionnaire three-item index in Finnish. J Clin Med 2021;10(21):4887.

[41] Akoglu H. User's guide to correlation coefficients. Turk J Emerg Med 2018;18(3):91–3.

[42] Jeka J, Kiemel T, Creath R, Horak F, Peterka R. Controlling human upright posture: velocity information is more accurate than position or acceleration. J Neurophysiol 2004;92(4):2368–79.

[43] Era P, Sainio P, Koskinen S, Haavisto P, Vaara M, Aromaa A. Postural balance in a random sample of 7,979 subjects aged 30 years and over. Gerontology 2006;52(4):204–13.

[44] Ruhe A, Fejer R, Walker B. Is there a relationship between pain intensity and postural sway in patients with non-specific low back pain? BMC Musculoskelet Disord 2011;12:162.

[45] Maribo T, Schiøttz-Christensen B, Jensen LD, Andersen NT, Stengaard-Pedersen K. Postural balance in low back pain patients: criterion-related validity of centre of pressure assessed on a portable force platform. Eur Spine J 2012;21(3):425–31.

[46] Degache F, Goy Y, Vat S, Haba Rubio J, Contal O, Heinzer R. Sleep-disordered breathing and daytime postural stability. Thorax 2016;71 (6):543–8.

[47] Furtado F, Gonçalves BD, Abranches IL, Abrantes AF. Chronic low quality sleep impairs postural control in healthy adults. PLoS One 2016;11(10):e0163310.

[48] Mazaheri M, Heidari E, Mostamand J, Negahban H, van Dieen JH. Competing effects of pain and fear of pain on postural control in low back pain? Spine (Phila Pa 1976) 2014;39(25):E1518–23.

[49] Buchbinder R, Underwood M, Hartvigsen J, Maher CG. The Lancet Series call to action to reduce low value care for low back pain: an update. Pain 2020;161(Suppl 1):S57–64.

[50] McCaskey MA, Wirth B, Schuster-Amft C, de Bruin ED. Postural sensorimotor training versus sham exercise in physiotherapy of patients with chronic non-specific low back pain: an exploratory randomised controlled trial. PLoS One 2018;13(3):e0193358.

[51] Maher C, Underwood M, Buchbinder R. Non-specific low back pain. Lancet 2017;389(10070):736–47.