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The Influence of Centralization and Directional Preference on Spinal Control in Patients With Nonspecific Low Back Pain

STUDY DESIGN: Prospective cohort, test-retest design.

BACKGROUND: Directional preference (DP) with centralization (CEN) and DP without CEN are common pain-pattern responses assessed by Mechanical Diagnosis and Therapy (MDT). Although there is evidence that MDT can reduce pain and disability in the short term by treating the patient with direction-specific exercises concordant with the patient's DP, the mechanism responsible for this is unclear.

OBJECTIVE: To determine whether clinical signs of impaired spinal control improve immediately after eliciting a DP-with-CEN response or a DP-without-CEN response in patients with nonspecific low back pain.

METHODS: Participants underwent a standardized MDT assessment and were classified into the following pain-pattern subgroups: DP with CEN, DP without CEN, or no DP. Clinical signs of impaired spinal control were assessed pre–MDT assessment and post–MDT assessment by an independent examiner. Four spinal control tests were conducted: aberrant lumbar movements while bending forward, the active straight leg raise (ASLR) test, the Trendelenburg test, and the prone instability test. Differences in spinal control pre–MDT assessment and post–MDT assessment were calculated for the 3 pain-pattern subgroups and compared with chi-square tests. We hypothesized that a larger proportion of patients in the DP-with-CEN subgroup would exhibit improved spinal control than patients categorized as DP without CEN or no DP.

RESULTS: Of 114 patients recruited, 51 patients (44.7%) were categorized as DP with CEN, 23 (20.2%) as DP without CEN, and 40 (35.1%) as no DP. Before MDT assessment, between 28.9% (Trendelenburg test) and 63.7% (ASLR test) of patients showed impaired spinal control. After MDT assessment, a larger proportion of patients in the DP-with-CEN subgroup (43%) showed improvement than those in the no-DP subgroup (7%) on aberrant lumbar movements ($P = .02$). Likewise, more patients in the DP-with-CEN subgroup (50%) improved on the ASLR test than those in the no-DP subgroup (8%, $P<.01$) or the DP-without-CEN subgroup (7%, $P = .01$). Changes in Trendelenburg test and prone instability test outcomes did not reach statistical significance.

CONCLUSION: Immediately following MDT assessment, a larger proportion of patients with a DP-with-CEN pain pattern showed improvement in clinical signs of spinal control compared to patients with a DP-without-CEN or no-DP pain pattern. The current study was registered in the Dutch trial registry at http://www.trialregister.nl/trialreg/index.asp (NTR4246).

LEVEL OF EVIDENCE: Therapy, level 2b.

J Orthop Sports Phys Ther 2016;46(4):258-269. Epub 26 Jan 2016. doi:10.2519/jospt.2016.6158

KEY WORDS: *Mechanical Diagnosis and Therapy, motor control, physical therapy*

A key challenge in low back pain (LBP) research is the identification of homogeneous subgroups according to evidence-based classification systems.[11] One classification system that has the potential to improve outcomes is the Mechanical Diagnosis and Therapy (MDT), or McKenzie, method.[12,32,33] Classification according to this approach uses the patient's history, clinical presentation, and a physical examination. Patients are categorized into 1 of 3 main syndromes (derangement, dysfunction, and posture) to guide treatment decisions.

In MDT, important clinical signs and symptoms are centralization (CEN) and directional preference (DP). Centralization and DP are nontransient therapeutic responses that are elicited during the

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MDT assessment and observed in some patients. Centralization is a phenomenon by which distal pain originating from the spine progressively moves to, and remains in, a more central location in response to certain postures or repeated end-range movements. When only mid-lumbar pain is present, CEN requires resolution of the pain or reduction in the area of pain. Directional preference encompasses a broader range of responses than CEN and describes the clinical phenomenon in which certain postures or repeated end-range movements result in a clinically relevant, lasting decrease in symptom severity and/or positive mechanical response, such as an increase in range of motion (ROM), though not always a change in location of pain.[33] Thus, all patients categorized as CEN have a DP, but some patients with a DP do not have CEN.[51] Patients who have a response of DP with CEN or a response of DP without CEN are prescribed direction-specific exercises concordant with their DP.

Although the underlying physiologic mechanisms are still uncertain, DP with CEN and DP without CEN have been studied extensively. Research has shown that pain diminishes and mobility improves more rapidly in patients who receive direction-specific exercises concordant with their DP (eg, extension exercises) than in patients receiving nonconcordant exercises, or in patients without a DP.[8,28] Directional preference with CEN and DP without CEN appear to be useful treatment-effect modifiers and indicators of prognosis,[17,32] although recent research suggests that DP without CEN may be a less useful prognostic indicator than DP with CEN.[53] Clinicians who use MDT frequently observe rapid improvements in spinal control (a better balance between stiffness and movement[19]) or a reduction in neurological signs (eg, improvement in muscle power of the calf) when patients with DP with CEN or DP without CEN are treated with direction-specific exercises.[29] This rapid and spontaneous improvement in spinal control in patients who receive direction-specific exercises matching their DP could be an important clinical finding. Impaired spinal control may potentially be an important factor in the persistence or recurrence of nonspecific LBP.[19] Moreover, understanding the influence of MDT on spinal control may provide additional insight into the mechanisms mediating outcomes of MDT. Furthermore, if MDT can improve spinal control rapidly in a specific subgroup of patients with LBP, then it is reasonable to suggest that, for this subgroup, the MDT method could be a useful alternative or supportive treatment in spinal control management.

Based on the absence of evidence to explain the underlying physiologic mechanism of DP with CEN and DP without CEN, the primary aim of this study was to systematically evaluate whether clinical signs of impaired spinal control improve in patients with nonspecific LBP after an MDT assessment, and whether this differs between the 3 MDT pain-pattern subgroups (DP with CEN, DP without CEN, and no DP). Following recent research suggesting that DP without CEN might be a less useful prognostic indicator than DP with CEN,[53] we hypothesized that a larger proportion of patients in the DP-with-CEN subgroup would exhibit improved spinal control than patients categorized as DP without CEN or no DP. The secondary aim was to evaluate whether pain severity and ROM would improve after an MDT assessment, and whether these improvements would be related to the 3 MDT pain-pattern subgroups.

METHODS

This study was a single-group, within-subject, test-retest design. The Institutional Scientific Review Board of the EMGO Institute for Health and Care Research (VU University Medical Center in Amsterdam, the Netherlands) approved the study. The Medical Ethics Committee of the VU University Medical Center concluded that no formal approval was required according to the Dutch Medical Research Involving Human Subjects Act (registration number 2013\16). The current study was registered in the Dutch trial registry at http://www.trialregister.nl/trialreg/index.asp (NTR4246).

Patients

Patients were recruited from 3 private multidisciplinary clinics in the Netherlands (Medical Back Neck Center in The Hague, and the Rugpoli in Delden and Tilburg), and from 1 private physical therapy practice in Belgium (McKenzie Clinic Limburg in Maasmechelen). Consecutive patients presenting for treatment of LBP received written information about the study. Eligibility criteria were LBP as the primary complaint, with or without associated leg pain; visiting the practice for the first, second, or third time for the current LBP episode; aged over 17 years; and able to read and write Dutch. Patients were excluded if they had known or suspected specific LBP (eg, cauda equina compression, fractures), severe radiculopathy, spondylolisthesis (grade 2 or greater), serious comorbidity (eg, metastases, AIDS, cerebrovascular accident), psychopathology, were currently pregnant or had given birth in the past 3 months, had lumbar spinal surgery in the previous 6 months, or had personal reasons not to participate. Patients with mild sensory loss and diminished myotomal strength on the ipsilateral lower extremity of not less than 4 with standardized manual muscle testing (0-5 scale)[22] were not excluded.

Examination Procedures

Patients received written information about the study at or before their first MDT assessment at the practice. For ethical reasons patients were given at least 2 days to consider their participation in the study. Patients were usually assessed at either their first or second visit. A few were assessed at their third visit, as they required more time to decide on participation. Information was collected from the patients regarding sex, age, duration of symptoms, previous history of LBP,

pain intensity, functional status, education, and employment and psychosocial status. All patients received standardized assessment of spinal control via a set of 4 standardized clinical tests by an independent examiner. Immediately after this, patients received a standardized MDT assessment by an examiner with a diploma in MDT. After MDT assessment, a follow-up examination was conducted and the same independent examiner (who was blinded to the outcome of the MDT assessment) assessed spinal control with the same 4 standardized spinal control tests. Written evaluations of the examiners who assessed spinal control and of those with diplomas in MDT were placed in envelopes to ensure that the examiners were blind to each other's findings during the study. Patients were unaware of the hypothesis under investigation and were told not to discuss findings of the MDT assessment or of the spinal control tests with the examiners. All participating clinicians received written instructions regarding all study procedures.

Examiners of Spinal Control

Participating examiners of spinal control (n = 10) were 7 physical therapists, all credentialed in MDT and with 7 to 28 years of experience in orthopaedic settings, and 3 medical doctors, each with more than 30 years of experience in orthopaedic settings. The mean age of the examiners was 47 years (range, 31-59 years).

MDT Clinicians

All MDT assessment procedures were conducted by 4 clinicians who had received diploma-level training in MDT, which is the most advanced level of training in the MDT system. The 4 examiners with diplomas in MDT ranged in age between 41 and 51 years, had 14 to 23 years of experience in MDT, and had 18 to 28 years of experience in treating patients with LBP. Recently, Werneke et al[52] published a large interrater reliability study of the MDT system with MDT-trained examiners. The study used a formal MDT procedure and independent, consecutive examinations in patients with LBP. The study showed that agreement percentages for categorizing patients in 1 of 4 MDT subgroups (postural, dysfunction, derangement, and other) were satisfactory, but the kappa values were low. Compared to the examiners with diplomas in MDT in the present study, the examiners in the study by Werneke et al[52] had a lower level of training (levels A through D). May and Aina[32] found in a systematic review that more training in the MDT approach was associated with higher levels of reliability.

Spinal Control Assessment

It has been proposed that spinal control may be related to LBP and relevant in clinical management.[19] However, there are fundamental questions regarding its clinical presentation and assessment. A simple, reliable, and valid tool for quantifying spinal control in clinical practice is still lacking.[19] In the present study, 4 clinical spinal control tests with some evidence supporting their reliability were selected. They are used frequently in daily practice and research and are easy to conduct. Recently, 3 of the 4 tests (aberrant lumbar movements, the active straight leg raise [ASLR] test, and the prone instability test [PIT]) were recommended in clinical practice guidelines for LBP.[12] The 4 tests were standardized, and operational definitions are provided in the **APPENDIX**.

Aberrant Lumbar Movements Aberrant lumbar movements are among the strongest identifiers of clinical lumbar instability selected by Delphi participants.[9] In the present study, aberrant lumbar movements were assessed as described by Hicks et al.[18] The patient is assessed in standing and is asked to flex forward as far as possible and return to standing. Aberrant movements included the presence of instability catch, painful arc of motion in flexion, painful arc on return from flexion, thigh climbing, or reversal of lumbopelvic rhythm. Four interrater reliability studies[14,18,41,47] have shown conflicting findings, with agreement rates of 50%[47] to 84%[18] and kappa values of 0.00[47] to 0.64.[41]

The ASLR Test The ASLR test was originally introduced as a test to diagnose posterior pelvic pain after pregnancy.[36,37] The ASLR test assesses the ability to transfer load between the lumbopelvic region and the legs while lying in supine, and is also used in patients with nonspecific LBP to assess spinal stability and lumbopelvic motor control.[27,43] The patient scores the ASLR for each leg on a 6-point Likert scale ranging from 0 (not difficult at all) to 5 (unable to do). The final score ranges between 0 and 10, as both sides are summed. Scores were trichotomized as 0 (no load-transfer dysfunction), 1 to 4 (medium load-transfer dysfunction), and 5 to 10 (severe load-transfer dysfunction).[34] Scores on the ASLR test have moderate to substantial correlation with objective isometric forces recorded with a digital force gauge, irrespective of the height of the leg raise (0 or 20 cm).[35] The test-retest reliability with a 1-week time interval was shown to be adequate in a group of 50 women with lumbopelvic pain (Pearson correlation coefficient = 0.87 and intraclass correlation coefficient = 0.83).[36] In patients with LBP, interrater reliability varies from moderate (κ = 0.53; 95% confidence interval [CI]: 0.20, 0.84) to very good (κ = 0.87; 95% CI: 0.77, 1.00).[25,41,43]

The Trendelenburg Test The Trendelenburg test, or standing hip flexion test, was described by Friedrich Trendelenburg to determine the integrity of hip abductor muscle function, with specific reference to congenital dislocation of the hip and progressive muscular atrophy.[42] However, in the present study, this test was used to assess the ability to transfer load between the lumbopelvic region and the legs in standing. The test has been extensively investigated, and different methods of performing the test exist.[1,10,31,43,48] In the present study, the test was performed as indicated in Albert et al.[1] The patient is instructed to raise 1 leg at 90° of hip flexion. The test is positive if the pelvis is descending on the flexed side. As far as the authors know, no data are avail-

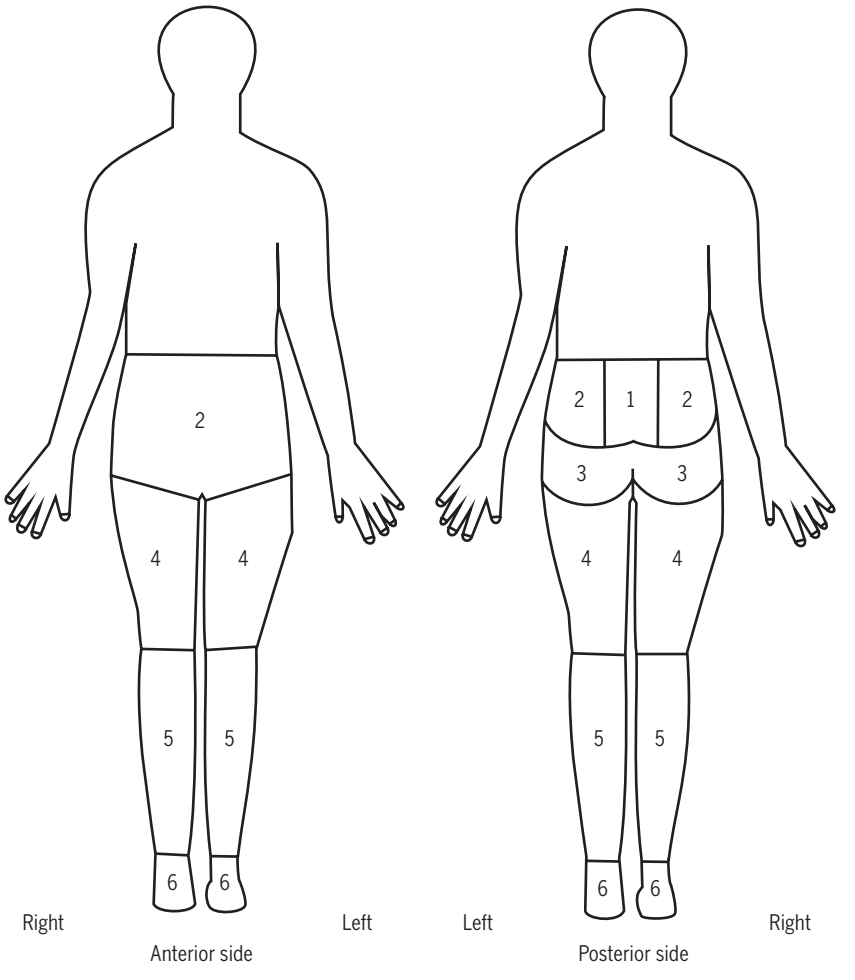

FIGURE. Body pain diagram.

able regarding the reliability or validity of this version of the Trendelenburg test in patients with nonspecific LBP.

The PIT In contrast to the other 3 tests, the PIT is a pain-provocation test that is intended to apply a shear load across the lumbar spine. The examiner applies posterior/anterior (PA) forces on the patient's lumbar spine while the patient lies prone on the examination table, with the legs over the edge of the table and the feet resting on the floor. The PA provocation test is first applied with the patient's low back muscles in a resting state, then with an active contraction of the back extensors. If pain is produced with muscles relaxed but does not occur when muscles are activated, it is assumed that the activity of the lumbar extensors has reduced the shearing forces, indicating the presence of passive instability. Four studies have found acceptable interrater reliability values of the PIT,[14,18,41,47] and agreement rates range between 68%[47] and 91%[18] and kappa values between 0.30[47] and 0.87.[18]

MDT Assessment

The examiners with diplomas in MDT conducted a comprehensive MDT assessment of approximately half an hour in duration. This MDT assessment included standardized history taking (eg, frequency of episodes, current duration, intensity, and location of symptoms) and monitoring of symptomatic and mechanical responses during repetitive end-range lumbar test movements (flexion, extension, sidegliding, and/or flexion-rotation) and/or prolonged positioning. Before and after MDT assessment, each patient was asked to record the location of any current symptoms on a body diagram and the intensity of their current most distal pain on a numeric rating scale (NRS; 0-10) in standing. The body diagram was divided into 6 sections, from 1 to 6 (1, pain/symptoms around the lumbar segments; 6, pain/symptoms in the foot) (**FIGURE**).

Patients were categorized as DP with CEN, DP without CEN, or no DP. A patient was classified as the three pain-pattern subgroups if the most distal location of the pain moved to a more central position for at least 1 region (eg, from 4 [thigh] to 3 [gluteal]) after MDT assessment. Interrater reliability for documenting the 3 pain-pattern subgroups using body diagrams has demonstrated almost perfect agreement (κ = 0.96-1.00).[50]

A patient was classified as DP without CEN if there was a clear DP (eg, more pain with flexion and less pain with extension or a large improvement of lumbar active range of motion [AROM]) without CEN, and as no DP if there was no DP with CEN and no DP without CEN. Patients with a no-DP classification were categorized into 1 of the following MDT classifications: postural or dysfunction syndrome, irreducible derangement, nonmechanical condition, pain not presumed to originate from the lumbar spine (eg, sacroiliac joint pain), or inconclusive.

Immediately before and after MDT assessment, the examiner with a diploma in MDT measured patients' active lumbar flexion and extension ROM with the modified Schober skin distraction method[49] and patients' fingertip-to-floor distance while bending with straight knees (centimeters).[40] For the first 2 measurements, the examiner placed 2 marks on the lumbosacral spine, the first mark in the middle of the line joining the dimples of Venus and the second mark 15 cm above the first mark. The lumbar flexion AROM is measured on a continuous

TABLE 1 Baseline Patient Characteristics

Characteristic	Total Sample (n = 114)	DP With CEN (n = 51)	DP Without CEN (n = 23)	No DP (n = 40)
Age, y*	43.9 ± 11.2	44.9 ± 10.4	41.1 ± 11.7	44.1 ± 12.1
Female, %	51.8	56.0	40.9	52.6
History of LBP				
Time since first LBP episode, mo†	72.0 (19.0-186.0)	72.0 (21.0-210.0)	72.0 (19.0-186.0)	66.0 (12.8-186.0)
Previous episodes of LBP, %	66.1	70.0	76.2	55.3
Duration of current LBP, mo†	6.0 (1.2-24.0)	3.9 (0.9-13.5)	3.0 (0.6-14.0)	12.0 (3.7-41.3)
0-6 wk, %	28.4	38.0	42.9	7.9
7-12 wk, %	8.3	10.0	4.8	7.9
>12 wk, %	63.3	52.0	52.4	84.2
LBP past week (NRS, 0-10)*	5.2 ± 2.5	5.2 ± 2.3	5.7 ± 2.8	4.8 ± 2.7
Leg pain past week (NRS, 0-10)†‡	3.0 (0.0-6.0)	3.0 (0.0-5.3)	4.0 (0.5-5.5)	4.0 (0.0-6.3)
Pain radiated into the leg, %	43.0	43.1	39.1	45.0
Active lumbar flexion ROM (modified Schober), cm*§	20.0 ± 1.8	20.1 ± 1.8	19.7 ± 2.1	20.0 ± 1.6
Active lumbar extension ROM (modified Schober), cm*‖	13.3 ± 0.9	13.1 ± 0.9	13.5 ± 0.7	13.6 ± 0.8
Fingertip-to-floor distance while bending with straight knees, cm†	12.0 (0.0-26.0)	11.0 (0.0-19.0)	25.0 (10.0-34.0)	11.5 (0.8-24.8)
Oswestry Disability Index (0-100)*	25.2 ± 15.5	23.8 ± 13.4	24.5 ± 15.3	27.4 ± 18.3
Education, n (%)				
Low	13.2	16.7	9.5	10.8
Middle	33.0	27.1	42.9	35.1
High	53.8	56.3	47.6	54.1
Employed, %	83.5	82.0	95.2	78.9
Employed and currently working, %	72.7	73.2	72.2	72.2
Employed but currently on sick leave, %	27.3	26.8	27.8	27.6
ÖMPSQ (0-210)†¶	86.0 (63.8-104.3)	84.0 (64.0-99.0)	85.0 (66.0-93.0)	86.0 (56.5-126.7)
SF-36¶				
Physical component summary (0-100)*	39.7 ± 8.6	38.8 ± 7.8	40.1 ± 8.2	40.3 ± 9.9
Mental component summary (0-100)*	47.4 ± 11.6	46.7 ± 11.4	49.5 ± 11.5	47.4 ± 12.0

Abbreviations: CEN, centralization; DP, directional preference; LBP, low back pain; NRS, numeric rating scale; ÖMPSQ, Örebro Musculoskeletal Pain Screening Questionnaire; ROM, range of motion; SF-36, Medical Outcomes Study 36-Item Short-Form Health Survey.
**Values are mean ± SD.*
†Values are median (interquartile range).
‡Calculated for all patients.
§Range, 15 cm (no mobility) to 25 cm (hypermobility).
‖Range, 15 cm (no mobility) to 10 cm (hypermobility).
¶Missing data for the ÖMPSQ (6.8%) and the SF-36 (5.8%) were imputed using the expectation maximization method.

scale, with values from 15 cm (no flexion mobility) to greater than 15 cm, and the opposite for extension ROM, with values from 15 cm (no extension mobility) to less than 15 cm. For the third measurement, the fingertip-to-floor test, mobility values vary from 0 cm, indicating normal or hypermobility, to values of ±50 cm and above, indicating hypomobility. The measurements have been found to be reliable and valid in clinical practice.[4,40,49]

Sample-Size Estimation

The prevalence rates of the pain patterns DP with CEN, DP without CEN, and no DP were expected to be around 40%, 30%, and 30%, respectively.[32,50] The proportion of positive (impaired) spinal con-

TABLE 2 Results of Spinal Control Tests Before and After 1 Mechanical Diagnosis and Therapy Assessment*

	DP With CEN (n = 51)			DP Without CEN (n = 23)			No DP (n = 40)					
	Pretest	Posttest	Change, n (%)	Pretest	Posttest	Change, n (%)	Pretest	Posttest	Change, n (%)	DP With CEN-DP Without CEN†	DP With CEN-No DP†	DP Without CEN-No DP†
Positive results												
ALM	30	17	−13 (43)	5	4	−1 (20)	15	14	−1 (7)	.63	.02‡	.45
ASLR	32	16	−16 (50)	15	14	−1 (7)	25	23	−2 (8)	.01‡	<.01‡	1.0
Trendelenburg test	13	7	−6 (46)	8	4	−4 (50)	12	8	−4 (33)	1.0	.69	.65
PIT	19	7	−12 (63)	7	1	−6 (86)	16	10	−6 (38)	.38	.18	.07
Negative results												
ALM	21	20	−1 (5)	16	15	−1 (6)	25	25	0 (0)	1.0	.46	.39
ASLR	19	18	−1 (5)	8	7	−1 (13)	14	14	0 (0)	1.0	1.0	.36
Trendelenburg test	38	36	−2 (5)	15	15	0 (0)	28	28	0 (0)	1.0	.50	NA
PIT	31	28	−3 (10)	15	13	−2 (13)	23	22	−1 (4)	1.0	.63	.55

Abbreviations: ALM, aberrant lumbar movements; ASLR, active straight leg raise; CEN, centralization; DP, directional preference; NA, not applicable; PIT, prone instability test.
**Values are n unless otherwise indicated.*
†P value for chi-square test.
‡Significant difference between groups in the proportion of patients who changed test status from pretest to posttest, by chi-square test.

trol tests was expected to be around 30% for all 4 tests before MDT assessment.[5] Sample-size calculations were based on the assumption that there would be 50% fewer positive spinal control tests in patients with DP with CEN, and 0% fewer in patients with DP without CEN and no DP. It was estimated that negative spinal control tests would remain negative after MDT assessment for all 3 pain-pattern subgroups (DP with CEN, DP without CEN, and no DP). To detect a significant difference between participants with DP with CEN and DP without CEN or no DP, 75 patients would be needed (power = 0.9 and α = .05). To account for possible overestimation of the prevalence rates and spinal control results, the plan was to recruit at least 100 patients in total and at least 50 patients with a pain pattern of DP with CEN.

Data Analysis

Descriptive statistics and frequency distributions of all variables were assessed. Missing items from the Örebro Musculoskeletal Pain Screening Questionnaire (ÖMPSQ) and the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) were imputed using the expectation maximization method using IBM SPSS Statistics Version 22.0 (IBM Corporation, Armonk, NY), which estimates missing values by an iterative process. The proportion of positive spinal control tests assessed before and after the MDT assessment was calculated, as well as the proportion of the 3 pain-pattern subgroups (DP with CEN, DP without CEN, and no DP). Differences in baseline characteristics between the 3 pain-pattern subgroups were analyzed with appropriate methods (chi-square tests, Mann-Whitney tests, and unpaired *t* tests). The differences between spinal control results pre-MDT and post-MDT were calculated as a percentage within each pain-pattern subgroup and analyzed with pairwise chi-square tests. Aberrant lumbar movements, the Trendelenburg test, and the PIT were scored as positive or negative. To calculate differences in the ASLR score, the present study used the trichotomized ASLR score (0, 1-4, 5-10).[34] A patient's spinal control improved or worsened if the ASLR score changed 1 or 2 categories.

In secondary analyses, differences between patients' most distal current pain, lumbar flexion and extension ROM, and fingertip-to-floor distance before and after MDT assessment were analyzed by the Wilcoxon matched-pairs signed-rank test. Generalized estimating equations were used to analyze whether differences between pre–MDT assessment and post–MDT assessment scores differed between the 3 pain-pattern subgroups. Generalized estimating equations are a generalization of generalized linear model approaches that take into account within-group correlations. For all tests, $P<.05$ was considered significant. The data were analyzed using IBM SPSS Statistics Version 22.0.

RESULTS

Between March and October 2013, 114 patients were recruited (52% female, 48% male). Although no data about the number of potential eligible patients were collected, it was

TABLE 3 Current Distal Pain and Lumbar Mobility Before and Immediately After 1 Mechanical Diagnosis and Therapy Assessment*

	DP With CEN (n = 51)		DP Without CEN (n = 23)		No DP (n = 40)				
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	DP With CEN-DP Without CEN†	DP With CEN-No DP†	DP Without CEN-No DP†
CMDP (NRS, 0-10)	3.0 (2.0-6.0)	0.0 (0.0-3.0)‡	4.0 (3.0-7.0)	2.0 (1.0-4.0)‡	4.0 (1.0-6.8)	4.0 (1.0-7.0)	0.6 (−0.4, 1.6)	1.1 (0.2, 2.1)§	0.6 (−0.7, 1.8)
Flex AROM (MS), cm‖	20.0 (18.5-21.1)	21.0 (19.0-22.0)‡	20.0 (18.5-21.0)	21.0 (19.5-21.5)‡	20.0 (19.0-21.0)	20.0 (19.6-21.8)‡	0.2 (−0.6, 1.0)	0.2 (−0.5, 0.9)	0.04 (−0.7, 0.8)
Ext AROM (MS), cm¶	13.0 (12.5-13.5)	12.5 (11.3-13.0)‡	13.5 (13.0-14.0)	13.0 (12.0-14.0)‡	13.5 (13.0-14.0)	13.3 (13.0-14.0)	0.5 (0.1, 0.9)§	0.8 (0.5, 1.2)§	0.3 (−0.1, 0.7)
FtF distance, cm#	11.0 (0.0-19.0)	5.0 (0.0-17.0)‡	25.0 (10.0-34.0)	22.0 (7.0-28.0)‡	11.5 (0.8-24.8)	10.5 (0.0-23.8)	8.4 (1.1, 15.7)§	2.3 (−3.3, 7.9)	−6.1 (−13.8, 1.6)

Abbreviations: AROM, active range of motion; CEN, centralization; CMDP, current most distal pain; DP, directional preference; Ext, extension; Flex, flexion; FtF, fingertip to floor; MS, modified Schober; NRS, numeric rating scale.
**Values are median (interquartile range) unless otherwise indicated.*
†Values are regression coefficient (95% confidence interval).
‡Statistically significant difference (P<.05) from pretest to posttest, by the Wilcoxon matched-pairs signed-rank test.
§Statistically significant difference (P<.05) between groups from pretest to posttest, by generalized estimating equation adjusted for duration of low back pain. Positive values denote a reduction in pain or improved mobility.
‖Range, 15 cm (no mobility) to 25 cm (hypermobility).
¶Range, 15 cm (no mobility) to 10 cm (hypermobility).
#While bending with straight knees.

estimated that approximately 10% of eligible patients did not participate, mostly due to the patient's lack of time or the examiner's unavailability. Patients were assessed during their first (58.2%), second (25.5%), or third visit (16.3%) for the current LBP episode. Their mean ± SD age was 43.9 ± 11.2 years, and the median duration of their LBP was 6 months (interquartile range, 1.2-24.0 months). Missing data on the ÖMPSQ (6.8%) and the SF-36 (5.8%) were imputed using the expectation maximization method. **TABLE 1** shows the descriptive statistics for the main characteristics of the participating patients. With respect to baseline characteristics, the 3 pain-pattern subgroups were significantly different for duration of current LBP (DP with CEN and DP without CEN, shorter duration compared to no DP) and for AROM (DP with CEN, more extension AROM compared to no DP and less fingertip-to-floor distance compared to DP without CEN).

Fifty-one patients (44.7%) were categorized as DP with CEN, 23 (20.2%) as DP without CEN, and 40 (35.1%) as no DP (**TABLE 2**). Nine patients reported no pain before MDT assessment. Four of these patients were classified as DP without CEN and 5 as no DP (2 dysfunction syndrome, 1 sacroiliac joint pain, and 2 inconclusive) by their MDT clinician. Prior to MDT assessment, the proportions of positive spinal control tests were 44.6% for aberrant lumbar movements (50/112), 63.7% for the ASLR test (score greater than 0) (72/113), 28.9% for the Trendelenburg test (33/114), and 37.8% for the PIT (42/111). The rate of missing data for spinal control tests was low (1.1%).

The percentage of participants who improved on the spinal control tests after MDT assessment varied from 43% to 63% for DP with CEN, 7% to 86% for DP without CEN, and 7% to 38% for no DP (**TABLE 2**). A larger proportion of patients in the subgroup DP with CEN (43%) improved compared to those in the no-DP subgroup (7%) on aberrant lumbar movements (P = .02). Likewise, more patients in the DP-with-CEN subgroup (50%) improved on the ASLR test than did those in the no-DP subgroup (8%, P<.01) or the DP-without-CEN subgroup (7%, P = .01). Changes in proportions of positive Trendelenburg tests or PITs were consistent in direction but not statistically significant (**TABLE 2**). The percentage of patients who showed deteriorating spinal control varied between 5% and 10% for DP with CEN, 0% and 13% for DP without CEN, and 0% and 4% for no DP, and these proportions were not statistically significantly different (**TABLE 2**).

In contrast to patients with no DP, patients with a DP-with-CEN or a DP-without-CEN pain pattern experienced a statistically (P<.05) and clinically relevant reduction (2 or greater on the NRS) of their most distal pain (**TABLE 3**).[39] Four patients experienced substantially more pain after the MDT assessment: 2 patients reported an increase of 2 points, and 2 an increase of 3 points, on the NRS. For the subgroups of DP with CEN and DP without CEN, patients' lumbar flexion and extension AROM improved significantly after 1 MDT assessment. For the subgroup of no DP, only lumbar flexion AROM improved significantly (**TABLE 3**).

A generalized estimating equation adjusted for duration of LBP was used to examine differences between pre–MDT assessment and post–MDT assessment

for the 3 pain-pattern subgroups in pain and AROM. Patients with a DP with CEN showed a greater increase in extension AROM compared to those with no DP (0.8 cm; 95% CI: 0.5, 1.2; $P<.001$) and to those with DP without CEN (0.5 cm; 95% CI: 0.1, 0.9; $P = .01$). Likewise, patients with a DP with CEN showed a greater reduction in fingertip-to-floor distance compared to those with DP without CEN (8.4 cm; 95% CI: 1.1, 15.7; $P = .02$) and more reduction in current most distal pain compared to those with no DP (1.1; 95% CI: 0.2, 2.1; $P = .02$) (**TABLE 3**).

DISCUSSION

To our knowledge, this is the first study that has systematically assessed the influences of DP with CEN and DP without CEN on clinical signs of impaired spinal control in patients with LBP. In line with our hypotheses, immediately after MDT assessment, a larger proportion of patients with a DP-with-CEN pain pattern showed improvement on spinal control tests than did those in the DP-without-CEN and no-DP subgroups. Furthermore, some measures of lumbar AROM improved significantly more in patients with a DP-with-CEN pain pattern than those with a DP-without-CEN or no-DP pain pattern. Our hypotheses were based on a study by Werneke et al,[53] which found that in 584 patients with LBP, functional status results at discharge from rehabilitation were better in patients classified as DP with CEN compared to DP without CEN or no DP. The findings of the present study and those of Werneke et al[53] suggest that DP with CEN might be a more clinically important sign, at least in the short term, than DP without CEN.

The present study also showed that, compared to patients with a no-DP pain pattern, patients with a DP-with-CEN or DP-without-CEN pain pattern experienced a significant and clinically meaningful reduction in pain (median, 2 or more units on the NRS)[39] after only 1 MDT assessment. This is in keeping with findings of several other studies[8,28,30,53] and supports the claim that patients with a DP-with-CEN or DP-without-CEN pain pattern improve rapidly when they are treated with specific exercises that match their individual DP.

The underlying physiologic mechanism of the DP-with-CEN response is still uncertain. The common explanation that DP with CEN might be a sign of reduction of the extent of the nuclear displacement and therefore must be associated with an intact annulus[13] has been criticized in recent years.[2,7] Studies comparing magnetic resonance imaging findings to pain responses have shown that DP with CEN also commonly occurs in patients with lumbar discs in which the nucleus material is sequestrated or extruded.[2,7] Previous research provides several possible explanations for eliciting a DP-with-CEN response or an instant reduction of pain, for example, recovery of creep,[45] restoration of reflex activation,[16] increased lumbar multifidus recruitment,[15] decrease in spinal stiffness,[15] improved distribution of tissue loading,[44] increased flow of blood and nutrition,[46] improved instantaneous axis of rotation,[44] lessening of pain sensitivity,[6] and/or activation of the immune system.[3] Developing a better understanding of the mechanisms underlying the DP-with-CEN response will assist in optimizing treatment strategies.

Numerous studies have shown that patients with LBP have altered trunk muscle recruitment patterns, and that nociception and anticipation of pain change spinal control.[19,20,38] The results of the current study suggest that DP with CEN and the associated reduced pain perception and improved AROM have a positive effect on spinal control. Our results correspond with prior research showing that only 1 or 2 treatment sessions with manipulation induce recovery of motor function.[15,23,24] It should be noted, however, that the mechanism for the improvement in spinal control is still unclear.

In the present study, 3 quasi-static tests (ASLR test, Trendelenburg test, and the PIT) and 1 dynamic test (aberrant lumbar movements while bending forward) were used. The present study found significant differences between DP-with-CEN, DP-without-CEN, and no-DP subgroups for the ASLR test and aberrant lumbar movements, but not for the Trendelenburg test and the PIT. It can be argued that the ASLR test and aberrant lumbar movements give a better clinical assessment of spinal control compared to the Trendelenburg test and the PIT. Positive ASLR scores and aberrant lumbar movements are adaptive motor control strategies, and it has been suggested that both tests address impaired spinal control.[19,21,41] This is much less clearly the case for the Trendelenburg test and the PIT. The Trendelenburg test used in the present study was based on the study by Albert et al[1] and lacks data to support its reliability and validity. The PIT is a pain-provocation test and is commonly advocated for use in patients suspected of having clinical signs of impaired spinal control.[26,41] However, it is still uncertain whether this test measures spinal control or just painful tissues.

The present study should be interpreted in the context of its strengths and limitations. To decrease variability in MDT assessments, all MDT assessments were performed by examiners with diplomas in MDT who had extensive experience in MDT and LBP. A diploma represents the highest level of training in MDT. Our overall prevalence rates of the 3 pain-pattern subgroups and positive (impaired) spinal control tests were quite similar to those suggested by the power analysis and those reported in other studies.[5,32,34,41] It is important to note that the results of this study may be generalizable only to clinicians with extensive experience in MDT and LBP, and may not be similar in clinicians with less training or experience in MDT methods. When patients were assessed at the second or third visit, the MDT

clinician had prior knowledge of the patient. However, this information was never available to the examiners who assessed the clinical signs of impaired spinal control.

We selected 4 commonly-used standardized spinal control tests; however, it should be noted that none of these tests had empirical evidence to support its validity. The assumption that these tests would measure spinal control was primarily based on face validity. We did not assess the intrarater or interrater reliability of the 4 spinal control tests or of the MDT assessment. No specific practical instruction sessions were provided to assessors of the 4 spinal control tests; however, standardized and operational definitions were provided, and patients were always examined by the same examiner before and after the MDT assessment to maximize the reliability of the assessments. Examiners were blinded to the outcome of the MDT assessment.

Although our results were in line with our hypothesis, we acknowledge that we cannot ascertain whether spinal control actually changed in response to the MDT assessment, or whether the changes were a function of the reliability of the measures. Furthermore, changes on spinal control measures were only assessed immediately after treatment, and it remains to be seen whether improvements remain in the long term. Active range of motion was assessed by examiners with diplomas in MDT who were aware of the outcome of the MDT assessment. This awareness might have biased the AROM results favoring the DP-with-CEN and DP-without-CEN subgroups. Finally, the results in **TABLE 2** may be confounded by duration of current LBP symptoms, which was shortest in the DP-with-CEN and DP-without-CEN subgroups and longest in the no-DP subgroup. However, generalized estimating equation models as presented in **TABLE 3** included duration of LBP as a covariate and showed a similar pattern of results to that of the unadjusted analyses.

Clinical Implications

Our results support the contention that clinical signs of impaired spinal control can be reduced in 1 MDT assessment in a subgroup of patients with LBP. The underlying reason for these immediate effects is still unclear, but may be multifactorial (eg, less stiffness, DP-with-CEN pain pattern, reduction of pain) and may vary between individuals.[15,20,38] In line with this reasoning, in cases of impaired spinal control, it may be advantageous to combine or to precede spinal control training with other interventions (eg, MDT,[12] manipulation,[12] cognitive behavioral treatment,[20] medication[38]) tailored to the patient's needs; however, further research is required to investigate this possibility.

CONCLUSION

Immediately following MDT assessment, a larger proportion of patients with a DP-with-CEN pain pattern showed improvement in clinical signs of spinal control compared to patients with a DP-without-CEN or no-DP pain pattern. More research into the reliability and validity of clinical measures of the construct of spinal control is necessary. ◉

KEY POINTS

FINDINGS: In patients with nonspecific LBP, a DP-with-CEN phenomenon might have a positive influence on clinical signs of impaired spinal control in the short term. Spinal control tests differentiated DP-with-CEN from DP-without-CEN and no-DP pain patterns, supporting our hypotheses.

IMPLICATIONS: The DP-with-CEN phenomenon usually takes place rapidly and might be useful to improve spinal control in clinical practice.

CAUTION: Clinical signs of improved spinal control were only assessed immediately after treatment. None of the spinal control tests we used has empirical evidence to support its validity, and we did not test the reliability of the tests. The results of this study may be confounded by duration of current LBP symptoms.

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APPENDIX

OPERATIONAL DEFINITIONS FOR THE ASSESSMENT OF SPINAL CONTROL

Patient Standing

Test	Procedure and Criteria
Aberrant lumbar movements	The patient is asked to flex the trunk forward as far as possible and bend back to the erect position. The existence of any of the following 5 abnormalities is noted. The score is positive if 1 or more aberrant movements are present
1. Painful arc in flexion	Transient midrange pain felt during full flexion
2. Painful arc on return	Transient midrange pain felt on the way up from full trunk flexion
3. Gower sign ("thigh climbing")	Using the hands for assistance during return from the flexed to the erect position
4. Instability catch	Any sudden acceleration, deceleration, or lateral deviation of the trunk during full flexion or from the flexed to the erect position
5. Reversal of lumbopelvic rhythm	The patient bends the knees and shifts the pelvis anteriorly before returning to the erect position
Trendelenburg test	The patient is instructed to raise 1 leg at 90° of hip flexion. The test is positive if the pelvis is descending on the flexed side. If the patient is not able to hold the test position without using the hands, the test is scored not applicable

Patient Lying Supine

Test	Procedure and Criteria
Active straight leg raise test	The patient lies with legs straight and feet 20 cm apart, and is instructed to raise 1 leg 5 cm above the couch without bending the knee. The patient is asked to score the perceived effort of raising the leg on a 6-point scale with the following options: 0 (not difficult at all), 1 (minimally difficult), 2 (somewhat difficult), 3 (fairly difficult), 4 (very difficult), 5 (unable to perform).[36] This procedure is repeated with manual compression of the pelvis by the examiner in order to assess if patient's perceived effort changes. Finally, this procedure is repeated without compression of the pelvis. The scores from both sides are added (only from the last procedure), with the summed score ranging from 0 to 10. The summed score is defined as follows: 0, negative; 1 to 4, moderate dysfunction; and 5-10, severe dysfunction[34]

Patient Lying Half Prone

Test	Procedure and Criteria
Prone instability test	The patient lies prone on the examination table, with the legs over the edge of the table and the feet resting on the floor. While the patient rests in this position, the examiner applies a posteroanterior pressure on the lumbar spine to identify a painful segment. Any provocation of pain is reported. The patient then lifts the legs off the floor to a height of 10 to 20 cm with straight knees, while holding the table to maintain position. In this position, passive intervertebral motion testing is applied again to the segments that were identified as painful. The test is positive if pain is present in the first position but subsides in the second position