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Examination of the lumbar movement pattern during a clinical test and a functional activity test in people with and without low back pain

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Abstract

Background: It is assumed that the lumbar movement pattern observed during a clinical test is representative of the movement pattern used during a functional activity. Very little is known about the how the lumbar movement pattern during a clinical test is associated with the lumbar movement pattern during a functional activity, and how the lumbar movement pattern is associated with functional limitation.

Objective: The purpose was to examine the lumbar movement pattern during a clinical test and a functional activity test in people with and people without low back pain (LBP), and the relationship of lumbar motion to LBP-related functional limitation.

Design: Observational study.

Participants: 16 back-healthy adults and 32 people with chronic LBP.

Methods: Participants performed a standardized clinical test of forward bending and a functional activity test of picking up an object.

Main Outcome Measurements: Maximal lumbar excursion and lumbar excursion at 0-50% and 50-100% of movement time were examined.

Results: Significant associations were present between the two movement tests for both back-healthy people and people with LBP ($r = 0.47-0.73$). In people with LBP the amount of lumbar motion in the 0-50% of movement time interval for both tests was significantly associated with functional limitation ($r = 0.43-0.62$).

Conclusion: Lumbar movement patterns were similar between the two tests, and lumbar motion early in the movement of a functional test was related to self-report of functional limitation.

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Introduction

Low back pain (LBP) is a highly prevalent musculoskeletal¹ condition with a high rate of recurrence.² For many people, LBP becomes a chronic condition characterized by persistent pain and limitations in functional activities.^{2,3} Several conceptual models have been proposed to describe factors that may contribute to the development and course of LBP. One such model is the Kinesiopathologic Model.⁵ Based on the model; direction-specific lumbar movement patterns may develop as a result of repetition of movements and postures used during daily activities. Over time, it is proposed that the lumbar movement patterns become altered, and the repeated use of altered lumbar movement patterns may contribute to the development and course of LBP.⁴ The typical pattern is characterized by the lumbar spine moving more readily in a specific direction(s) than other joints such as the thoracic spine or hip.⁴⁻⁹ The repeated use of the *same* patterns across activities is suggested to produce sub-failure magnitude loading, tissue stress, and LBP symptoms.^{10,11} Finally, it is considered that until a person's pattern is modified the LBP will recur or persist.^{12,13}

Typically, a clinician will assess a person's lumbar movement pattern during standardized clinical tests.^{9,14,15} One clinical assumption is that findings from clinical tests provide insight into how someone moves during functional activities across his day. This assumption, however, has not been systematically examined in people with LBP. This is particularly important because the primary reason people with chronic LBP seek medical care is difficulty performing regular functional activities.^{16,17} However, assessing the lumbar movement pattern during functional activities is not common practice. Prior research that has examined lumbar movement during functional activities has been limited to examining maximal or end range lumbar excursion.¹⁸⁻²⁰ This is problematic because most functional activities only require between 3% and 60% of available lumbar excursion.²³⁻²⁵

A second clinical assumption is that the lumbar movement pattern is relevant to the person's LBP-related functional limitation. Findings from prior research examining lumbar excursion and self-report measures of LBP-related functional limitation are equivocal.²¹⁻²³ Prior studies, however, have all focused on maximal or end-range lumbar excursion. We have reported that the lumbar excursion in the early part of movement (1st 50% of movement time) during a functional activity test and LBP-related functional limitation are significantly associated.^{24,25} However, we have not examined this association during a standardized clinical test. Therefore, we sought to determine if we could replicate our prior results, as well as examine the association between lumbar excursion in the early part of movement during a clinical test and LBP-related functional limitation.

The purpose of this study was to have people with LBP and BH people perform both a standardized clinical test as well as a functional activity test and examine (1) the association between the lumbar movement pattern between the two tests, and (2) the association between the lumbar movement pattern during each test and functional limitation. It was hypothesized that (1) the lumbar movement pattern during the two tests would be related in BH people and in people with LBP, and (2) a person's LBP –related functional limitation would be associated with the amount of lumbar excursion in the early part of movement during each test.

Methods

Participants

Thirty-two people with chronic LBP and 16 BH people participated. Inclusion and exclusion criteria are listed in Table 1. Chronic LBP was defined as having LBP present on greater than ½ the days in the prior year²⁶ Back healthy was defined as having no history of LBP defined as LBP symptoms that resulted in (1) 3 or more consecutive days of missed work or school or altered daily activities, or (2) seeking some type of LBP-related medical or healthcare intervention. BH participants were excluded if they reported a history of LBP as defined, or reported pain, functional limitation, or fear avoidance behaviors associated with LBP on the day of testing. All participants provided informed consent approved by the Human Research Protection Office of Washington University in St Louis School of Medicine prior to participating in the study.

Clinical Measures

Prior to kinematic testing, all participants completed self-report measures that included (1) a demographic and LBP-history form, (2) a numeric pain rating scale (NRS),^{26,27} (3) the Modified Low Back Pain Disability Questionnaire (MLBPDQ),²⁸ (4) the Fear-Avoidance Beliefs Questionnaire (FABQ),²⁹ and (5) the 36-Item Short-Form Health Survey.³⁰ BH participants who reported pain, functional limitation or fear-avoidance behavior associated with LBP were excluded.

Laboratory Measures

Kinematic data were collected using an 8-camera, 3-dimensional motion capture system (Vicon Motion Systems, LTD, Denver, CO) with a sampling rate of 120Hz, and processed in Visual 3D software (C-Motion, Inc., Germantown, MD) and custom programs in MATLAB software (MathWorks Inc., Natick, MA).. Retroreflective markers were placed on predetermined landmarks of the trunk, pelvis and lower extremities (Table 2). A 4th-order, dual-pass Butterworth filter with a cut-off frequency of 3 Hz was applied to marker position data.

Data Processing

A vector from the C7 marker to the T12/L1 marker defined the thoracic segment. The lumbar segment was defined by a vector from the T12/L1 marker to the L5/S1 marker. The pelvis segment was defined by markers at the distal aspect of the sacrum, the anterior superior iliac spines, posterior superior iliac spines, and iliac crests. The thigh segment was defined by a vector from markers on the knee joint line and greater trochanter.

Participants performed three trials each of the clinical test of Forward Bending (FWB)³¹ and the functional activity test of Pick Up an Object (PUO)²⁴ presented in random order. The average of the 3 movement trials for each test was examined.

The start of motion was defined as a 1° change in sagittal excursion of the trunk from the initial standing position. The trunk was defined as the combined thoracic, lumbar and pelvis segments from the initial standing position. The stop of motion was defined as the point

equal to 98% of the maximal forward trunk excursion. Movement time (MT) was calculated as the time between the start and stop of motion. Angular displacements of the thoracic, lumbar and pelvis segments in the sagittal plane were calculated across time. Thoracic excursion was expressed as the angular displacement of the thoracic segment relative to the lumbar segment. Lumbar excursion was expressed as the angular displacement of the lumbar segment relative to the pelvis segment. Pelvis excursion was expressed as the angular displacement of the pelvis segment relative to the thigh segment.

Maximal excursion as well as excursion from 0–50% and 50–100% of MT was calculated for each segment. Intraclass correlation coefficients (ICC) and standard error of the measure (SEM) were calculated using the 16 BH participants. The ICC's for maximal lumbar excursion, and lumbar excursion from 0–50% and 50–100% of MT were determined to be acceptable for FWB (ICC_[3,1] = 0.83–0.95, SEM = 1.40°–1.60°) and for PUO (ICC_[3,1] = 0.88–0.91, SEM = 0.95°–1.52°).

Data Analyses

The sample size was determined based on a desired power of 80%, with $p = .05$ and the ability to detect an effect size (Pearson correlation) of at least 0.45 (20% explained variance).³² Statistical analyses were performed with SPSS version 23.0 (IBM® SPSS® Statistics Inc., Chicago, IL). Descriptive statistics were calculated on participant characteristics for both groups. Differences between the groups were examined using the chi-square test of independence or independent samples t-test. One-way analysis of covariance (ANCOVA) was used to test for differences in maximal and excursion at 50% increments of MT when MT was significantly different between the groups. Pearson product-moment correlation coefficients were calculated to index the relationship between lumbar excursion at 50% increments of MT during the FWB and PUO tests. Correlation coefficients were calculated for lumbar excursion at 50% increments of MT and MLBPDQ for participants with LBP. All statistical analyses were two-tailed tests with a significance level of $p = .05$.

Results

Participant Characteristics

There were no differences in participant characteristics between the groups. For both the FWB test and the PUO test, the BH participants had significantly shorter movement time compared to the LBP group ($p < .01$; Table 3).

Kinematics

Forward Bending test.—(Table 4) There were no differences between the BH and LBP groups in maximal excursion or excursion at 50% increments of MT ($p > .05$) for lumbar or pelvis segments. Because MT was different between the BH and LBP groups, separate analyses were conducted using an ANCOVA examining lumbar excursion from 0–50% of MT for the FWB test with MT as a covariate. There was no significant difference between the BH group and the LBP group in lumbar excursion from 0–50% of MT when including MT as a covariate ($F = 0.5$, $p = .49$).

Pick Up an Object test.—(Table 4) There were no differences between the BH and LBP groups in maximal excursion or excursion at 50% increments of MT ($p > .05$) for lumbar or pelvis segments. Because MT was different between the BH and LBP groups, separate analyses were conducted using an ANCOVA examining lumbar excursion from 0–50% of MT for the PUO test with MT as a covariate. Compared to the BH group, the LBP group had significantly more lumbar excursion from 0–50% of MT when including MT as a covariate ($F = 4.2$, $p = .04$).

Relationship Between Movement Tests

For all participants, lumbar excursion from 0–50% of MT during FWB was significantly associated with lumbar excursion from 0–50% of MT during the PUO test ($r = 0.73$, $r^2 = 0.53$, $p < .01$). When separated by group, lumbar excursion from 0–50% of MT was significantly associated between the two tests for the BH ($r = 0.73$, $r^2 = 0.53$, $p < .01$) and for the LBP participants ($r = 0.73$, $r^2 = 0.53$, $p < .01$; Figure 1). Lumbar excursion from 50–100% of MT also was significantly associated between the two tests for the BH ($r = 0.63$, $r^2 = 0.40$, $p = .01$) and LBP participants ($r = 0.45$, $r^2 = 0.20$, $p = .01$).

Relationship to functional limitation

There were significant associations between lumbar excursion from 0–50% of MT and MLBPDQ for the FWB ($r = 0.43$, $r^2 = 0.19$, $p = .02$) and PUO tests ($r = 0.62$, $r^2 = 0.38$, $p < .01$; Figure 2). There was not a significant association between lumbar excursion from 50–100% of MT and MLBPDQ for the FWB test ($r = 0.15$, $r^2 = 0.02$, $p = .42$). The association between lumbar excursion from 50–100% of MT and MLBPDQ however, was significant for the PUO test ($r = 0.35$, $r^2 = 0.12$, $p = .05$).

Discussion

Our purpose was to examine the association between the lumbar movement pattern during a clinical test and a functional activity test and to examine the relationship between the pattern of lumbar excursion and LBP-related functional limitation. As hypothesized, the lumbar movement pattern between FWB and PUO was significantly associated in both BH people and people with LBP, indicating a similar lumbar movement pattern is used during the two tests. In people with LBP we also found that lumbar excursion, particularly excursion early in each of the test movements, was associated with functional limitation. Together, these findings suggest that the lumbar movement pattern during a clinical test reflects how a person moves the lumbar spine during a functional activity and, the more lumbar excursion a person uses early in the movement, the more his functional limitation, particularly when assessed during a functional activity.

Studies where participants performed 2 or more movement tests primarily have focused on differences between (1) BH people and people with LBP,^{6,33} (2) LBP subgroups,^{5,8,34} or (3) patterns of movement at different movement speeds and object locations rather than the relationship between the movement during the tests.^{24,35,36} A recent study by Alqhtani et al. reported an association between maximal upper ($r = 0.57$) and lower ($r = 0.83$) lumbar excursion during FWB and during a functional activity test separately.³⁷ Different from the

current study, however, the Alqhtani study included only BH males, there was no examination of lumbar excursion at increments of movement time, and the functional activity test involved picking up an object from the floor. Thus, it is unknown whether, in people with LBP, the lumbar movement pattern during a clinical test is associated with the lumbar movement pattern during a functional activity test. We examined lumbar excursion early in the test movement because most functional activities require between 3%–60% of lumbar motion.^{38–40} Our results suggest that the lumbar movement pattern used during a clinical test may reflect the lumbar movement pattern used during similar functional activities in both people with LBP as well as BH people. An important next step would be to examine associations between additional clinical tests and more typical functional activities.

In a recent study, we reported consistent significant associations between LBP-related functional limitation and lumbar excursion in the early part of movement when conditions of a functional activity test were varied.²⁴ Our interest was based on the fact that (1) limitations in performance of functional activities is a key reason people with chronic LBP seek repeat treatment,^{16,17,41} and (2) functional activities typically are performed in the early to mid-ranges of lumbar motion.^{19–21} The current study replicated our previous findings for lumbar excursion in the early part of movement and functional limitation during the PUO test ($r = 0.62$, $r^2 = 0.38$, $p < .01$). A unique aspect of this study is that we also observed a significant association between lumbar excursion during the FWB test and functional limitation. Interestingly, while the associations observed during both the FWB and PUO tests were statistically significant, the amount of variance explained during the FWB test ($r^2 = 0.19$) was less than ½ the amount explained by the PUO test ($r^2 = 0.38$). However, both the FWB and PUO tests provide insight into how a person's lumbar movement pattern is related to his functional limitation, suggesting that the more lumbar motion a person displays early in the movement, the greater his functional limitation.

Prior studies have examined the relationship between maximal lumbar excursion during a FWB test and functional limitation. The correlations reported ranged from 0.09–0.73.^{16–18} We examined the association between functional limitation and movement during the early as well as late part of the FWB test. The amount of variance explained was greater in the early ($r = 0.43$, $r^2 = 0.19$, $p = .02$) compared to the late part of the movement ($r = 0.15$, $r^2 = 0.02$, $p = .42$). Thus, how a person moves in the early part of both a functional activity test and a clinical test appears to be more related to the person's functional limitation than how the person moves in the late part of both tests. Importantly, as the amount of lumbar excursion increases, so does the amount of functional limitation. An important next step would be to examine whether lumbar excursion in the early part of movement during a clinical test and functional activity test is associated with additional self-report measures of pain and fear avoidance behavior.

Across a series of studies we have shown that the amount of lumbar excursion in the early part of movement during a functional activity test, and now a clinical test, is positively associated with a person's self-report of LBP-related functional limitation. We also found that people with LBP demonstrate greater amount of lumbar excursion in the early phase of movement during the PUO test when MT is controlled. These findings suggest that people with LBP move the lumbar spine in a specific manner and that the movement pattern is

associated with LBP-related functional limitation. Specifically, the more lumbar excursion in the early part of movement during a test movement, the more functional limitation the person reports. While our research has reported on a single functional activity test of PUO, our studies provide important insights into the lumbar movement pattern of people with LBP during functional activities. An important next step would be to examine whether interventions directed at reducing the amount of lumbar excursion early in the movement will improve, or decrease functional limitation.

Study Limitations

One potential limitation is that in the functional activity test the object was placed in a position that was scaled to the individual. The participants also were provided standardized instructions to pick up the object with both hands and not move their feet. It is unknown whether the standardized procedures used in this study reflect the participant's typical performance of a functional activity.

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FIGURE 1.

Scatterplots of lumbar excursion from 0-50% of movement time (MT) for the Forward Bending test (FWB) and the Pick Up an Object test (PUO) for the (a) back-healthy participants ($r = 0.73$, $r^2 = 0.53$) and (b) participants with low back pain ($r = 0.73$, $r^2 = 0.53$). Correlations are significant ($p < .05$).

FIGURE 2.

Scatterplots of Modified Low Back Pain Disability Questionnaire (MLBPDQ) score and lumbar excursion from 0-50% of movement time (MT) during the (a) Forward Bending (FWB) test ($r = 0.43$, $p = .02$) and (b) Pick Up an Object (PUO) test ($r = 0.62$, $p < .01$) for all people with low back pain (LBP).

TABLE 1.

Inclusion and exclusion criteria for participants with low back pain (LBP) and back-healthy (BH) participants.

Inclusion criteria
<i>All participants</i>
Age 18-60
Body mass index <30kg/m ²
<i>LBP Participants</i>
History of LBP [*]
LBP condition for at least 12 months duration
LBP symptoms present on ½ the days in the prior 12 months
Exclusion criteria
<i>BH Participants</i>
History of LBP [*]
Current LBP [†]
<i>All Participants</i>
Spinal complications (i.e., tumor or infection)
Previous lumbar surgery
Neurological disease requiring hospitalization
Diagnosis of any of the following spinal conditions:
Marked kyphosis/ scoliosis, spinal stenosis, Spondylolysis, spinal fracture or dislocation, Osteoporosis, Ankylosing spondylitis, lumbar disc herniation with current radicular symptoms, Rheumatoid arthritis
Current pregnancy
Undergoing treatment for kidney or bladder infection, or cancer
Sensory deficit or weakness/numbness in the extremities
Pain, numbness, or tingling below the knee
Difficulty standing or walking without assistance
Receiving disability benefits or worker's compensation, or involved in litigation for LBP

^{*} A history of LBP was defined as LBP symptoms that resulted in (1) 3 or more consecutive days of missed work or school or altered daily activities, or (2) seeking some type of LBP-related medical or healthcare intervention (e.g., physician, chiropractor, physical therapist) for LBP

[†] Current LBP was defined as reporting any pain, functional limitation, or fear avoidance behaviors associated with LBP at the time of data collection.

TABLE 2.

Locations of retroreflective markers.

Marker	Location Details
Acromion [†]	Center of acromion
Manubrium	Superior aspect of manubrium
C7 [‡]	Spinous process 7 th cervical vertebrae
T3	4 cm lateral to the spine: 1/4 distance C7 to T12
T6 [‡]	1/2 distance from C7 to T12
T10	4 cm lateral to the spine: 2/3 distance T6 to T12
Lateral T12	Lateral midline of body, directly lateral to T12
T12 [‡] /L1 ^{‡*}	Spinous process 12 th thoracic or 1 st lumbar vertebrae
L2	4 cm lateral to the spinous process of the 2 nd lumbar vertebrae
L3 [‡]	Spinous process 3 rd lumbar vertebrae
L4	4 cm lateral to the spinous process of the 4 th lumbar vertebrae
L5/S1 [*]	Spinous process 5 th lumbar vertebrae or 1/2 distance from L5 to S2
Iliac Crest [†]	Most superior aspect of iliac crest
PSIS [†]	Most superior aspect of posterior superior iliac spine
Sacrum	Distal aspect of sacrum
ASIS [†]	Most prominent aspect of anterior superior iliac spine
Greater Trochanter [†]	Most superior aspect of greater trochanter
Thigh [†]	4-marker plate lateral distal aspect of thigh
Shank [†]	4-marker plate lateral distal aspect of shank
Knee [†]	Lateral and medial aspect of knee joint line
Ankle [†]	Prominent bony aspect of the lateral and medial malleoli

* A marker was placed at either location depending on the marker set used. A separate sub-study was conducted to examine excursion differences between the two marker sets, and found no differences in sagittal plane excursion using either marker set.

[†] Marker location included markers placed on bilateral landmarks

[‡] Marker location included markers placed superficial to the spinous process as well as at 4cm lateral to the spinous process

TABLE 3.

Descriptive statistics for participant characteristics for the back-healthy (BH) group and the participants with low back pain (LBP).*

Characteristic	BH (n = 16)	LBP (n = 32)	p-value
Female, n (%)	9 (56)	15 (47)	.54
Age, y	32.1 (9.4)	33.8 (10.1)	.55
Height, m	1.72 (0.12)	1.72 (0.10)	.48
Weight, kg	71.8 (11.1)	74.3 (13.0)	.52
MLBPDQ [†]		18.9 (11.5)	
Low back pain duration, y		7.6 (6.9)	
Pain intensity [‡]			
Current		3.5 (2.0)	
Worst (prior 7 days)		6.3 (2.2)	
Average (prior 7 days)		4.0 (1.8)	
FABQ-physical activity subscale [§]		12.5 (6.0)	
FABQ-work subscale		8.8 (8.6)	
Movement time, sec			
Forward Bending test	1.9 (0.5)	2.7 (1.0)	<.01
Pick Up an Object test	1.2 (0.2)	1.4 (0.3)	.03

Bold font indicates significance at $p = .05$

* Values expressed are means (SD) unless otherwise indicated

[†] Modified Low Back Pain Disability Questionnaire, scores range from 0 to 100%

[‡] Numeric Pain Rating Scale, scores range from 0 ("no pain") to 10 ("worst pain imaginable")

[§] Fear Avoidance Beliefs Questionnaire physical activity subscale score, scores range from 0 to 24

^{||} Fear Avoidance Beliefs Questionnaire work subscale score, scores range from 0 to 42

TABLE 4.

Means in degrees, standard deviations and associated *p* values for maximal excursion as well as excursion at 50% increments of movement time (MT) for the lumbar and pelvis segments during the Forward Bending test and the Pick Up an Object test for back-healthy (BH) participants and participants with low back pain (LBP).

	BH (n = 16)	LBP (n = 32)	<i>p</i>-value
<i>Forward Bending test</i>			
Lumbar excursion			
Maximal	33.8 (7.1)	35.1 (9.3)	.60
0-50% of MT	19.7 (4.7)	20.7 (5.7)	.55
50-100% of MT	13.9 (3.8)	14.4 (7.4)	.80
Pelvis excursion			
Maximal	59.1 (15.3)	59.3 (15.4)	.97
0-50% of MT	30.6 (8.1)	31.9 (10.6)	.69
50-100% of MT	38.4 (8.4)	32.5 (13.8)	.13
<i>Pick Up an Object test</i>			
Lumbar excursion			
Maximal	21.3 (4.7)	24.9 (7.2)	.07
0-50% of MT	9.7 (3.1)	11.8 (4.0)	.07 *
50-100% of MT	11.7 (3.4)	13.2 (4.4)	.22
Pelvis excursion			
Maximal	36.7(10.5)	37.9 (8.7)	.67
0-50% of MT	13.7 (6.0)	14.6 (4.9)	.60
50-100% of MT	22.7 (6.9)	26.5 (7.1)	.09

* When MT was covaried, the LBP group demonstrated significantly more lumbar excursion from 0-50% of MT compared to the BH group ($F = 4.2, p = .04$)