

## ARTICLES

## The Effect of Modifying Patient-Preferred Spinal Movement and Alignment During Symptom Testing in Patients With Low Back Pain: A Preliminary Report

Linda R. Van Dillen, PhD, PT, Shirley A. Sahrman, PhD, PT, FAPTA, Barbara J. Norton, PhD, PT, Cheryl A. Caldwell, MHS, PT, CHT, Mary Kate McDonnell, MHS, PT, OCS, Nancy Bloom, MSOT, PT

**ABSTRACT.** Van Dillen LR, Sahrman SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom N. The effect of modifying patient-preferred spinal movement and alignment during symptom testing in patients with low back pain: a preliminary report. *Arch Phys Med Rehabil* 2003;84:313-22.

**Objective:** To examine the effect on symptoms of modifying patient-preferred movements and alignments of the lumbar spine during patient examination.

**Design:** Repeated-measures study in which patients with low back pain (LBP) participated in a standardized examination that included tests of symptoms with various movements and positions.

**Setting:** Six university-affiliated outpatient physical therapy clinics and the local community.

**Participants:** Five trained physical therapists examined a total of 185 patients (102 women, 83 men; mean age, 41.89±13.29y) with LBP. The majority of patients had multiepisode, chronic LBP.

**Interventions:** Not applicable.

**Main Outcome Measures:** The examination included tests of symptoms with various alignments and movements in several different positions. Seven tests were designated as primary tests. Tests that increased symptoms were followed immediately by a secondary test in which (1) patient-preferred lumbar spine movement was modified or (2) the lumbar spine was positioned in a neutral alignment. Patients reported the effect of the secondary test on symptoms relative to their symptoms with the primary test. Three responses were possible: symptoms increased, remained the same, or decreased.

**Results:** Eighty-three percent of the patients reported an increase in symptoms with 1 or more of the 7 primary tests. Ninety-five percent who reported an increase in symptoms with at least 1 of the primary tests reported a decrease in symptoms with 1 or more of the 7 secondary tests. The majority of patients reported a decrease in symptoms when the spinal movement or alignment was modified for 6 of the 7 secondary tests.

**Conclusions:** Modifying the symptom-provoking movements and alignments of the spine during symptom testing

resulted in a decrease in symptoms for the majority of patients. Information about specific modifications that provide relief of LBP symptoms is important because it can be used to design a treatment program that focuses on training a patient to modify the same movements and alignments in their everyday activities.

**Key Words:** Low back pain; Outcome assessment (health care); Rehabilitation; Spinal cord diseases.

© 2003 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation

A MAJOR GOAL OF NONSURGICAL management of patients with low back pain (LBP) is to alleviate symptoms. One source of information about symptoms is the patient's self-report during various tests performed in a standard examination. Traditionally, the assessment of symptoms in patients with LBP has focused on the effect of trunk movements and positions on symptoms.<sup>1,2</sup> In general, the patient performs single and repeated trunk movements or assumes different sustained, end-range trunk positions, and then reports his symptoms. The overall goal of the testing is to identify both the direction of trunk movements and the trunk alignments that either evoke or alleviate the patient's symptoms. The information is important in that it may provide insight into mechanical factors that may contribute to the patient's LBP.

Although some investigators have found that patients with LBP respond systematically to trunk movement and position testing during an examination,<sup>3-7</sup> others have found that symptom testing based on single and repeated trunk movements and sustained trunk positions is not successful with all patients with LBP.<sup>8</sup> For example, Delitto et al<sup>8</sup> reported that some LBP patients are either unaffected or report a worsening of symptoms with trunk testing. In our experience in examining patients with LBP, we have identified 3 phenomena we consider to be important in the assessment of symptoms. The first phenomenon is a change in LBP symptoms when patients actively move their limbs. Traditionally, limb-movement testing in LBP patients has focused on the effect of passive movements on symptoms. For example, the straight-leg raising test is used to determine the effect on symptoms of placing tension on specific peripheral nerves.<sup>9</sup> Passive movement of the legs into full hip and knee flexion is used to determine the effect on symptoms of fully flexing the lumbar spine.<sup>1</sup> We have noticed that patients with LBP often report a change in symptoms not only with movements and positions of the trunk, but also with active movements of the limbs.<sup>10</sup> For example, a patient may report an increase in LBP symptoms when he/she flexes the knee or rotates the hip while prone. We have included active limb movements in our examination because they can cause lumbar spine movements that increase symptoms. The second phenomenon is an apparent consistency across tests that is related to the direction of movements and alignments that evoke symptoms. For example, a patient may report an

From the Program in Physical Therapy, Washington University School of Medicine, St. Louis, MO.

Supported in part by the Foundation for Physical Therapy (grant no. 94R-03-NOR-02), and the National Institute of Child Health and Human Development, National Center for Medical Rehabilitation Research (grant no. 5-K01HD-01226-01A1).

Presented, in part, at the Combined Sections Meeting of the American Physical Therapy Association, February 2000, New Orleans, LA.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

Correspondence to Linda R. Van Dillen, PhD, PT, Program in Physical Therapy, Washington University School of Medicine, Campus Box 8502, St. Louis, MO 63108-2212, e-mail: vandillen@msnotes.wustl.edu. Reprints are not available.

0003-9993/03/8403-7346\$30.00/0

doi:10.1053/apmr.2003.50010

increase in symptoms when he/she flexes the trunk in standing, sits with the trunk unsupported, and rocks backward in the quadruped position. All 3 tests can result in flexion of the lumbar spine. The third phenomenon is that a patient's symptoms can be alleviated by modifying how he/she moves or aligns the lumbar spine during a test. The test is modified by having the patient either change a preferred pattern of lumbar spine movement during a movement test or assume a neutral<sup>11,12</sup> alignment of the lumbar spine during a position test. For example, patients who complain of increased symptoms with a trunk flexion movement from the relaxed standing position would be asked immediately to perform a follow-up test. That test would focus on increasing the amount of hip flexion and decreasing the amount of lumbar spine flexion during the overall trunk movement. Patients would then report the effect of the follow-up test movement on the symptoms, compared with the symptoms experienced during the initial test movement. To our knowledge, none of the 3 phenomena have been integrated into any standardized examination for LBP.

To test these phenomena, we developed a standardized examination<sup>13</sup> for patients with LBP that includes symptom tests. The tests require a patient to perform single repetitions of trunk or limb movements and to assume different trunk positions. Tests that evoke the patient's symptoms are followed by a second test to determine if modifying the patient's preferred movement or alignment alleviates the symptoms. After the examination, the clinician examines the test results for a pattern of symptom responses that reflects an association between symptom behavior and a specific direction of movement and alignment of the lumbar spine. The primary purpose of this study was to test the hypothesis that symptoms that increase with a movement or position test during the examination can be decreased by either changing the type, extent, or timing of the lumbar spine movement that occurred with trunk or limb movements, or positioning the lumbar spine in a neutral<sup>11,12</sup> alignment. We hypothesized that a significant number of the patients who reported an increase in symptoms would report a decrease when the patient-preferred lumbar spine movement or alignment was modified. A secondary purpose of the study was to identify characteristics that might be used to distinguish patients who reported an increase in symptoms with the secondary test from those who reported no change or a decrease in symptoms. This information could be important to clinicians who are deciding what types of examination procedures to use with different types of LBP patients.

## METHODS

### Participants

Subjects were recruited from among patients referred for treatment to any of 6 different outpatient physical therapy clinics in the St. Louis, MO, metropolitan area. Subjects also were recruited through family members and friends of the participants in this study who also had LBP. Advertisements were placed in a local community newspaper and posters were distributed throughout our medical center campus. Subjects between 18 and 75 years of age who had pain or paresthesia in either the region of the lower back, proximal lower extremity, or distal lower extremity<sup>14</sup> were eligible for the study. Exclusion criteria included pregnancy, severe kyphosis or scoliosis, spinal stenosis, spinal surgery in the last 3 months, more than 1 surgical procedure on the spine, pending spinal surgery, cancer, rheumatoid arthritis, ankylosing spondylitis, neurologic disease, and an inability to stand and walk without an assistive device. Before participating in the study, all subjects read and signed an informed consent approved by the Washington Uni-

versity School of Medicine Human Studies Committee. A total of 188 patients with LBP participated in the study. Five tests were administered as part of an examination to screen for magnified symptom behavior.<sup>15</sup> The 5 tests included simulation (axial loading, simulated rotation), distraction, tenderness, regional disturbances, and overreaction. Appendix 1 provides a detailed description of the 5 tests. Three patients met the criterion of 3 or more positive tests<sup>15</sup> and were excluded from further analyses. Table 1 lists the characteristics of the 185 patients who were included in the analyses. Table 2 lists the medical diagnoses they reported at the time of the examination.

### Examination Items

The items of interest in our study are part of a standardized examination<sup>13</sup> that consists of history and physical examination items. The history questions are related to patient characteristics, LBP history, and characteristics of the current LBP episode. The physical examination includes tests in which symptoms are assessed with various movements (trunk, limb) and alignment, and judgments of movement and alignment in different positions. Patients also are screened for neurologic involvement and magnified symptom behavior.<sup>15</sup> Interrater reliability of the examiners administering the examination items has been reported.<sup>13</sup> Data were collected on 95 patients with LBP and percentage of agreement and generalized  $\kappa$  coefficients were used to analyze the data. Percentage of agreement values for the tests of symptoms with positions and movements included in the study ranged from 98% to 100%, and generalized  $\kappa$  coefficients ranged from .87 to 1.00.

Fourteen tests of symptoms were examined in the current study. They were organized into 7 primary and 7 secondary tests. During a primary test, patients reported their symptoms with a particular movement (limb, trunk) or alignment in a specific position that they performed using their preferred pattern. If a patient reported an increase in symptoms with a primary test, that test was immediately followed by a secondary test in which the patient's preferred movement or alignment of the spine was modified. The secondary tests were included to assess the effect of alignments and movements that might alleviate the patient's LBP. The patient reported symptoms with the secondary test relative to the symptoms with the primary test. Five of the primary tests required patients to perform trunk or limb movements, and the other 2 tests required patients to assume specific positions (appendix 2). The secondary tests for the trunk and limb movement items required patients to modify the timing of the movement of the lumbar spine relative to the hips, or the amount and type of lumbar spine and pelvic movement that occurred with either trunk or limb movements (appendix 2). The focus of the secondary tests for the alignment items was on achieving a neutral<sup>11,12</sup> alignment of the lumbar spine. To achieve the modifications during testing, the examiner gave verbal instructions, demonstrations, and physical assistance as deemed appropriate.

Table 3 lists the primary tests that were paired with a secondary test in the original examination.<sup>13</sup> The 7 primary tests examined in the current study were symptoms with (1) forward bending, (2) return from forward bending, (3) sitting knee extension, (4) hip lateral rotation and abduction in partial hook lying (a position in which the patient is supine with the hip and knee of 1 leg flexed so that the foot is maintained flat on the supporting surface, and the other leg is in an anatomically neutral position), (5) prone, (6) natural alignment in the quadruped position, and (7) rocking backward in the quadruped position. A more detailed description of the 7 primary tests and the corresponding secondary tests is given in appendix 2. The operational definitions for the 3 response options for the align-

**Table 1: Characteristics of Patients Who Reported Increased Symptoms With 1 or More Primary Tests Versus Patients With No Increase in Symptoms**

Characteristic	Patient Group	
	Symptoms	No Symptoms
Gender (n)		
Male	70	13
Female	84	18
Mean age $\pm$ SD (y)	41.86 $\pm$ 13.09	41.84 $\pm$ 14.49
Mean height $\pm$ SD (cm)	171.17 $\pm$ 10.76	169.01 $\pm$ 12.52
Mean weight $\pm$ SD (kg)	75.63 $\pm$ 16.19	67.50 $\pm$ 15.25
Mean pain intensity rating over previous week $\pm$ SD (0-5) <sup>16</sup>	1.87 $\pm$ .91	1.67 $\pm$ .55
LBP symptom characteristics (%)		
Pain only	69	81
Paresthesias only	1	0
Both pain and paresthesias	30	19
Location of current symptoms <sup>14</sup> (%)		
Low back only	64	81
Low back/proximal LE	12	10
Low back/distal LE	4	7
Low back/proximal LE/distal LE	20	3
Duration of current LBP symptoms <sup>14</sup> (%)		
Acute: <7d	8	13
Subacute: 7d-7wk	20	16
Chronic: >7wk	72	71
History of spinal surgery (%)		
Yes	4	0
No	96	100
Symptoms located below the buttock	34	18
History of previous episode of LBP	90	79
Mean no. of episodes of LBP in the previous 12mo $\pm$ SD	6.01 $\pm$ 4.31	4.15 $\pm$ 4.19
Mean Oswestry Disability Questionnaire <sup>17</sup> scores $\pm$ SD (%)	25 $\pm$ 15	17 $\pm$ 10
Currently working (part-time or full-time) (%)	56	64
Retired (%)	9	12
Student (%)	24	20
Currently receiving workers' compensation (%)	1	0
Currently receiving disability benefits for LBP problem (%)	7	0
Involved in litigation related to LBP problem (%)	8	4

Abbreviations: SD, standard deviation; LE, lower extremity.

ment or movement tests were (1) symptoms increased: the patient's symptoms (pain or paresthesia) were evoked, or increased in intensity, or were extended more distally; (2) symptoms remained the same: the patient's symptoms were unchanged in intensity or location; or (3) symptoms decreased: the patient's symptoms were diminished or absent, or were located more proximally relative to symptom responses with a reference test.

In accord with previous studies,<sup>1,3-8</sup> we prioritized the behavior of the distal symptoms over the proximal symptoms.

### Procedures

Each patient was examined by 1 of 5 orthopedic physical therapists who were trained and tested for their reliability in administering the standardized examination.<sup>13</sup> To ensure that data collection procedures were consistent, therapists were occasionally randomly paired and then examined a patient concurrently, following our original procedures for reliability testing.<sup>13</sup> The data then were examined to determine the therapists' consistency in judging and recording the patient's responses. The clinical experience of the therapists ranged from 5 to 35 years (mean  $\pm$  standard deviation, 16.8 $\pm$ 8.73y). The sequence of examination items was the same for all patients. The sequence of test positions used for administering the examination was standing, sitting, supine, partial hook lying, prone, and the quadruped position.

### Data Analysis

Data analysis was performed using Systat, version 9.0,<sup>a</sup> for Windows. The number of patients who were unable to complete each of the 7 primary and 7 secondary tests was tabulated, and their reasons for being unable to perform a test were noted. Percentage of agreement values were calculated for each of the examination items. Descriptive statistics were calculated for patient characteristics. Frequency distributions of the patients' responses (increased, same, decreased) were generated for each of the 14 tests. The frequency distribution for each secondary test included only the responses of the patients who reported an increase in symptoms with the corresponding primary test. A chi-square goodness of fit analysis was performed on the frequency distribution of obtained responses for each secondary test to determine if the distribution was different across the 3 response options. The null hypothesis was that the proportions of responses would be equal across those options. The probability level for significance testing was set at the .05 level. Additional analyses were done when the chi-square statistic for a secondary test was not significant. These analyses were conducted to determine if there were specific characteristics that distinguished the patients who responded in a particular way to the secondary testing. Specifically, the chi-square goodness of fit analysis and the Student *t* test for independent groups

**Table 2: Percentages of Medical Diagnoses Reported by Patients**

Reported diagnoses <sup>†</sup>	Patient Group*	
	Symptoms (n=154) (%)	No Symptoms (n=31) (%)
None <sup>‡</sup>	53	71
Degenerative arthritis of spine	10	0
Herniated disk	4	3
Bulging disk	4	3
Disk problem	3	4
Degenerative disk disease	3	3
Slipped disk	2	0
Lumbar muscle spasm	2	3
Disk reinjury	1	0
Ruptured lumbar disk	1	0
Herniated disk and bulging disk	1	0
Annular dysfunction	1	0
Bulging disk and dislocated coccyx	1	0
Degenerative arthritis of spine and osteoporosis	1	0
Degeneration of L5 vertebra	1	0
Scoliosis	1	0
Spondylolisthesis	1	3
Sacroiliac joint dysfunction	1	0
Scoliosis with degenerative disk disease	1	0
Scoliosis with Ehlers-Danlos syndrome	1	0
Fracture of transverse process:		
L1	1	0
L2-5	1	0
Spurring of L5-S1 with scoliosis	1	0
Fusion of L3-5 vertebra	0	3
Rods in lumbar spine	1	0
L5-S1 laminectomy	1	0
Sciatica	1	0
Piriformis syndrome with sacroiliitis	1	0
Pinched nerve	1	0
Lumbar muscle spasm with sciatic nerve irritation	1	0
Myofascial pain syndrome	1	0
Lumbar strain	1	0
Lumbar sprain	1	0
Pain from epidural injection	1	0
Osteoporosis and slipped disk	0	3
6th lumbar vertebra	0	3

\* Groups are organized by patients who reported an increase in symptoms with 1 or more primary tests versus patients who reported no increase in symptoms.

<sup>†</sup> Medical diagnosis reported by the patient at the time of the examination.

<sup>‡</sup> Patients who were unable to identify a specific diagnosis for their problem other than LBP, or they were not seen by a physician for their current LBP.

were used to test for differences in patient characteristics between the patients who reported an increase in symptoms with the secondary test and the patients who reported that symptoms remained the same or decreased in the secondary test. Appropriate effect size indices and power estimates also were calculated for each comparison.

## RESULTS

### Reliability

Seven examinations were conducted by various pairs of examiners during the data collection period. Percentage of agreement values ranged from 95% to 100%. Additional reli-

ability coefficients were not calculated for the paired data because of the limited number of subjects who were examined by the pairs of examiners.

### Exceptions

Three patients could not perform 1 or more of the 7 primary tests of symptoms. One patient was unable to tolerate the supine or prone positions and was unable to be positioned in quadruped for more than 1 test because of discomfort. For this reason, we were unable to assess symptoms for this patient with the primary tests of hip lateral rotation and abduction in partial hook lying, prone, and rocking backward in the quadruped position. Two other patients were unable to perform the primary test of rocking backward in the quadruped position, one because of arthritic knees and the other because of obesity.

Four patients who reported an increase in symptoms with a primary test were unable to perform the associated secondary test correctly. Two patients were unable to perform the test with corrected forward bending, another was unable to perform the test with corrected return from forward bending, and a fourth was unable to perform the test with corrected rocking backward in the quadruped position. In each instance, the patients were unable to appropriately correct their preferred movement strategy as instructed within the examination time.

### Primary Tests

Patient characteristics are summarized in table 1. Table 4 shows the frequency distribution of responses for each of the 7 primary tests. Overall, 83% of the patients reported an increase in symptoms with 1 or more of the 7 primary tests. The primary test of forward bending from a standing position had the highest reported percentage (52%) of increased symptoms, and the primary tests in quadruped position had the lowest reported percentages (23% and 25%, respectively) of increased symptoms. Each of the primary tests also resulted in reports that symptoms remained the same for some patients. The primary test of active hip abduction and lateral rotation in partial hook lying had the highest reported percentage (71%) of no change in symptoms. Finally, the primary tests performed in the quadruped position resulted in the highest percentages of decreased symptoms. Twenty-six percent of the patients reported a decrease in symptoms when they assumed the quadruped position, and 25% reported a decrease in symptoms with rocking backward in the quadruped position.

### Secondary Tests

Overall, 95% of the patients reported a decrease in symptoms with 1 or more of the 7 secondary tests when compared with symptoms in the corresponding primary test. The chi-square goodness of fit statistic, used to test the null hypothesis that the distributions were equal across the 3 response options, was significant for 6 of the 7 secondary tests. For each of those tests, the majority of patients reported a decrease in symptoms when their preferred movement or alignment was modified. The percentage of patients who reported decreases ranged from 90% for the test of corrected return from forward bending to 49% for the test of corrected alignment in the quadruped position. Corrected alignment in that position was the only secondary test in which the distribution of responses did not reach significance ( $\chi^2=4.65$ ,  $P>.05$ ). Table 5 shows the frequency distributions of responses for the 7 secondary tests for patients who reported an increase in symptoms with the corresponding primary test, and the statistical results from the chi-square analyses.

**Table 3: Primary and Secondary Tests of Symptoms<sup>13</sup> Organized by Associated Direction of Lumbar Spine Movement or Alignment**

Primary Test	Secondary Test <sup>†</sup>	Associated Direction of Lumbar Spine Movement or Alignment*		
		Flexion	Extension	Rotation
Symptoms with return from forward bending	Symptoms with corrected return from forward bending		*	
Symptoms in prone	Symptoms with corrected prone		*	
Symptoms with active hip abduction/lateral rotation in partial hook lying	Symptoms with corrected hip abduction/lateral rotation in partial hook lying			*
Symptoms with forward bending	Symptoms with corrected forward bending	*		
Symptoms with active knee extension in sitting	Symptoms with corrected active knee extension in sitting	*		*
Symptoms with rocking backward in quadruped position	Symptoms with corrected rocking backward in quadruped position	*		*
Symptoms with natural alignment in quadruped position	Symptoms with corrected alignment in quadruped position	*	*	*

\* Some test items may be associated with either 1 or a combination of the directions of lumbar spine movements and alignments listed.

<sup>†</sup> Overall, secondary tests included verbal instructions, demonstration, and tactile cues by the examiner to assist the patient in modifying movement or alignment.

### Additional Analyses

Table 6 shows the results of comparisons between patients who reported that symptoms increased with corrected alignment in the quadruped position versus the patients who reported that the symptoms remained the same or decreased with corrected alignment in the quadruped position. Table 6 also includes the estimated effect size and power for each comparison. The analyses reveal 2 significant differences: (1) patients who reported increased symptoms were more likely to have symptoms that extended below the buttocks than patients who reported no change or a decrease in symptoms, and (2) 30% of the patients who reported increased symptoms had a history of lumbar spine surgery. None of the patients who reported no change or a decrease in symptoms had a history of lumbar spine surgery. There were no differences between the groups with regard to gender, age, height, weight, average pain intensity rating,<sup>16</sup> duration of current LBP symptoms, history of previous episodes of LBP, number of episodes of LBP in the previous 12 months, or Oswestry Disability Questionnaire<sup>17</sup> scores. Also, there were no differences between the 2 groups with regard to work status, disability benefits, or involvement in litigation, and none of the patients from either group was receiving workers' compensation benefits. The estimated effect

sizes for 8 of the 16 comparisons were categorized as small,<sup>18,19</sup> and the power associated with the 8 comparisons was low, with values ranging from .08 to .18. Seven of the 16 comparisons had estimated effect sizes that were categorized as medium.<sup>18,19</sup> The power associated with the 7 comparisons ranged between .06 and .81. Finally, 1 of the 16 comparisons had an estimated effect size categorized as large,<sup>18,19</sup> and the power associated with the comparison was .84.

### DISCUSSION

Our findings support the hypothesis that symptoms elicited with various trunk and limb movement tests and trunk position tests during an examination can be improved by modifying the patient's preferred lumbar spine movement or alignment. A significant number of patients reported a decrease in LBP with each of the 5 secondary tests in which lumbar spine movement was modified during a trunk or limb movement. Additionally, a significant number of patients reported a decrease in LBP when their lumbar spine was positioned in a neutral alignment while in the prone position, compared with a position of lumbar spine extension while prone (table 5). These findings suggest that information can be obtained during an examination about whether the patient's symptoms can be decreased by specific changes in move-

**Table 4: Frequencies and Percentages of Responses Reported With the 7 Primary Tests of Symptoms Organized by Associated Lumbar Spine Movement or Alignment**

Primary Test*	N <sup>†</sup>	Decreased	Same	Increased
Flexion				
Symptoms with forward bending	185	22 (12)	66 (36)	97 (52)
Flexion/rotation				
Symptoms with active knee extension in sitting	185	1 (1)	122 (66)	62 (33)
Symptoms with active rocking backward in quadruped position	182	46 (25)	90 (50)	46 (25)
Rotation				
Symptoms with active hip abduction/lateral rotation in partial hook lying	184	0 (0)	131 (71)	53 (29)
Flexion/extension/rotation				
Symptoms with natural alignment in quadruped position	185	47 (26)	95 (51)	43 (23)

NOTE. Values are n (%).

\* The number of patients included for each primary test may differ because, in some instances, a patient was unable to physically perform the test.

<sup>†</sup> Some test items may be associated with either 1 or a combination of the directions of lumbar spine movements or alignments listed.

**Table 5: Frequencies and Percentages of Responses Reported With Each Secondary Test for Patients Who Reported an Increase in Symptoms With the Primary Test and Associated Statistical Results**

Secondary Test	n*	Decreased	Same	Increased	df	$\chi^2$ Value	P Value
<b>Extension</b>							
Symptoms with corrected return from forward bending	70	63 (90)	5 (7)	2 (3)	2	101.34	<.001
Symptoms in corrected prone	63	55 (87)	7 (11)	1 (2)	2	84.23	<.001
<b>Rotation</b>							
Symptoms with corrected active hip abduction/lateral rotation	53	36 (68)	17 (32)	0 (0)	1	6.81	<.01
<b>Flexion</b>							
Symptoms with corrected forward bending	95	84 (88)	9 (10)	2 (2)	2	130.51	<.001
<b>Flexion/rotation</b>							
Symptoms with corrected active knee extension	62	44 (71)	15 (24)	3 (5)	2	43.00	<.001
Symptoms with corrected active rocking backward	45	35 (78)	9 (20)	1 (2)	2	42.13	<.001
<b>Flexion/extension/rotation</b>							
Symptoms with corrected alignment in quadruped position	43	21 (49)	11 (26)	1 (25)	2	4.65	.10

NOTE. Values are n (%).

\* Number of patients may differ from those listed in table 4 because some patients were unable to perform the correction within the examination time allotted.

ment of the lumbar spine and limbs and alignment of the lumbar spine. The movement and alignment information gained from a secondary test can be used to design a patient-specific treatment program that emphasizes modification of both symptom-provoking movements of the trunk and limbs and alignments of the trunk that may be contributing to the patient's LBP.

Some patients reported that the modifications with the secondary test did not alter the symptoms they experienced in the primary test. This was not unexpected. There were a number of circumstances in which it was difficult to fully modify the patient's movement or alignment during the examination. First, when the patient's spine moved in more than 1 plane during a primary test, it was more difficult to perform the modification adequately in the secondary test. Second, the patient's size and weight distribution could have made it difficult for the examiner to modify a movement or alignment. Third, postural deviations may have been so severe that they were difficult to modify in just 1 examination session. Although our patients were screened for extreme anatomic deviations (eg, diagnosed scoliosis), there were some who had postural deviations such as a lumbar lordosis with an associated thoracic kyphosis. Such deviations may not have been modifiable or could not have been modified easily in a single examination session. Fourth, modification of spinal alignment and movement is based on the examiner's verbal cues, vision, and palpation. It is possible that a patient's actual alignment with a modification was slightly different from that perceived by the examiner.<sup>20</sup> Finally, for some patients, the LBP may not have been amenable to a movement- and alignment-based physical intervention and, therefore, would not respond to the modifications of movement and alignment used in the secondary tests. Because the clinicians were not required systematically to record the factors that might have influenced the test results, the extent to which these situations occurred is not known.

The secondary test of corrected alignment in the quadruped position required that the patient's spinal alignment be altered within a position. This test also was the only secondary test in which a significant number of patients did not have a reduction in their LBP. Twenty-five percent of the patients reported an increase in their symptoms with the secondary test, compared

with their symptoms when they assumed the quadruped position on their own. Analyses revealed that the patients with an increase in symptoms in the secondary test appeared to be more severely involved and more likely to have anatomic changes in the lumbar spine that were not amenable to modification than patients who reported either no change or a decrease in symptoms. For example, patients who reported an increase in symptoms in the secondary test were more likely to have had symptoms that extended below the buttock or to have had lumbar spine surgery (table 6). The finding that some patients had worse symptoms with the test of corrected alignment in the quadruped position is a good example of how the information from a secondary test can be used in making decisions about treatment. Currently, the quadruped position is used by some clinicians as a technique for symptom relief in patients with LBP.<sup>21</sup> The findings from our secondary test of corrected alignment in this position would give the clinician the specific information needed to decide if it is an appropriate position for an individual patient, as opposed to prescribing positioning in quadruped for all patients with LBP. Although we found 2 significant differences between patients with an increase in symptoms with corrected alignment in the quadruped position, and those with a decrease or no change in symptoms, we cannot say whether there were other differences, based on our current analyses. As shown in table 6, all but 2 of the power estimates were below the conventionally accepted power level of .80.<sup>22</sup> The relatively low-power estimates for many of the comparisons indicate a low probability of detecting a difference between the 2 groups for the majority of variables we tested. Therefore, there may have been an effect, but we were unable to detect it within the conditions present in our current study.

Our approach to symptom testing is unique. To our knowledge, no other examination includes tests that require modification of spinal movements with movements of the trunk and limbs, or modification of spinal alignments in the standardized manner we have described (appendix 2). Our examination approach is based on the theory that people develop a tendency to move the spine in a specific direction as the result of performing movements and assuming sustained positions repeatedly during their everyday activities.<sup>23</sup> For example, some

**Table 6: Characteristics of Patients Who Reported an Increase in Symptoms With the Primary Test of Alignment in Quadruped Position, Organized by Response to the Secondary Test of Corrected Alignment in the Quadruped Position and Associated Statistical Results**

Characteristic	Patient Group		df	Statistic Value	P Value	Power	Effect Size*
	Increased Symptoms With Correction	No Change in Symptoms or Decreased Symptoms With Correction					
Gender (%)							
Male	53	64	1	$\chi^2=.37$	>.05	.84	w=.50
Female	47	36					
Mean age $\pm$ SD (y)	42 $\pm$ 13.92	40 $\pm$ 12.05	15.5	t= -.295	>.05	.09	d=.10
Mean height $\pm$ SD (cm)	168 $\pm$ 12.02	173 $\pm$ 12.04	16	t=1.08	>.05	.17	d=.40
Mean weight $\pm$ SD (kg)	75.21 $\pm$ 14.47	72.42 $\pm$ 13.71	15.4	t= -.524	>.05	.08	d=.20
Mean pain intensity rating over previous week $\pm$ SD <sup>16</sup> (0-5)	2.2 $\pm$ 1.39	2.00 $\pm$ .842	5	$\chi^2=9.31$	>.05	.08	d=.20
LBP symptom characteristics (%)			2	$\chi^2=5.79$	>.05	.40	w=.29
Pain only	45	78					
Paresthesias only	9	0					
Both pain and paresthesias	46	22					
Location of current symptoms <sup>14</sup> (%)			2	$\chi^2=3.89$	>.05	.34	w=.34
Low back only	66	64					
Proximal LE	0	0					
Distal LE	0	0					
Low back/proximal LE	12	18					
Low back/distal LE	0	0					
Proximal LE/distal LE	0	0					
Low back/proximal LE/distal LE	22	18					
Duration of current LBP symptoms <sup>14</sup> (%)			2	$\chi^2=3.57$	>.05	.41	w=.31
Acute: <7d	18	3					
Subacute: 7d-7wk	27	19					
Chronic: >7wk	55	78					
Symptoms below buttock (%)			1	$\chi^2=6.18$	<b>&lt;.05</b>	.61	w=.41
Yes	64	23					
No	36	77					
History of spinal surgery (%)			1	$\chi^2=9.73$	<b>&lt;.01</b>	.18	w=.25
Yes	30	0					
No	70	100					
History of previous episode of LBP (%)	100	79	1	$\chi^2=2.54$	>.05	.11	w=.14
Mean no. of episodes of LBP in the previous 12mo $\pm$ SD	7.67 $\pm$ 4.39	6.35 $\pm$ 4.76	33	t=.731	>.05	.11	d=.28
Mean Oswestry Disability Questionnaire <sup>17</sup> scores $\pm$ SD	.31 $\pm$ .17	.25 $\pm$ .14	40	t= -1.154	>.05	.18	d=.40
Work status (%)			3	$\chi^2=1.923$	>.05	.38	w=.26
Currently working (part-time or full-time)	70	50					
Retired	10	7					
Student	10	30					
Not working because of LBP problem	10	13					
Currently receiving disability benefits for LBP problem (%)	10	13	1	$\chi^2=.07$	>.05	.81	w=.45
Involved in litigation related to LBP problem (%)	20	3	1	$\chi^2=2.86$	>.05	.06	w=.33

NOTE. Bold face indicates a significant effect.

\* The index for effect size varies with statistical test calculated. Conventional operational definitions for effect sizes are as follows: small:  $d=.20$ ,  $w=.10$ ; medium:  $d=.50$ ,  $w=.30$ ; large:  $d=.80$ ,  $w=.50$ .<sup>18,19</sup>

patients may repeatedly perform small side bending movements in the lumbar spine. It has been proposed that such repeated movements result in increased flexibility of 1 or more segments of the lumbar spine in the direction of the side bend movement. The increased flexibility in specific segments results in a greater relative contribution of motion of the involved segments compared with other segments that could contribute to the motion. When it is repeated enough times, it can result in tissue injury and LBP.<sup>23</sup> The information gleaned from the 2 tests of symptoms described here is used by a clinician to design a treatment program that addresses the specific direc-

tions of movement and alignment that appear to contribute to a patient's symptoms during the examination. The primary treatment goal is to eliminate the symptom-provoking alignments and movements that are repeated throughout the patient's day.<sup>23,24</sup> We accomplish that goal in 3 ways. We educate patients on how to assume a neutral<sup>12,13</sup> alignment of the lumbar spine in different positions and how to modify the symptom-provoking patterns of movement they make repeatedly in daily activities. For example, the patient who has a tendency to align the lumbar spine in a side bend and perform side bending movements with trunk and limb movements

would first be told about his/her strategies that were identified on examination, and how those strategies relate to symptoms. The clinician would then teach the patient how to modify the specific positions and movements in which the patient repeats his/her preferred side bending strategies. For example, a patient may specifically complain of an increase in LBP when cycling. The clinician finds that the patient side bends his/her lumbar spine each time he/she flexes the right hip and knee while cycling. The patient would be taught to change his/her side bending strategy when flexing the right leg. Second, we use positioning techniques and external supports to alleviate stress on involved tissues. For example, a patient who exhibits side bending alignment and movement impairments might be instructed to place pillows between the knees and a towel roll between the iliac crest and the lower margin of the rib cage on the support side when side lying. These positioning techniques are used to eliminate factors that may contribute to a sustained side bend alignment of the lumbar spine. Third, we prescribe exercises directed at physical impairments, such as trunk strength or lower-extremity flexibility, which may prevent the patient from performing functional activities in the specifically prescribed manner. The patient who exhibited the side bending movement with hip and knee flexion, for example, might be given an exercise to lengthen the hip joint extensors while maintaining the lumbar spine in a neutral alignment. The exercise for the hip joint extensors is directed at lengthening hip structures that may be limiting hip flexion so that the patient has enough hip motion to perform hip flexion, without side bending the lumbar spine.

There were patients who reported a decrease in their symptoms when performing a primary test. In all but 1 instance, a decrease occurred when the test involved a trunk position or movement in the sagittal plane (table 4). For example, 12% of the patients reported a decrease in symptoms with forward bending, while no patients reported a decrease in symptoms with active hip abduction and lateral rotation. These findings are consistent with our clinical observations that patients who report an increase in symptoms only with trunk positions or movements in the sagittal plane may report a decrease in symptoms when the trunk is moved or positioned in the opposite direction in the sagittal plane. As suggested by the data in table 4, however, and through our clinical observations, many patients with LBP report an increase in symptoms not only with positions and movements of the trunk in the sagittal plane but also with limb movements that can impose asymmetric movements on the spine in the frontal and horizontal planes.

The finding that some patients were unable to modify their movement or alignment within the context of the examination was not unexpected. We have found that patients vary in their ability to learn how to modify a movement or alignment, even when such movements or alignments are painful (table 5). This does not mean that the modifications are inappropriate for the patient. In many instances, we found that the patient just required more time and practice with the clinician to understand specifically what and how to modify his/her alignment or movement.

One limitation of our study was that only 7 of the 20 tests of symptoms in our examination<sup>13</sup> were followed by an associated secondary test. Secondary tests could be developed and standardized for most primary tests of symptoms. Information gained from the additional secondary tests could improve the clinician's ability to confirm the specific direction of alignments and movements that appear to be contributing to the patient's LBP. A second limitation is that we did not record specifically what aspect (intensity or location) of the patient's symptoms changed with each secondary test. We also did not record the extent of change of symptoms (eg, decreased vs eliminated) that occurred with each secondary test. Such information may provide more insight into the specific types of patients who may benefit the most from the tests performed in our study. Finally, the majority of our patients were categorized as chronic (>7wk since onset of an LBP episode).<sup>14</sup> Additional experience with the primary and secondary tests of symptoms with patients in various stages of an LBP episode should provide important insight into the generalizability of the study findings.

## CONCLUSIONS

Our study provides evidence that positioning the lumbar spine in a neutral alignment and modifying patient-preferred lumbar spine movements that occur with symptom-provoking trunk and limb movements during an examination results in a decrease in symptoms in many patients with mechanical LBP. Information gained from the testing procedures during the examination can help clinicians develop patient-specific treatment programs that focus on modifying alignments and movements that appear to be contributing to a patient's LBP.

**Acknowledgment:** We thank Debra Fleming-McDonnell for her assistance in the development of the tests used in the study, as well as for her assistance in the data collection process. We thank Hadiya Green for data processing and analysis assistance.

### APPENDIX 1: DESCRIPTION OF 5 SCREENING TESTS FOR MAGNIFIED SYMPTOM BEHAVIOR<sup>15</sup>

**Simulation (axial loading and simulated rotation):** Axial loading and simulated rotation were performed with the patient standing. Axial loading required the examiner to apply a small vertical load through the patient's skull. Simulated rotation required the examiner to passively rotate the patient's shoulders and pelvis in the same plane, avoiding lumbar spine rotation. If the patient reported an increase in LBP with either test, the response to simulation testing was considered positive.

**Distraction:** The distraction test compared the consistency of the patient's response when formally tested for a physical sign and when the same movement was performed while the patient was distracted. The patient's response was assessed with a passive straight-leg raising test in the supine position and with passive knee extension in the sitting position while the patient was distracted. Inconsistency in the responses for the 2 tests was considered a positive response.

**Tenderness:** Tenderness testing involved superficial and deep palpation of the skin over the cervical, thoracic, lumbar, and sacral region. If the patient complained of LBP over a wide area of the skin or the complaints did not localize to 1 structure, the response was considered positive.

**Regional Disturbances:** Assessment of regional disturbances was a part of the motor and sensory screening of the lower extremities. A patient showed a positive regional disturbance if his responses to testing deviated from accepted neuroanatomy.

**Overreaction:** Overreaction was assessed by the examiner at completion of the examination, based on the patient's overall responses during the examination. A positive response was assigned if the examiner judged that the responses were exaggerated and inappropriate for some of the tests.

## APPENDIX 2: DESCRIPTION OF 7 PRIMARY TESTS AND 7 SECONDARY TESTS FROM THE EXAMINATION

**Standing**

**Symptoms with forward bending (primary test):** The patient began from a standing position with his feet positioned shoulder width apart. The patient was instructed to perform a forward bending movement from the natural standing position, bending forward as far as he could, and then returning to the standing position. The symptoms with the forward bending movement were compared with the patient's symptoms when standing.

**Symptoms with corrected forward bending (secondary test):** The patient began from a standing position with the feet positioned shoulder width apart. By using a prop positioned just above waist level, the patient placed his hands on the prop to help support the weight of his trunk. The patient then was instructed (1) to bend forward putting the weight of his trunk into his hands, (2) to keep his lumbar spine stationary and relaxed, and (3) to flex only in his hips. The examiner placed her hands on the patient's abdomen and lumbar spine before the forward bend motion to help the patient maintain the lumbar spine starting alignment throughout the bending motion. The examiner provided tactile and verbal feedback so that the patient kept his spine stationary and bent forward only with his hips as far as he could without changing the initial alignment of the lumbar spine. The symptoms with the corrected forward bending movement were compared with the symptoms with forward bending.

**Symptoms with return from forward bending (primary test):** The patient began from a standing position with the feet positioned shoulder width apart. The patient was instructed to perform a forward bending movement from the natural standing position, bending forward as far as he could, and then returning to the standing position. The symptoms with the return phase of the forward bending motion were compared with the patient's symptoms when standing.

**Symptoms with corrected return from forward bending (secondary test):** Beginning from a forward bent position and grasping a support positioned in front of him, the patient was instructed to tighten his buttock muscles and to pull his hips under his trunk as he returned from the forward bent position. The patient was also instructed to avoid a forward sway of the pelvis and a backward sway of the upper back as he completed the return motion. The examiner placed her hands on the abdomen and buttocks to help the patient avoid excessive lumbar spine extension, and to use his hip extensors as he returned from the forward bent position. The symptoms with the corrected return from forward bending motion were compared with the patient's symptoms with return from forward bending.

**Sitting**

**Symptoms with active knee extension (primary test):** The patient began from a sitting position in which the lumbar spine was in a neutral alignment, the hips were positioned in 90° of flexion, the femurs were fully supported and positioned in neutral hip abduction and adduction and neutral rotation, the lower extremities were relaxed, and the feet were positioned flat on a support surface. The patient was instructed to extend each knee as far as he could and to return it to the starting position. The test movement was performed separately with each lower extremity. The symptoms with each test movement were compared with the patient's symptoms in sitting with the lumbar spine positioned in a neutral alignment.

**Symptoms with corrected active knee extension (secondary test):** The test positioning and movement were the same as in the primary test with active knee extension in sitting, except that the examiner placed her hands over the tissue spanning the region from midline to 2in lateral to the lumbar spine area and provided counterpressure to prevent any flexion, side bending, shifting, or rotation of the lumbar spine as the patient moved each lower extremity. The lower-extremity movement was stopped when the examiner was unable to counter lumbar spine motion. The symptoms with each test movement were compared with the patient's symptoms with active knee extension without correcting the lumbar spine movement.

**Partial Hook Lying**

**Symptoms with active hip abduction and lateral rotation (without pelvis stabilized) (primary test):** The patient began from a back-lying position with 1 hip and knee flexed and the foot positioned flat on the supporting surface (partial hook lying). With the lower extremity that was flexed at the hip and knee, the patient performed active hip abduction and lateral rotation as far as he could, and then returned the lower extremity to the starting position. The test was performed separately with each leg. The symptoms with each test movement were compared with the patient's symptoms in the starting position of partial hook lying.

**Symptoms with corrected active hip abduction and lateral rotation (pelvis stabilized) (secondary test):** The test positioning and movement were the same as the primary test, except that the pelvis was stabilized, and the examiner placed her hand over the patient's anterior superior iliac spine (ASIS) opposite the lower extremity that was to be moved during the test. Before the patient initiated the lower-extremity movement, the examiner put pressure on the ASIS to counter any pelvic rotation that might occur during the extremity movement and the pressure was maintained throughout the movement. The symptoms with each test movement were compared with the patient's symptoms with active hip abduction with lateral rotation without the pelvis stabilized.

**Prone**

**Symptoms in prone (primary test):** The patient began from a face lying position with both lower extremities positioned in neutral adduction and abduction and rotation, and the arms positioned at his sides. The patient was allowed to turn his head to either side or to rest his forehead on a towel roll in the midline position—whichever was most comfortable. The symptoms in prone were compared with the patient's symptoms in a back-lying position with both hips and knees flexed and the feet positioned flat on the supporting surface (hook lying).

**Symptoms with corrected prone (secondary test):** The test positioning was the same as the primary test without abdominal support, except that 1 or more pillows were placed under the patient's abdomen and pelvis until the lumbar spine achieved a neutral alignment. The symptoms in prone with the abdominal support were compared with the patient's symptoms in prone without abdominal support.

**Quadruped Position**

**Symptoms with natural alignment (primary test):** The patient assumed a quadruped position without verbal instructions or physical cueing from the examiner. The symptoms in the quadruped position were compared with the patient's symptoms in prone.

## APPENDIX 2: DESCRIPTION OF 7 PRIMARY TESTS AND 7 SECONDARY TESTS FROM THE EXAMINATION (Cont'd)

**Symptoms with corrected alignment (secondary test):** The examiner verbally and physically assisted the patient in attaining the following alignment in the quadruped position: (1) a neutral lumbar spine without rotation, side bend, or lateral shift of the lumbar spine, or lateral pelvic tilt or pelvic rotation; (2) hip joint angle at 90° of hip flexion; (3) the hip in neutral abduction and adduction and neutral rotation; (4) the knee in 90° of flexion and neutral rotation; (5) the ankles plantarflexed; and (6) the shoulders positioned in 90° of flexion. The priority feature of the position was the alignment of the lumbar spine. The symptoms in the corrected quadruped position were compared with the patient's symptoms in the test of natural alignment in the quadruped position.

**Symptoms with rocking backward (primary test):** The patient began the motion from the corrected alignment in the quadruped position. The patient was instructed to perform a backward rocking motion until he was sitting on his heels, or as far back as possible, given the patient's anatomy, while keeping his hands in the initial starting position. The symptoms were compared with the patient's symptoms in the corrected starting alignment of the quadruped position.

**Symptoms with corrected rocking backward (secondary test):** The patient began the motion from the corrected alignment in the quadruped position. The examiner positioned herself behind and above the patient, placing her hands around the patient's iliac crests so that her thumbs were positioned over the superior and posterior aspect of the ilium on both sides, and her thumbs were aligned in the same plane. The patient then was instructed to rock backward while maintaining the lumbar spine in the initial corrected alignment, avoiding any lumbar flexion, extension, rotation, side bend, shift, lateral pelvic tilt, or pelvic rotation. The lumbar spine was expected to remain in the initial alignment until the hip and knee range of motion had been attained. The symptoms with corrected rocking backward in the quadruped position were compared with the patient's symptoms in the original rocking backward movement.

Verbal instructions, demonstration, and physical assistance were given as deemed appropriate by the examiner to attain the modifications during the secondary tests.

## References

- McKenzie RA. The lumbar spine: mechanical diagnosis and therapy. Waikanae (NZ): Spinal Publications; 1981.
- Spratt KF, Lehmann TR, Weinstein JN, Sayre HA. A new approach to the low-back physical examination. Behavioral assessment of mechanical signs. *Spine* 1990;15:96-102.
- Donelson R, Grant W, Kamps C, Medcalf R. Pain response to sagittal end-range spinal motion. A prospective, randomized, multicentered trial. *Spine* 1991;16:S206-12.
- Long AL. The centralization phenomenon. Its usefulness as a predictor of outcome in conservative treatment of chronic low back pain (a pilot study). *Spine* 1995;20:2513-21; discussion 2521.
- Karas R, McIntosh G, Hall H, Wilson L, Melles T. The relationship between nonorganic signs and centralization of symptoms in the prediction of return to work for patients with low back pain. *Phys Ther* 1997;77:354-60.
- Sufka A, Hauger B, Trenary M, et al. Centralization of low back pain and perceived functional outcome. *J Orthop Sports Phys Ther* 1998;27:205-12.
- Werneke M, Hart DL, Cook D. A descriptive study of the centralization phenomenon: a prospective analysis. *Spine* 1999;24:676-83.
- Delitto A, Erhard RE, Bowling RW. A treatment-based classification approach to low back syndrome: identifying and staging patients for conservative treatment. *Phys Ther* 1995;75:470-85.
- Mooney V, Robertson J. The facet syndrome. *Clin Orthop* 1976; Mar-Apr(115):149-56.
- Van Dillen LR, Sahrman SA, Norton BJ, et al. The effect of active limb movements on symptoms and lumbar spine movement in patients with low back pain. *J Orthop Sports Phys Ther* 2001; 31:402-13.
- Adams MA, Dolan P. Recent advances in lumbar spinal mechanics and their clinical significance. *Clin Biomech* 1995;10:3-19.
- McGill SM. The biomechanics of low back injury: implications on current practice in industry and the clinic. *J Biomech* 1997;30: 456-75.
- Van Dillen LR, Sahrman SA, Norton BJ, et al. Reliability of physical examination items used for classification of patients with low back pain. *Phys Ther* 1998;78:979-88.
- Scientific approach to the assessment and management of activity related spinal disorders. A monograph for clinicians. Report of the Quebec Task Force on Spinal Disorders. *Spine* 1987;12(7 Suppl): S16-21.
- Waddell G, McCulloch JA, Kummel E, Benner RM. Nonorganic physical signs in low back pain. *Spine* 1980;5:17-25.
- Roland M, Morris R. A study of the natural history of back pain. Part I: Development of a reliable and sensitive measure of disability in low-back pain. *Spine* 1983;8:141-4.
- Fairbank JC, Couper J, Davies JB, O'Brien JP. The Oswestry Low Back Pain Disability Questionnaire. *Physiotherapy* 1980; 66:271-3.
- Cohen J. Chi-square test for goodness of fit and contingency tables. In: Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. Mahwah (NJ): Lawrence Erlbaum; 1988. p 215-71.
- Cohen J. The *t* test for means. In: Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. Mahwah (NJ): Lawrence Erlbaum; 1988. p 19-74.
- Cholewicki J, McGill SM. Lumbar posterior ligament involvement during extremely heavy lifts estimated from fluoroscopic measurements. *J Biomech* 1991;25:17-28.
- Erhard RE, Delitto A, Cibulka MT. Relative effectiveness of an extension program and a combined program of manipulation and flexion and extension exercises in patients with acute low back syndrome. *Phys Ther* 1994;74:1093-100.
- Browner WS, Black D, Newman TB, Hulley SB. Estimating sample size and power. In: Hulley SB, Cummings SR, editors. *Designing clinical research*. Baltimore: Williams & Wilkins; 1988. p 139-50.
- Sahrman SA. *Diagnosis and treatment of movement impairment syndromes*. St. Louis (MO): Mosby; 2001.
- Maluf KS, Sahrman SA, Van Dillen LR. Use of a classification system to guide nonsurgical management of a patient with chronic low back pain. *Phys Ther* 2000;80:1089-111.

## Supplier

- SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.