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Original article

Further examination of modifying patient-preferred movement and alignment strategies in patients with low back pain during symptomatic tests☆

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Abstract

Our purpose was to examine the effect of modifying symptomatic movement and alignment tests in a sample of people with LBP referred to physical therapy. Fifty-one patients (19 males, 32 females; mean age 37±10.59 yr) with LBP and a mean Oswestry Disability Index score of 34±18% were examined. The examination included 28 *primary* tests in which patients used their preferred movement or alignment strategy and reported symptoms. Symptomatic tests were followed by a *secondary* test in which the patient's strategy was standardly modified to correct the spinal alignment or movement that occurred with the primary test. Symptoms and directions of movement or alignment modified were recorded. For 82% of the secondary tests, the majority of the patients' symptoms improved. For 54% of the secondary tests, some patients required modification of more than one direction of movement or alignment to eliminate symptoms. The findings suggest that the modifications described are generalizable across a number of tests with a moderately involved group of patients, and for individual tests there is variability in the numbers and directions of movements or alignments that appear to contribute to symptoms. Information obtained from the modifications is important because it can be used to confirm the patient's LBP classification and, within the context of the examination, immediately be used to teach the patient strategies to change movements and positions that appear to be contributing to his LBP.

Keywords: Low back pain; Rehabilitation

1. Introduction

Examinations to identify the mechanical factors contributing to a patient's low back pain (LBP) often include active movement tests and alignment tests in which symptoms are assessed. Judgments of impairments are also often made. Traditionally, such examinations have focused on symptoms with a variety of trunk movements and positions including (1) single (Cyriax, 1982; Maitland and Edwards, 1986; Cailliet, 1988; Spratt et al., 1990; Moffroid et al.,1994; Delitto et al., 1995; Van Dillen et al., 1998; McKenzie and May, 2003a) and repeated trunk movements (Spratt et al., 1990; Delitto et al., 1995; McKenzie and May, 2003a), (2) combined trunk movements with and without overpressure (Maitland, 1986; Edwards, 1994) or (3)

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sustained end-range trunk positions (Moffroid et al., 1994; Delitto et al., 1995; McKenzie and May, 2003a). Some of the examinations are used to classify the LBP (Moffroid et al., 1994; Delitto et al., 1995; Sahrmann, 2002; McKenzie and May, 2003b). The overall goal of testing is to identify the trunk movements and alignments that increase or decrease the patient's symptoms. Based on the findings various treatments may be implemented with the goal of improving the LBP problem.

Work has been ongoing to examine properties of one of these examinations (Van Dillen et al., 1998) used clinically to classify LBP problems (Sahrmann, 2002). Briefly, the examination includes *primary* tests of trunk movements and alignments as well as limb movements. Symptoms are assessed and impairments are identified. Each test is presumed to be associated with the direction(s) of flexion, extension, rotation, rotation and extension or rotation and flexion. The patient performs a primary test once using his preferred strategy and reports symptoms. Standardized modifications for a subset (N=9) of primary tests were initially included based on the observation that symptoms often decrease by modifying how the patient moves or aligns the lumbar region during tests and functional activities. These are referred to as *secondary tests*. Overall, modifications involve (1) restricting movement of the lumbar region while encouraging movement in other regions, for example, the thoracic region or hip joint or (2) positioning the lumbar region in as close to a neutral alignment as possible (Adams et al., 2002; McGill, 2002). If a primary test increases symptoms the associated secondary test immediately follows. Symptoms are compared to those with the primary test. A patient's LBP is classified based on the direction(s) of alignment and movement most consistently associated with a change in symptoms and impairments across the examination. A change in symptoms in this case refers to symptom behavior both with primary tests and with secondary tests. For example, a patient might report (1) an increase in symptoms with the flexion-related primary tests, (2) a decrease in symptoms with the associated flexion-related secondary tests, and (3) no change in symptoms with tests associated with other directions of movement and alignment. The patient's LBP classification would be lumbar flexion. Proposed LBP classifications include lumbar (1) flexion, (2) extension, (3) rotation, (4) rotation with flexion, and (5) rotation with extension (Sahrmann, 2002).

A preliminary study was conducted to examine whether the subset of secondary tests actually resulted in a decrease in symptoms. Overall, the majority of patients reported a decrease with eight of nine tests (Van Dillen et al., 2003a). These findings were important because they suggested that systematically modifying symptomatic tests could provide a clinical method for identifying the specific directions of movement and alignment that appear to contribute to the patient's LBP. Such data, therefore, provides confirmatory information for classifying the LBP.

Although these findings were encouraging, the effects were examined in only nine secondary tests. However, to obtain an adequate sample of tests of the directions of movement and alignment proposed to characterize different LBP subgroups (Sahrmann, 2002; Van Dillen et al., 2003b), we currently include 28 primary tests. We also know that patients vary in the types and numbers of primary tests that are symptom-provoking (Van Dillen et al., 2001a, 2003b). For example, a patient with a rotation with flexion problem may report symptoms with only 30% of flexion-related tests and 25% of rotation-related tests. Thus, in order to confirm a patient's classification we considered it essential to have secondary tests defined for each primary test. During our preliminary study we also did not document the (1) specific directions of movement and alignment modified or (2) extent of symptom change (decreased versus (vs.) eliminated). Such information would not only provide more specific confirmatory information, the consistency of responses could potentially lend insight into a patient's prognosis for rehabilitation. Finally, only 55% of our sample was recruited from clinics and many had already received treatment for their current LBP. The generalizability of the findings to clinically based, untreated patients, therefore, was limited. For these reasons we chose to examine patients with LBP on their first clinical visit using a revised examination that included secondary tests for all primary tests. We also recorded the specific directions of movement or alignment modified and extent of change with each test.

The primary purposes of the current study were to examine (1) whether our preliminary findings would generalize to a greater number of secondary tests in a more involved group of patients than the prior sample, (2) the percentages of patients who reported a decrease vs. elimination of symptoms, and (3) the directions of modifications with each test that resulted in an elimination of symptoms. We hypothesized that (1) the majority of patients would report a decrease or elimination of symptoms with each of the secondary tests and (2) some patients would require more than one direction to be modified with individual secondary tests to eliminate symptoms.

2. Methods

2.1. Subjects

Subjects were recruited from consecutive patients with a LBP-related diagnosis referred for treatment to a university-based outpatient physical therapy clinic in the St. Louis metropolitan area. At their initial visit, all patients with a LBP-related medical diagnosis on the physician's referral were given a self-report form

with a list of the exclusion criteria. The patient was eliminated if he answered positively to any of the criteria. Patients between 18 and 75 years of age who had symptoms related to a LBP problem in either the region of the lower back, proximal lower extremity (LE) or distal LE (Spitzer et al., 1987) were eligible for inclusion in the study. Subjects were excluded if the patient reported, or had a diagnosis on their referral of spinal stenosis, osteoporosis, spondylolisthesis, spinal fusion, rheumatoid arthritis, and ankylosing spondylitis. Subjects were also excluded in the case of severe kyphosis or scoliosis, neurological disease that required hospitalization, current treatment for cancer, or had current medical complications involving the spine. All patients who met the criteria read and signed an informed consent approved by the Washington University Medical School Human Studies Committee before participating. Table 1 provides the sample characteristics of the 51 patients (37% male, 63% female) who participated.

2.2. Examination items

The items of interest were the primary and secondary tests from the standardized clinical examination (Van Dillen et al., 1998). The primary tests included 7 tests of trunk alignment, 5 tests of trunk movement, and 16 tests of limb movements (eight/side). Secondary tests were defined for each primary test (see Appendix A). For each secondary test the examiner would give verbal instructions and physical assistance. Directions of movement or alignment modified were recorded (see Appendix A). Figs. 1 and 2 provide examples of modifying a trunk alignment and a limb movement, respectively.

The possible symptom responses included increased, same, decreased or eliminated (Van Dillen et al., 2001b). Appendix B provides the operational definitions. Inter-rater reliability of examiners performing 28 of the 56 tests in the current study has been reported (Van Dillen et al., 1998). Kappa coefficients for some items were attenuated due to low prevalence rates (Feinstein and Cicchetti, 1990). Using a test–retest design, reliability of the two examiners was also examined performing tests in the current study on 7 patients with LBP. Percent agreement values for assessment of symptoms for two of the secondary tests, modification of forward bend and of flexed sitting were 70%. Percent agreement values for the remaining tests ranged from 80% to 100%. Percent agreement values for the

Table 1
Characteristics of study sample

Characteristic	Value
Mean age in years (S.D.)	36 (10.59)
Mean height in centimeters (S.D.)	172.15 (10.62)
Mean weight in kilograms (S.D.)	88.02 (25.66)
Mean pain intensity rating over previous week (Bolton, 1999) (0–10) (S.D.)	5.29 (2.21)
Location of current symptoms[a] (Spitzer et al., 1987)	
Low back only	24 (47%)
Low back/proximal lower extremity (LE)	10 (20%)
Low back/distal LE	2 (4%)
Low back/proximal LE/distal LE	15 (29%)
History of previous episode of LBP	33 (65%)
Mean Oswestry disability questionnaire scores (Fairbank, et al., 1980) (S.D.)	32 (18%)
LBP category[b]	
Acute	2 (4%)
Subacute	19 (38%)
Chronic	30 (58%)

[a] Definitions for location of symptoms from the Quebec task force on spinal disorders (Spitzer et al., 1987). Low back: region from T12 to gluteal fold; proximal LE: region from gluteal fold to knee; distal LE: below knee.

[b] Definitions for LBP categories from the Quebec task force on spinal disorders (Spitzer et al., 1987). Acute: onset of symptoms <7 days; Subacute: onset of symptoms 7 days–7 weeks; chronic: onset of symptoms >7 weeks.

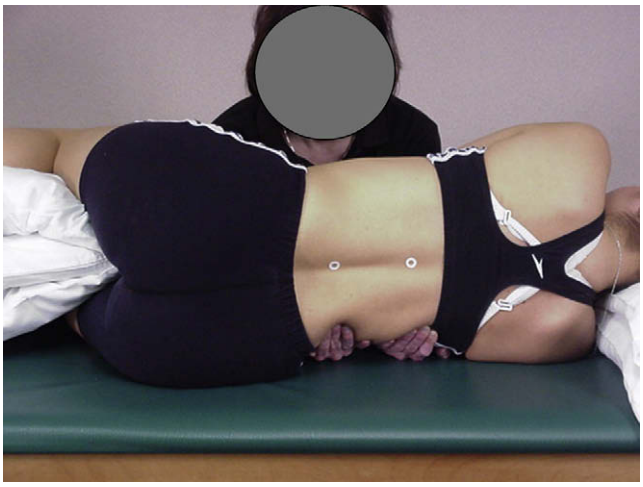

Fig. 1. Example of modification of right side lying during a secondary test of alignment.

Fig. 2. Example of modification of hip lateral rotation in prone during a secondary test of movement.

movement and alignment judgments ranged from 65% to 100%. Additional reliability statistics were not calculated due to sample size (Cicchetti and Sparrow, 1981).

2.3. Procedures

Each patient was examined on the first visit to the clinic by one of two trained physical therapists. The therapists were 42 and 25 years of age. One therapist had 17 years of experience and the other therapist had just completed her Master's degree in Physical Therapy. For each patient the sequence of test positions (standing, sitting, supine, side lying, prone, quadruped) was randomized to control for order effects.

2.4. Data analysis

Data analysis was performed using Systat version 10.2 for Windows (SPSS, Inc., Chicago, IL). Descriptive statistics were calculated for patient characteristics and diagnoses. Frequencies and percentages of symptom responses for each secondary test were calculated for only those patients who reported an *increase* in symptoms with the corresponding primary test. For each secondary test a χ^2 goodness-of-fit analysis then was performed on the frequencies of responses to examine if the percentages of patients in each of 3 response categories (decreased, same, increased) were different. The decreased response for this analysis included patients with a decrease *or* an elimination of symptoms. To examine how much symptoms improved, a one-way analysis of variance (ANOVA) was conducted on the percentage of patients with a decrease vs. elimination of symptoms. Finally, to examine if more than one direction of movement or alignment had to be modified to eliminate symptoms, frequencies and percentages of the directions modified were calculated. These statistics were calculated for each secondary test for only patients who reported an elimination of symptoms. The probability level for all significance testing was set at the $P \leqslant .05$ level.

3. Results

3.1. Patient characteristics

Descriptive statistics for patient characteristics are summarized in Table 1. The majority of patients (64%) were referred with a diagnosis of LBP. Ten percent were diagnosed as a lumbar sprain or strain, 8% as lumbar radiculopathy and 8% as lumbar segmental dysfunction. Four percent were diagnosed as degenerative disc or joint disease and another 4% were myofascial pain. Finally, 2% were referred with a diagnosis of lumbago.

3.2. Exceptions

Three percent (49/1428) of the total responses for the primary tests were not obtained. Nine patients were unable to provide a response for at least one of the primary tests. Five (56%) patients did not schedule sufficient time, 3 had neck, shoulder, or knee pain that limited some positions and one could not assume quadruped due to obesity.

3.3. Secondary tests

Appendix A includes a list of the secondary tests and directions of lumbar region movement or alignment that potentially would need to be modified to decrease symptoms. Table 2 lists the secondary tests and the percentages who reported a decrease in symptoms with each secondary test. Overall, all 51 patients reported a decrease or elimination of symptoms with one or more of the 28 tests. The mean percentage of patients who reported a decrease in symptoms was 84±10% with a range of 100–58%. The majority of patients reported a decrease in symptoms for 23 (82%) of the 28 secondary tests (all comparisons $P \leqslant .05$). The five tests in which the majority did not report a decrease in symptoms included 2 trunk alignments (left side lying and quadruped) and 3 right limb movement tests (hip abduction/lateral rotation, hip lateral rotation and shoulder flexion in quadruped). For each of the secondary tests some patients reported a decrease and some reported an elimination of symptoms. On average, 52±3% reported a decrease in symptoms and 48±4% reported an elimination of symptoms ($F=0.55$, $P=0.460$). For 6 of the 7 trunk alignment tests (86%) all patients required only one direction of alignment modified. One patient required modification of 2 directions of alignment with left side lying. For all 5 of the trunk movement tests (100%) some patients required modification of 2 directions of movement. Finally, for 9 of the 16 limb movement tests (56%) some patients required modification of 2 directions of movement. These tests included knee extension in sitting (bilateral), hip and knee flexion in supine (bilateral), knee flexion in prone (bilateral), hip extension in prone (bilateral), and right arm lift in quadruped.

4. Discussion

4.1. Primary findings

Our purpose was to examine, in patients at their initial physical therapy visit, the effects of standardly modifying examination tests used to classify LBP. The findings from the current study extend the findings from our preliminary work (Van Dillen et al., 2003a). The modifications can be

Table 2
Percentages of patients who reported a decrease[a] in symptoms with each secondary test[b]

Test category[c]	Secondary test	Percentage reporting decreased symptoms (%)		
		Right	Left	Other
Trunk alignment	Sitting: flexion			75
	Sitting: extension			88
	Supine			94
	Side lying	73	58[d]	
	Prone			78
	Quadruped			75[d]
Trunk movement	Standing: forward bend			90
	Standing: return from forward bend			90
	Standing: lateral bend	96	81	
	Quadruped: rock back			83
Limb movement	Sitting: knee extension	83	91	
	Supine: hip and knee flexion	81	73	
	Supine: hip abduction and lateral rotation	75[d]	100	
	Prone: knee flexion	85	100	
	Prone: hip lateral rotation	71[d]	86	
	Prone: hip medial rotation	93	86	
	Prone: hip extension	95	89	
	Quadruped: shoulder flexion	71[d]	80	

[a] Decreased responses include patients who reported a decrease or an elimination of symptoms when the primary test was modified.
[b] Secondary test findings from those who had an increase in symptoms with the corresponding primary test. Modifications include (1) aligning the lumbar region in as close to neutral as possible (Adams and Dolan, 1995; McGill, 2002) or (2) restricting lumbar region movement and encouraging movement in other regions, e.g., hip joint, thoracic region.
[c] There were three categories of tests: (1) tests of trunk alignment, (2) tests of trunk movement, and (3) tests of limb movements.
[d] Indicates no difference between those reporting decreased vs. same for symptoms with the secondary test. For all other secondary tests, the majority of patients reported a decrease in symptoms ($P \leqslant .05$).

applied to all of the primary tests and to a clinically based group of patients with higher levels of symptoms and LBP-related disability than our original study (Table 1). A significant number of patients reported an improvement in their symptoms with 71% of the alignment tests and 86% of the movement tests (Table 2). On average, patients' symptoms were decreased 50% of the time and eliminated 50% of the time with the secondary tests. Finally, for individual tests we identified the number of directions of movements or alignments required to eliminate symptoms. These findings are important because (1) they suggest it is possible to obtain immediate information about whether the patient's symptoms can be changed by direction-specific modifications, (2) many patients improve with the modifications, and (3) some patients will require modification of more than one direction of movement or alignment to eliminate symptoms. The specific movement and alignment information and response to modifications is essential for confirming the patient's direction-specific LBP classification. Classifying LBP problems is important for direction of treatment and prognosis (Spitzer et al., 1987).

4.2. Clinical relevance

The findings from the described methods are used to assist in classifying the movement-system aspect of a patient's LBP problem (Sahrmann, 2002). The findings are of particular relevance because tests are given more significance in the decision-making process if a primary test produces increased symptoms and the associated secondary test produces decreased symptoms. Thus, each modification provides the clinician with immediate and confirmatory information about the specific direction(s) of movement or alignment related to the patient's LBP. Because patients vary in the type and number of tests that are symptomatic, it is essential to have methods that confirm the specific movements and alignments contributing to the patient's symptoms for each examination test to effectively classify the LBP. The classification assigned describes the direction(s) of movement and alignment that are most consistently associated with changes in symptoms and impairments identified *across* the examination. Such changes in symptom behavior are considered both during primary and secondary tests associated with a particular direction of movement or alignment. For example, an increase in symptoms with primary tests associated with lumbar region flexion, a decrease or elimination of symptoms during the associated secondary tests and no change in symptoms with primary tests associated with other directions of movement and alignment would result in a flexion-related classification. Considering the classification identifies the movement-system contribution to

the LBP problem it can then be used to direct treatment. Treatment includes (1) education about how generalizing the identified movement and alignment strategies across multiple activities potentially contributes to acceleration of lumbar region tissue stress and symptoms (Mueller and Maluf, 2002) and (2) modification of strategies through retraining of functional activities and exercise. For example, a patient classified as lumbar flexion would be educated about his tendency to flex the lumbar region with multiple functional activities. The patient would be educated about how the repetitive use of flexion movements and alignments across the day potentially contributes to increased lumbar region tissue stress and symptoms, particularly because they are performed in the same direction. Each of the patient's symptom-provoking functional activities, as well as those frequently repeated throughout the day, then would be observed, analyzed, and modified. Emphasis would be placed on modifying the activities so the patient could accomplish the activities without the use of lumbar flexion. Finally, secondary test modifications that resulted in a decrease or elimination of symptoms with primary tests from the examination would be prescribed as exercises.

The secondary test responses are also considered to be related to the patient's prognosis in two ways. First, based on clinical observation, it appears that the course of the different LBP classifications identified, in part, with the secondary tests, may differ. Knowledge of prognoses for different classifications will assist the clinician in treatment and goal setting. Second, if the patient's modifications are readily implemented and improve symptoms the prognosis for treatment is likely to be good. Thus far, descriptive and pilot work examining classification-based treatment based, in part, on the associated modifications, has resulted in positive short- and long-term outcomes (Maluf et al., 2000; Harris Hayes et al., 2005; Van Dillen et al., 2005; Van Dillen and Sahrmann, 2006). Future randomized clinical trials, however, comparing classification-based treatment to other treatments are required to fully test these preliminary outcomes.

4.3. Prior literature

McKenzie described a symptom assessment method in which the patient performs single and repeated end-range spinal movements or assumes sustained end-range spinal alignments (McKenzie and May, 2003a). The findings from testing are used for LBP classification to assist in treatment and prognosis. Similar to the current study, Donelson et al. examined patients' responses to McKenzie's testing within a single session in patients with varying levels of acuity and symptom location (Donelson et al., 1991). The authors reported that more subjects' symptoms improved with repeated extension than repeated flexion movements. Because we do not perform repeated spinal movements for symptom assessment the current findings cannot be directly compared to the Donelson et al. study. Both studies, however, suggest that the majority of patients appear to positively respond to the described methods of symptom testing. Future studies need to compare the characteristics of patients who respond positively to one, both, or neither of the symptom assessment methods to determine the optimal methods to be applied to different patient types.

The McKenzie method appears applicable to a number of people with LBP (Fritz et al., 2003; Long et al., 2004), and centralization has been related to a good prognosis (Donelson et al., 1990; Long, 1995). There is data, however, to suggest that not all patients will respond systematically to the described symptom testing (Fritz & George, 2000; Fritz et al., 2003; Long et al., 2004) and a suggestion that treatment effects based on results of the McKenzie symptom testing are not always consistent (Delitto et al., 1995). Considering the majority of people in the current study improved with the tests examined, the described methods could provide an alternative method for those who do not systematically respond to McKenzie methods.

4.4. Acuity and location of symptoms

We did not examine differential effects of the secondary test methods based on acuity or location of symptoms. These were not performed because currently there is no theoretical basis to suggest that the results of individual secondary tests or the different classifications we identify based, in part, on the secondary test results would differ based on these variables. The primary directions of movement and alignment that are considered to contribute to a patient's LBP are considered to be the same irrespective of acuity or symptom location. For example, a patient classified with lumbar rotation with flexion (1) may seek treatment in the acute, subacute or chronic stage and (2) may or may not have symptoms that extend to the proximal or distal LE. Based on pilot work and clinical observation we do know that, within a patient, what may vary based on acuity or location is the (1) number of primary tests that are symptomatic and (2) extent of change in symptoms (decreased vs. eliminated) with secondary tests (unpublished data).

4.5. Limitations

One potential limitation is that not all patients completed all 28 primary tests (Table A1). Only four patients, however, were unable to perform some of the tests because of their LBP problem (Table A1). Because of the number and inter-relationships among the tests (Van Dillen et al., 2003b), missing responses to some of the tests should not preclude classification. A second

potential limitation is that only a minimal amount of testing has been done on the reliability of clinicians inexperienced in the use of the symptom testing and examination (Turner et al., 2005). The findings from the current study, therefore, may not be easily replicated. Future studies could focus on training inexperienced clinicians to determine if similar changes in symptoms can be obtained. A third limitation is that the prognostic value of the findings from the symptom testing is speculative at this point in time. The data currently available are case reports of people with LBP who responded positively to the symptom testing and were treated based on results of the testing and their LBP classification, and a pilot study of outcomes of people treated based on their LBP classification compared to an untreated group of people with LBP (Maluf et al., 2000; Harris Hayes et al., 2005; Van Dillen et al., 2005; Van Dillen and Sahrmann, 2006). Longitudinal studies of outcomes of patients who do and do not respond positively to the symptom testing are indicated. A fourth limitation is that the symptom testing, classification system and treatment based on the results of symptom testing are based on a proposed conceptual model for LBP that is not fully tested. Work is ongoing to test assumptions of the proposed LBP model (Van Dillen et al., 2001a, 2003a, 2005; Gombatto et al., 2006; Van Dillen and Sahrmann, 2006; Gombatto et al., 2007; Scholtes and Van Dillen, in press) and to test the reliability and validity of the classification system based on the proposed model (Van Dillen et al., 1998,2003b; Maluf et al., 2000; Norton et al., 2004; Harris Hayes et al., 2005; Turner et al., 2005; Van Dillen et al., 2005; Van Dillen and Sahrmann, 2006). Considering the status of testing, the validity of the assumptions underlying the effects of the described symptom testing is still tentative. A fifth limitation is the current study is focused on only some of the variables that would assist in understanding and identifying the various contributions to the patient's LBP problem. Consistent with the biopsychosocial model (Waddell, 1998), information about several other variables (history, self-report, laboratory measures) are essential to designing treatment and prognosing. The variables focused on in the current study provide insight only into some of the movement-system variables potentially contributing to the LBP problem. A final limitation is that we do not know if any of the patients in our sample demonstrated high levels of fear-avoidance behavior (Waddell et al., 1993). We would assume, however, that if this was an issue a patient would avoid performing any tests that increase symptoms. The four patients who did not perform a few of the tests because of their LBP did perform other tests that increased symptoms. Future work could examine how people who display different levels of fear-avoidance behavior respond during the tests described.

5. Conclusions

The findings suggest that the modifications are generalizable across a number of tests and to a clinically based sample of patients who have not been treated for their current LBP, and result in a decrease in symptoms in the majority of patients. Additionally, for many tests there is variability in the numbers of movements or alignments that appear to contribute to symptoms and that would need to be modified to improve symptoms. Information obtained from the modifications is important because it can be used to assist in confirming a patient's LBP classification and thus, assist in directing treatment and prognosis.

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Appendix A. Directions of movement or alignment potentially needed to be modified during secondary tests to decrease symptoms

Primary tests are tests in which the patient assumes a trunk position or performs a trunk or limb movement using his preferred strategy. Symptoms with each primary test are monitored and compared to a reference position or movement. Any symptom-provoking primary test is immediately followed by a secondary test. Secondary tests are directed at decreasing the patient's symptoms compared to symptoms during the associated primary test. The primary goal of the secondary tests for alignment is to attempt to position the lumbar region in as close to a neutral alignment (Adams and Dolan, 1995; McGill, 2002) as possible. The primary goal of the secondary tests for movement is to restrict or eliminate movement of the lumbar region while encouraging movement in other regions such as the thoracic region, shoulder joint or hip joint. Tests that involve movement of the limbs or movement of the trunk in the frontal or horizontal plane are performed both to the left and to the right. Specific directions of lumbar region movement or alignment may need to be modified to successfully decrease symptoms with individual secondary tests. The directions of movement or alignment that would potentially need to be modified for each test are provided below, see Table A1.

Table A1

Secondary test	Directions of movement or alignment potentially needed to be modified during secondary tests to decrease symptoms				
	Flexion[a]	Extension[a]	Rotation[a,b]	Flexion and rotation[c]	Extension and rotation[c]
Tests of trunk alignment					
Sitting: flexion	X			X	
Sitting: extension		X			X
Supine		X			
Side lying			X	X	X
Prone		X			
Quadruped	X	X	X	X	X
Tests of trunk movement					
Standing: forward bend	X			X	
Standing: return from forward bend		X			X
Standing: lateral bend			X	X	X
Quadruped: rock back	X		X	X	
Tests of limb movement					
Supine: knee extension	X		X	X	
Supine: hip and knee flexion	X	X	X		X
Supine: hip abduction and lateral rotation			X		
Tests of limb movement					
Prone: knee flexion		X	X		X
Prone: hip lateral rotation			X		
Prone: hip medial rotation			X		
Prone: hip extension		X	X		X
Quadruped: shoulder flexion			X		

[a] Indicates only one direction of movement or alignment would need to be modified to decrease symptoms.
[b] Because rotation and lateral bending are coupled motions in the lumbar region (Pearcy and Tibrewal, 1984; White and Panjabi, 1990) we currently categorize either of these as rotation.
[c] Indicates both directions of movement or alignment would need to be modified to decrease symptoms.

Appendix B. Operational definitions for symptom responses for primary and secondary tests

1. *Increased*: Symptoms were evoked or increased in intensity, or extended more distally.
2. *Same*: Symptoms were unchanged in intensity or location.
3. *Decreased*: Symptoms were diminished in intensity, or were located more proximally.
4. *Eliminated*: Symptoms were eliminated.
   - In instances in which the findings for proximal and distal symptoms are different, the examiner prioritizes the behavior of the most distal symptoms to decide on the response (Van Dillen et al., 2001b).

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