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Trunk Rotation-Related Impairments in People With Low Back Pain Who Participated in 2 Different Types of Leisure Activities: A Secondary Analysis

Linda R. Van Dillen, PT, PhD[1]
Shirley A. Sahrmann, PT, PhD[2]
Cheryl A. Caldwell, DPT, MHS, CHT[3]
Mary Kate McDonnell, DPT, MHS, OCS[3]
Nancy J. Bloom, DPT, MSOT[3]
Barbara J. Norton, PT, PhD[4]

Study Design: Cross-sectional, secondary analysis.
Objectives: To examine whether there were differences in the numbers and types of impairments on examination between 2 groups of people with low back pain (LBP), those who participated in symmetric leisure activities and those who participated in asymmetric leisure activities.
Background: It has been proposed that people who repeatedly perform an activity that involves trunk movements and alignments in the same direction will develop strategies that are generalized to many activities. The repeated use of these strategies is proposed to contribute to impairments identifiable on examination and to LBP.
Methods and Measures: Forty males and 40 females (mean ± SD age, 41.4 ± 13.9 years) with LBP who reported participation in either a symmetric or an asymmetric leisure activity participated in a standardized examination. Responses from 10 trunk-rotation-related impairment tests were analyzed using the Mann-Whitney *U* and chi-square statistics.
Results: Thirty people participated in asymmetric leisure activities and 50 people participated in symmetric leisure activities. The total number of rotation-related impairments was different for the 2 groups (U = 1112, $P < .01$). The asymmetric group displayed more total rotation-related impairments (median, 4.0; range, 7) than the symmetric group (median, 2.0; range, 6). A greater percentage of the asymmetric group displayed more impairments on 5 out of 10 individual tests, as compared to the symmetric group ($P \leq .05$ for all comparisons).
Conclusions: Our results provide preliminary data to suggest that trunk-rotation–related impairments, identified on examination, may be related to the general type of movements and alignments used repeatedly by patients with LBP. *J Orthop Phys Ther 2006;36:58-71.*

Key Words: *examination, lumbar spine, spinal disorders, sports*

[1] *Assistant Professor, Program in Physical Therapy, Washington University School of Medicine, St Louis, MO.*
[2] *Professor, Program in Physical Therapy, Washington University School of Medicine, St Louis, MO.*
[3] *Assistant Professor, Program in Physical Therapy, Washington University School of Medicine, St Louis, MO.*
[4] *Associate Professor and Associate Director of Post-Professional Studies, Program in Physical Therapy, Washington University School of Medicine, St Louis, MO.*
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Address correspondence to Linda R. Van Dillen, Program in Physical Therapy, Washington University School of Medicine, Campus Box 8502, St Louis, MO 63110. E-mail: vandillenl@msnotes.wustl.edu

Many of the activities that people participate in on a regular basis have the potential to contribute to a low back pain (LBP). Activities associated with prolonged postures and repeated movements of the trunk, in particular, have been found to be associated with LBP. For example, work-related activities involving sustained nonneutral postures, frequent bending and twisting, and repetitive work have been linked to LBP.[6,7,11,16] Furthermore, various sports-related activities have been associated with a high incidence of LBP[2,8,12,23] and specific spine abnormalities and degenerative changes in the spine have been identified in certain types of athletes.[8,9,14,23] Not everyone, however, who participates in work- or sports-related activities develops LBP. The reason that some people develop LBP problems while others do not is theorized to be related, in part, to the specific movement patterns one develops as one performs various activities repeatedly.[19]

Sahrmann has developed an approach to diagnosis and treatment[19] based on the idea that a person's LBP is primarily related to 2 factors. The first factor is repetition of movements, both trunk and limb, that are proposed to induce a specific direction(s) of movement in the lumbar region. The second factor is assumption of specific trunk postures repeatedly and for prolonged periods. For example, an office assistant may (1) repeatedly flex and rotate his lumbar region to the right when he reaches to answer the phone, and (2) continually sit in lumbar flexion and rotation to the right at his desk. In both cases, the specific direction of lumbar region movement and alignment associated with the work activity is flexion and rotation to the right. Sahrmann[19] proposes that the repeated use of these movements and alignments contributes to specific strategies that are used by the person throughout the day. The use of the term strategy in our report refers to a specific movement pattern that occurs automatically and is thus most likely based on a motor program. The motor program consists of a set of muscle commands that are organized before a movement begins and are sent to muscles in a sequence that allows the movement to be performed, without feedback from the periphery.[1,20]

Previously, we standardized an examination that includes tests for assessing physical impairments and their underlying strategies.[25] For example, one of the tests requires the patient to rotate the hip laterally while in prone. While the patient moves the hip, the examiner focuses on the lumbopelvic region. Given the assumption that the spine should remain relatively stable during limb movements,[19] the test would be considered positive for a trunk rotation-related impairment if the patient's lumbopelvic region moved along with the hip. Similar responses on several different tests would lead to categorization of the patient's LBP problem as a lumbar rotation syndrome.[27]

One way to test the proposal that the alignments and movements a person uses repeatedly are related to his LBP problem is to examine different groups of people with LBP who engage in different types of activities. For this report we conducted a secondary analysis on a data set that included 2 different subgroups of people with LBP. One group was comprised of people who participated in leisure activities that were performed more frequently and with one side of the body to a greater degree than the other (asymmetric activities). The second group was comprised of people who participated in leisure activities that were primarily performed using both sides of the body with similar frequency and degree (symmetric activities). Because trunk rotation is a direction of movement or an alignment that is theorized to be performed asymmetrically, we hypothesized that the patients with LBP who participated in asymmetric leisure activities would display more trunk rotation-related impairments on examination than the patients with LBP who participated in a symmetric leisure activity.

One purpose of this secondary analysis was to test the hypothesis that the people with LBP who participated in asymmetric leisure activities would display a greater number of trunk rotation-related impairments on examination than people with LBP who participated in symmetric leisure activities. A second purpose was to examine which of the individual rotation-related tests differed between the 2 groups of people with LBP.

MATERIALS AND METHODS

Subjects

The original sample consisted of 188 patients with LBP who were part of a study examining (1) the reliability of clinicians performing examination items proposed to be important for classification of LBP problems,[25] (2) validity of a subset of the proposed LBP classifications,[27] and (3) the effect of limb movements on LBP symptoms.[24] The ability of clinicians to modify symptoms during tests from the examination[26] also has been reported. Subjects were recruited from (1) patients referred for treatment to 1 of 6 different outpatient physical therapy clinics (57%), (2) family members and friends of patients with LBP participating in the current study who also had LBP (19%), as well as (3) advertisements in a local community newspaper and posters distributed in the St. Louis area where the study was conducted (23%). Subjects 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, or distal lower extremity were eligible for inclusion in the study.[21] Subjects were excluded in the case of pregnancy, severe kyphosis or scoliosis, spinal stenosis, a history of spinal surgery in the last 3 months, more than 1 surgical procedure on the spine, pending spinal surgery, cancer, rheumatoid arthritis, ankylosing spondylitis, neurological disease, and the inability to stand and walk without an assistive device. All subjects read and signed an informed consent approved by the Human Studies Committee of Washington University Medical School before participating in the study.

Examination Items

The items of interest in the current study were part of a standardized clinical examination.[25] The examination consisted of a history and a set of physical tests and measures. Each subject first answered the history questions and then participated in the physical examination. The same therapist administered

TABLE 1. Activities and frequency counts of patients in the active group who reported participation in a specific activity.

Activity	Number of Patients
Aerobics	3
Basketball	8
Bowling	4
Cycling	12
Darts	1
Floor exercise	4
Garden	1
Golfing	2
Hunting	1
Jogging	4
Pool exercise	1
Racquetball	2
Rock climbing	1
Rollerblading	2
Running	6
Skating	1
Squash	1
Stair climbing	2
Swimming	5
Tennis	6
Volleyball	5
Walking	46
Weight training	6

both the history and physical tests for an individual patient. The history questions (n = 59) were related to patient characteristics and medical, LBP, and activity history. The physical tests focused on assessment of symptoms with various movements (trunk and limb) and positions, as well as judgments of alignment and movement of the lumbar or lumbopelvic region during trunk and limb movements (n = 72 judgments or questions). The tests were performed in several different positions. The majority of test items were included to identify impairments of alignment or movement in the directions of flexion, extension, or rotation. Because rotation and lateral bending are coupled motions in the lumbar spine,[15,28] impairments that involve either motion were categorized as trunk rotation-related impairments. Interrater reliability of 5 examiners administering the examination items was reported previously.[25] Kappa values for items included in the present study ranged from 0.21 to 0.76 and percent agreement values ranged from 55% to 90%.

Procedures

Patient Selection We used reports of leisure activities obtained during the history to determine the patients to study. Patients were asked whether or not they regularly participated in any leisure activities over the prior 12 months. A leisure activity was defined as any activity that was not work related. Household-related activities were not considered leisure activities. Participation of a minimum of once per month was defined as regular. Information regarding whether the patient's participation was beyond the 12-month criterion was not obtained. All activity responses were generated by the patient. If the patient reported participation in more than 1 activity, the information about the type and frequency of participation was recorded for each activity. The primary activity then was the activity the patient participated in most frequently. Other activities were considered secondary. We included the data from only those who participated in their primary activity once a week or greater. We reasoned that a person would need to meet at least the once a week participation level for any obtained relationship to be biologically plausible. One hundred twenty-four of the 188 patients (66%) met the defined criterion. These patients reported participation in 23 different leisure activities. Table 1 lists the leisure activities and frequency counts of the patients who participated in each activity.

We categorized the 23 activities as (1) asymmetric, (2) symmetric, or (3) neither, based on a survey completed by 7 orthopedic physical therapists. Items in which there was 70% (5/7) or more agreement among the therapists for an individual activity were included in the analyses. Items that did not meet the 70% criterion or items categorized as neither were excluded from further analyses. The therapists consistently categorized 4 of the 23 (17%) activities as symmetric and 9 of the 23 (39%) activities as asymmetric. Thirty (24%) patients reported participation in an asymmetric activity and 56 (45%) patients reported participation in a symmetric activity. The asymmetric leisure activities agreed on were (1) tennis, (2) racquetball, (3) squash, (4) golf, (5) volleyball, (6) basketball, (7) skating, (8) bowling, and (9) dart throwing. The symmetric leisure activities were (1) walking, (2) jogging, (3) running, and (4) cycling.

We compared the symmetric and asymmetric groups for equivalence with regard to relevant characteristics. Table 2 lists the values for the patient, LBP- and activity-related characteristics for each group, and results of associated statistical tests of differences. The patient groups were different with regard to 4 characteristics. Compared to the asymmetric group, the symmetric group (1) reported higher average LBP, (2) higher Oswestry disability scores, (3) had a slightly higher body mass index (BMI), and (4) a higher frequency of participation per month in their leisure activity ($P<.05$ for all comparisons). In an effort to make the groups equivalent regarding variables that could pose alternative explanations for any obtained effects, the data set was further reduced. A

TABLE 2. Characteristics of initial sample of people with low back pain (LBP) who reported participation in a symmetric activity or an asymmetric activity (n = 86).

Characteristic	Group: Symmetric	Group: Asymmetric	Statistical and Probability Values
Gender (%)			χ^2 = 0.21, P>.05
Male	48.0	53.0	
Female	52.0	47.0	
Mean (SD) age (y)	43.7 (12.5)	39.4 (15.9)	t = –1.39, P>.05
Mean (SD) body mass index (kg/m^2)	26.2 (6.2)	23.0 (2.9)	t = –2.91, P<.05*
Pain intensity rating over prior week (0-5 wk)[18] (range)†	2 (6)	1 (4)	U = 574, P<.05*
Location of current symptoms[21] (%)†			χ^2 = 5.11, P>.05
Low back only	57.1	80.0	
Low back/proximal lower extremity (LE)	14.3	6.7	
Low back/distal LE	5.4	0.0	
Low back/proximal LE/distal LE	23.2	13.3	
Duration of current LBP symptoms[21] (%)			χ^2 = 0.75, P>.05
Acute (<7 d)	12.7	6.9	
Subacute (7 d-7 wk)	21.8	20.7	
Chronic (>7 wk)	65.4	72.4	
History of previous episodes of LBP (%)	88.2	85.7	χ^2 = 0.10, P>.05
Mean (SD) Oswestry Disability Questionnaire[5] scores (%)	25.6 (15.9)	16.9 (13.8)	t = –2.54, P<.05*
Frequency of participation in activity per mo† (range)	12 (19)	8 (19)	U = 379, P<.01*

*Indicates a significant difference between the groups.
† Indicates median value.

process was used in which the cases in the symmetric group were iteratively removed, beginning with the case with the highest Oswestry disability score. After removal of each case the 2 groups were compared across the 3 variables that posed alternative explanations for any obtained effects (average LBP, Oswestry score, and BMI). Removal of cases was continued until the 2 groups were equivalent. Six cases were removed from the symmetric group data set. The iterative process was used instead of individual matching of patients to preserve as much power as possible for comparisons. Table 3 lists the primary activities and the number of patients who participated in each activity. Seventeen of the patients also reported participation in secondary activities. Table 4 lists the primary and secondary activities for these 17 patients. Five of the patients in the symmetric group reported participation in secondary activities. The secondary activities for the symmetric group were categorized as symmetric. Twelve of the patients in the asymmetric group reported participation in secondary activities. Three of the secondary activities for the asymmetric group were categorized as symmetric, 2 were categorized as asymmetric, and 1 was categorized as neither.

Test Items The responses to a subset of 10 of the physical test items were the focus of the current study. The 10 items, impairments assessed, and values for reliability statistics[25] for each item are provided in Table 5. These test items included assumption of different positions, such as standing or sitting, or

TABLE 3. Primary activities and frequency counts of people who were included in final analyses (n = 80).

Activity	Number of Patients
Basketball	7
Bowling	4
Cycling	8
Dart throwing	1
Golfing	2
Jogging	3
Racquetball	2
Running	3
Skating	2
Squash	1
Tennis	7
Volleyball	5
Walking	35

performance of overt trunk or limb movements, such as trunk lateral bending in standing or hip rotation in prone. Two of the impairment judgments were related to alignment and 8 were related to movement. The responses for the test items required judgments by the examiner, based on visual or visual and tactile information. The item responses were operationalized based on criteria developed by a clinical expert[19] and 5 orthopedic physical therapists. There were 2 responses possible for the items included in the current study: an impairment was either present or absent. The emphasis of the responses for the alignment and movement items was on (1) the presence of lumbopelvic region rotation or lateral bending, or (2) asymmetry of lumbopelvic region rotation or lateral bending.

A criterion of a 1.28-cm or greater difference between sides in tissue depth was used for the judgments of alignment impairments. For example, alignment of the lumbar region in quadruped was assessed by having the patient assume the preferred position. The examiner, positioned behind and above the patient, placed his/her hands on the lumbar paraspinal region between L1 and L5 so that the thumbs were aligned parallel to each other. Based on visual information, the therapist made a judgment about whether or not there was a sufficient difference in tissue depth on the right to left side of the spine. This decision was based on whether or not one thumb was higher than the other by at least a thumb's depth. A criterion of 1.28-cm or greater movement, or movement difference when movement of one side was compared to the other, was used for the majority of judgments of lumbopelvic region movement impairments. For example, a judgment of lumbopelvic region rotation during hip rotation in prone was made by having the examiner stand next to the patient at pelvic level on the side opposite the lower extremity to be moved. The examiner placed a hand across the patient's sacrum so that her metacarpophalangeal joints were aligned on top of, and parallel with, the median sacral crest. Based on visual and tactile information, the examiner judged whether or not the patient moved the pelvis 1.28 cm or more when the patient rotated the hip. The criterion for the presence of impairment for each test was based on clinical expert opinion and decided on during initial testing of the standardized examination.[25] The 10 impairment tests are listed in Table 5. The Appendix provides the procedures for the tests and the operational definitions for the responses.

TABLE 4. Leisure activities* and frequencies of the 17 patients in the symmetric and asymmetric groups who participated in more than 1 leisure activity.

Group	Primary	Secondary		Number of Patients
		First	Second	
Symmetric	Cycling	Run		2
	Cycling	Run	Walk	3
Asymmetric	Tennis	Run		2
	Golf	Walk		1
	Racquetball	Run		1
	Volleyball	Basketball		1
	Racquetball	Swim†		1
	Squash	Swim†		1
	Tennis	Golf		1
	Basketball	Run		1
	Tennis	Walk	Cycle	1
	Racquetball	Walk	Run	1
	Tennis	Walk	Run	1

* Activities are ordered by frequency of participation; the primary activity has the highest frequency, the first secondary activity has the next highest frequency, the second secondary activity has the lowest frequency.

† This item was categorized as "neither" by the 7 therapists who participated in the survey to categorize leisure activities reported by patients in study.

TABLE 5. Subset of test items from physical examination, associated alignment or movement impairment assessed and reliability statistics[25]

		Value of Reliability Statistic[25*]	
Test	Impairment	Kappa Coefficient	Percent Agreement
Alignment of lumbar region in standing	Rotation of the lumbar region†	0.27	84
Active lateral bending in standing	Asymmetrical lumbar region motion with lateral bending, right versus left	0.26	65
Active knee extension in sitting	Rotation of the lumbopelvic region‡	0.58	86
Active hip lateral rotation and abduction in partial hook lying	Rotation of the lumbopelvic region‡	0.60	88
Active knee flexion in prone	Rotation of the lumbopelvic region‡	0.76	90
Active hip rotation in prone	Rotation of the lumbopelvic region‡	0.56	83
Active hip rotation in prone	Asymmetrical lumbopelvic region rotation, right versus left	0.52	74
Alignment of lumbar region in quadruped	Rotation of the lumbar region†	0.52	83
Active arm lifting in quadruped	Asymmetrical rotation of the lumbar region, right versus left	0.21	55
Active rocking back in quadruped	Pelvic rotation or pelvic tilt	0.51	82

* Reliability coefficients from a group of 5 clinicians trained in examination procedures and operational definitions.[25]
† Indicates an impairment of alignment. All others are impairments of movement.
‡ Indicates impairment can occur with either or both lower extremities.

Data Analyses

Frequency counts of the total number of rotation-related impairments identified in the examination were tabulated for each patient. A Mann-Whitney *U* analysis was conducted to test for whether or not the total number of rotation-related impairments was different for the symmetric and asymmetric groups. The Mann-Whitney *U* analysis tests for a difference in the distribution of responses between the 2 groups in percentages of people who have from 0 to 10 positive impairments on examination. A chi-square goodness-of-fit analysis then was conducted on the responses (positive versus negative) for each of the 10 trunk-rotation–related tests to examine whether the percentages of people who displayed impairment with each test were different for the 2 groups (symmetric versus asymmetric). The probability level for all testing was set at $P \leq .05$. Because this was a secondary analysis of data, the numbers of subjects in our 2 groups were limited. Therefore, to determine if there were any potential trends in the data, we conducted post hoc power analyses to examine the effect size and power available to detect an effect in instances in which the groups were not different with regard to impairment with an individual test.

RESULTS

Patient Characteristics

The final 2 groups analyzed were equivalent with regard to each of the following variables: (1) gender distribution, (2) age, (3) BMI, (3) average pain intensity over the prior week, (4) location of symptoms, (5) duration of symptoms, (6) history of previous LBP episodes, (7) Oswestry disability score[5] ($P > .05$ for all comparisons). The symmetric group reported a higher level of participation in their leisure activities than the asymmetric group ($P < .05$). Table 6 lists the values for each of these variables for each of the groups included in the final analyses and the associated statistical and probability values.

Rotation-Related Impairments

On average, patients in the asymmetric group displayed more rotation-related impairments (me-

TABLE 6. Characteristics of final sample of people with low back pain (LBP) who reported participation in a symmetric activity or an asymmetric activity (n = 80).

Characteristic†	Group*		Statistical and Probability Values
	Symmetric	Asymmetric	
Gender (%)			χ^2 = 0.46, *P*>.05
Male	47.0	55.0	
Female	53.0	45.0	
Mean (SD) age (y)	42.3 (12.6)	40.2 (15.7)	*t* = 0.66, *P*>.05
Mean (SD) body mass index (kg/m^2)	25.3 (5.2)	23.3 (3.0)	*t* = 1.88, *P*>.05
Pain intensity rating over prior week (0-5)[18] (range)†	2.0 (4)	1.0 (3)	*U* = 609, *P*>.05
Location of current symptoms[21] (%)			χ^2 = 3.42, *P*>.05
Low back only	66.0	78.8	
Low back/proximal lower extremity (LE)	12.8	6.1	
Low back/distal LE	0.0	6.4	
Low back/proximal LE/distal LE	15.1	14.9	
Duration of current LBP symptoms[21] (%)			χ^2 = 1.70, *P*>.05
Acute (<7 d)	15.2	6.2	
Subacute (7 d-7 wk)	23.9	21.9	
Chronic (>7 wk)	60.9	71.9	
History of previous episodes of LBP (%)	85.7	83.9	χ^2 = 0.05, *P*>.05
Mean (SD) Oswestry Disability Questionnaire[5] scores (%)	19.2 (9.6)	16.5 (13.4)	*t* = –0.98, *P*>.05
Frequency of participation in activity per mo (range)†	12.0 (19)	8.0 (19)	*U* = 329, *P*<.05*

* Indicates median value.
† The only significant difference between the 2 groups was on frequency of participation in activity.

dian, 4; range, 8) than those who participated in symmetric leisure activities (median, 2; range, 7; *U* = 1112, *P*<.01). Table 7 provides the percentages of responses for the symmetric group and the asymmetric group for each of the trunk-rotation–related tests and the associated statistical and probability values for individual tests of differences. Compared to the symmetric group, a larger percentage of patients in the asymmetric group displayed a rotation-related impairment with each of the following 5 tests: (1) lateral bending in standing, (2) knee extension in sitting, (3) knee flexion in prone, (4) hip rotation in prone, rotation of the lumbopelvic region, (5) rocking back in quadruped (*P*<.05 for all comparisons). There were no differences between the 2 groups in the percentages of patients who displayed a rotation-related impairment with (1) alignment in standing (power, 0.99; effect size, 0.70), (2) hip abduction and lateral rotation in partial hook lying (power, 0.99; effect size, 0.66), (3) hip lateral rotation in prone, lumbopelvic rotation (power, 0.64; effect size, 0.27), (4) alignment in quadruped (power, 0.97; effect size, 0.44), and (5) arm lifting in quadruped (power, 0.43; effect size, 0.20). The estimated effect sizes for alignment in standing and hip abduction and lateral rotation in partial hook lying are considered large.[3] The estimated effect sizes for hip lateral rotation in prone and arm lifting in quadruped are considered small, while the estimated effect size for alignment in quadruped is considered medium.[3] The power associated with the comparison of the symmetric and asymmetric group was sufficient (>0.80)[3] for 3 of the 5 tests.

DISCUSSION

The findings from our current study provide some preliminary data to suggest that there may be a relationship between results on the trunk-rotation–related impairment tests we have standardized and described,[19,25] and the general category of leisure activity in which a person participates. The people with LBP who participated in activities categorized as asymmetric displayed a greater number of rotation-related impairments across the examination than the people with LBP who participated in activities categorized as symmetric. The asymmetric group also displayed a greater percentage of rotation-related impairments on 5 of the 10 individual impairment tests when compared to the symmetric group. These findings suggest the need for further examination, in a more homogenous cohort of individuals with LBP, of the relationship between types of impairments on examination and types of activities participated in.

A few other investigators have studied the relationship between examination findings and LBP in people who regularly participate in work- or sports-related activities. For example, Nadler et al[13] found an increased incidence of LBP in athletes who, in their preseason examination, exhibited overuse or lower extremity laxity. Overuse was considered present if there was a positive history of ongoing discomfort and tenderness with palpation over musculotendinous regions in the lower extremities.[13] Raty et al[17] found that a decrease in lumbar mobility was associated with a history of heavy work but not with sports activities. Evans et al[4] found that golfers with LBP displayed a decrease in endurance of the transversus abdominus muscle compared to golfers without low back pain. None of the investigators, however, examined the relationship between the general directions of movements and alignments a person performs with an activity and a group of

TABLE 7. Tests, impairments, and percentages of positive responses for judgments of lumbar or lumbopelvic region impairments in people who participate in symmetric versus asymmetric leisure activities.*

		Group		
Test	Impairment	Symmetric (%)	Asymmetric (%)	Statistical and Probability Values
Alignment of lumbar region in standing	Rotation of the lumbar region	15	21	χ^2 = 0.54, $P>.05$
Active lateral bending in standing	Asymmetrical lumbar region motion with lateral bending, right versus left	48	82	χ^2 = 8.94, $P<.01$†
Active knee extension in sitting	Rotation of the lumbopelvic region	34	55	χ^2 = 3.34, $P<.05$†
Active hip lateral rotation and abduction in partial hook lying	Rotation of the lumbopelvic region	17	21	χ^2 = 0.18, $P>.05$
Active knee flexion in prone	Rotation of the lumbopelvic region	38	64	χ^2 = 4.98, $P<.05$†
Active hip rotation in prone	Rotation of the lumbopelvic region	42	64	χ^2 = 3.45, $P>.05$
Active hip rotation in prone	Asymmetrical lumbopelvic region rotation, right versus left	21	48	χ^2 = 6.54, $P<.01$†
Alignment of lumbar region in quadruped	Rotation of the lumbar region	28	36	χ^2 = 0.68, $P>.05$
Active arm lifting in quadruped	Asymmetrical rotation of the lumbar region, right versus left	47	55	χ^2 = 0.35, $P>.05$
Active rocking back in quadruped	Pelvic rotation or pelvic tilt	30	52	χ^2 = 3.85, $P<.05$†

* Two different rotation-related impairments are assessed during the hip lateral rotation test in prone.
† Indicates a significant difference in percentages of impairments between the 2 groups.

RESEARCH REPORT

responses on direction-specific impairment tests. The importance of our findings is that the results suggest that the directions of movement and alignment associated with a general activity category (symmetric versus asymmetric) appear to be related to the person's direction-related movement and alignment impairments on examination and thus may provide a potential focus for a person's treatment. For example, if the hypothesis is correct and the person with LBP displays a predominance of rotation-related impairments on examination, the clinician could examine whether or not rotation-related strategies are being used during symptom-provoking work, leisure, and daily activities. Treatment then might include exercises to alleviate the factors that appear to contribute to the impairments and instruction in modification of the strategies used with activities that are symptom provoking. Considering the preliminary nature of the findings from the current study, however, there is a need for future work to examine the proposed treatment-related hypotheses.

The criterion of a minimum of once-per-week participation could be considered too low to induce the predicted changes in movement and alignment. We used this criterion, however, only as a threshold for inclusion into the study. The average participation for both groups was higher; people in the symmetric group reported a median of 3 times a week of participation and people in the asymmetric group reported a median of 2 times a week of participation. Thus, the participation level for the majority of individuals was above the stated criterion. It also could be argued that people participated more frequently in many other activities across a week—in particular work activities—that could have induced the changes we identified. Although patients reported their current work-related activity in the history portion of the examination, we were unable to test the relationship between the general types of work-related activities (symmetric versus asymmetric) and types of impairments. The patients in our data set reported a variety of different occupations. Our pilot studies examining the agreement among clinicians on the directions of trunk movements and alignments associated with each work-related activity were unsuccessful. Such disagreement may have been due to the fact that few people in our sample reported participation in repetitive manual-labor activities, for example work on an assembly line, where the trunk movements might be more easily identified and categorized.

Our 2 groups were different in their activity participation levels. The difference was not surprising considering the nature of the activities in which people participated. In general, the symmetric group was involved in activities that had fewer requirements for participation than the activities in which the asymmetric group participated. For example, the symmetric group reported activities that involved only the patient, such as walking, running, or jogging. In contrast, the asymmetric group reported participation in activities that required special equipment, and often also required at least 1 other person for participation, such as tennis, racquetball, or volleyball. We believe that the finding that patients in the symmetric group participated more frequently in their activities than those in the asymmetric group, yet displayed less rotation-related impairments on examination, adds support to the proposal of interest in the current study.

Some participants reported regular participation in more than 1 activity (secondary activity). The secondary activities the people in the symmetric group participated in were all categorized as symmetric and, therefore, would not alter our predictions about the type of impairments this subgroup of people would present with on examination. On the other hand, the people in the asymmetric group participated in secondary activities that were categorized as symmetric, asymmetric, or neither. Irrespective of the categorization of the secondary activities the people in the asymmetric group participated in, our predictions for these people also would not be affected. Our reasoning is that if a person's secondary activity was considered asymmetric and the primary activity was also asymmetric, participation would potentially add to the predicted effect. If the person's secondary activity was considered symmetric, then participation would increase the person's overall activity level, but not directly alter our prediction of the presence of trunk rotation-related impairments on examination. Participation in secondary activities, therefore, was not a deterrent to conducting the analyses of interest in the current report.

The chi-square analyses for individual tests were conducted to gain insight into the prevalence of individual impairments in each group in our sample. Because the current study is preliminary in nature, such information could be used to guide future studies focusing on the specific rotation-related tests that are more prevalent and potentially more important with regard to rotation-related LBP problems. For example, it appears that asymmetry of lumbar region motion with trunk lateral bending is different between the 2 groups of people we studied. Previous studies have reported that trunk lateral bending is a risk factor for LBP,[10,11] but the specific details of the lumbar region movement patterns has not been fully investigated. Further investigation into the movement-pattern–related aspect of trunk lateral bending, therefore, appears to be warranted. The chi-square analyses of responses with individual tests also revealed that 4 of the 5 tests in which a larger proportion of the asymmetric group displayed a rotation-related impairment compared to the symmetric group were (1) movement-related tests and (2) tests in which the hip muscles were being stretched in the sagittal or horizontal plane (Table 7). Thus, it appears that movements of the lower extremity, such as hip rotation in prone, or combined movements of the trunk and lower extremity, such as rocking backward from quadruped, that require flexibility of many of the hip muscles and the hip joint may be related to trunk rotation-related impairments of the lumbar or lumbopelvic region. Such information is important because it provides the clinician with a priori information about the impairments to expect on examination and, therefore, has the potential to contribute to increased efficiency in examination, diagnosis, and treatment of the associated LBP problem.

The 2 groups did not differ significantly in the percentage of rotation-related impairments for 5 of the tests. The comparisons for 3 of these tests had an associated power level to detect an effect that would be considered acceptable, ie, greater than 0.80.[3] Thus, these findings suggest that these 3 impairments (rotation of the lumbar region in standing, rotation of the lumbopelvic region with hip abduction and lateral rotation, rotation of the lumbar region in quadruped), as measured in the current study, are not likely to be different between the 2 groups in the population. Because the comparisons with the other 2 tests (hip lateral rotation in prone and arm lifting in quadruped) had power levels below 0.80, conclusions about differences between the 2 groups could not be made based on the findings from the current secondary analyses.

There are some potential limitations of the current study that may affect the generalizability of the results. The first potential limitation is that the same examiner conducted both the history and physical tests on individual patients. Thus, examiner bias could have affected judgments of responses on the impairment tests. We believe, however, that there are a number of factors that would have attenuated any potential examiner bias regarding the current findings. First, the subset of items analyzed for this report was part of a larger clinical examination that included several additional history questions and physical tests.[25] There were a total of 59 history questions the examiners were required to answer and 72 judgments related to the physical tests that had to be made. The examiners' focus, therefore, was not specifically on the rotation-related items. Second, much of the data were collected as part of a study of the reliability of examiners performing the examination.[25] Thus, it is not likely that the examiners were focusing on the type of activities for which the patient reported participation, but on conducting the procedures correctly and following the rules for making judgments about responses to individual tests. Third, because this was a secondary analysis the hypothesis tested in this study was formulated a posteriori. Thus, examiners had no prior knowledge of a specific hypothesis relating directions associated with impairments on examination to general directions of movements and alignments associated with categories of activities.

A third potential limitation is that we did not record (1) whether or not patients associated participation in their current leisure activity with an increase in their LBP, or (2) details regarding their history of participation in leisure activities before the 12 months prior to participating in the examination. Because the purpose of our original data collection was on reliability[25] and validity[27] issues, attention was not focused on the potential effects of specific current or past activities on findings from the physical tests. Potentially, if a person in the symmetric group had a past history of participation in an asymmetric activity, this involvement might affect his current responses. The person's past participation, however, would work to diminish the effect we detected in the current study. Logically, past regular participation in a symmetric activity by a person in the asymmetric group should also have no effect on the current findings. Future work could be directed at determining the effect of current, as well as past leisure activities on the impairments and symptoms identified on examination.

CONCLUSION

Patients with LBP who regularly participated in leisure activities generally categorized as asymmetric displayed more trunk rotation-related impairments on examination than patients with LBP who regularly participated in leisure activities generally categorized as symmetric. These findings provide some preliminary data to suggest that impairments on examination may be different among people with LBP and, to some degree, related to the general types of activities in which the person is involved. Further prospective investigation to examine whether or not the type of activity a person with LBP participates in and types of impairments displayed on examination may be warranted.

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REFERENCES

1. Brooks VB. What is motor control? In: Brooks VB, ed. *The Neural Basis of Motor Control.* New York, NY: Oxford University Press; 1986:5-17.
2. Chard MD, Lachmann SM. Racquet sports—patterns of injury presenting to a sports injury clinic. *Br J Sports Med.* 1987;21:150-153.

RESEARCH REPORT

3. Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Mahwah, NJ: Lawrence Erlbaum; 1988.
4. Evans C, Odreive W. A study to investigate whether golfers with a history of low back pain show a reduced endurance of transversus abdominis. *J Man Manip Ther.* 2000;8:162-174.
5. Fairbank JC, Couper J, Davies JB, O'Brien JP. The Oswestry low back pain disability questionnaire. *Physiotherapy.* 1980;66:271-273.
6. Garg A, Moore JS. Epidemiology of low-back pain in industry. *Occup Med.* 1992;7:593-608.
7. Hoogendoorn WE, Bongers PM, de Vet HC, Ariens GA, van Mechelen W, Bouter LM. High physical work load and low job satisfaction increase the risk of sickness absence due to low back pain: results of a prospective cohort study. *Occup Environ Med.* 2002;59:323-328.
8. Hosea TM, Gatt CJ, Jr. Back pain in golf. *Clin Sports Med.* 1996;15:37-53.
9. Kelsey JL. An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. *Int J Epidemiol.* 1975;4:197-205.
10. Marras WS, Lavender SA, Leurgans SE, et al. Biomechanical risk factors for occupationally related low back disorders. *Ergonomics.* 1995;38:377-410.
11. Marras WS, Lavender SA, Leurgans SE, et al. The role of dynamic three-dimensional trunk motion in occupationally-related low back disorders. The effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. *Spine.* 1993;18:617-628.
12. McCarroll JR. The frequency of golf injuries. *Clin Sports Med.* 1996;15:1-7.
13. Nadler SF, Wu KD, Galski T, Feinberg JH. Low back pain in college athletes. A prospective study correlating lower extremity overuse or acquired ligamentous laxity with low back pain. *Spine.* 1998;23:828-833.
14. Ong A, Anderson J, Roche J. A pilot study of the prevalence of lumbar disc degeneration in elite athletes with lower back pain at the Sydney 2000 Olympic Games. *Br J Sports Med.* 2003;37:263-266.
15. Pearcy MJ, Tibrewal SB. Axial rotation and lateral bending in the normal lumbar spine measured by three-dimensional radiography. *Spine.* 1984;9:582-587.
16. Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB. Back disorders and nonneutral trunk postures of automobile assembly workers. *Scand J Work Environ Health.* 1991;17:337-346.
17. Raty HP, Battie MC, Videman T, Sarna S. Lumbar mobility in former elite male weight-lifters, soccer players, long-distance runners and shooters. *Clin Biomech (Bristol, Avon).* 1997;12:325-330.
18. 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;8:141-144.
19. Sahrmann SA. *Diagnosis and Treatment of Movement Impairment Syndromes.* St Louis, MO: Mosby; 2002.
20. Shumway-Cook A, Woollacott M. *Theories of Motor Control.* Baltimore, MD: Williams & Wilkins; 1995.
21. Spitzer WO, LeBlanc FE, Dupuis M. 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:S1-59.
22. Sward L, Hellstrom M, Jacobsson B, Nyman R, Peterson L. Disc degeneration and associated abnormalities of the spine in elite gymnasts. A magnetic resonance imaging study. *Spine.* 1991;16:437-443.
23. Sward L, Hellstrom M, Jacobsson B, Peterson L. Back pain and radiologic changes in the thoraco-lumbar spine of athletes. *Spine.* 1990;15:124-129.
24. Van Dillen LR, Sahrmann SA, Norton BJ, et al. Effect of active limb movements on symptoms in patients with low back pain. *J Orthop Sports Phys Ther.* 2001;31:402-413; discussion 414-408.
25. Van Dillen LR, Sahrmann SA, Norton BJ, et al. Reliability of physical examination items used for classification of patients with low back pain. *Phys Ther.* 1998;78:979-988.
26. Van Dillen LR, Sahrmann 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;84:313-322.
27. Van Dillen LR, Sahrmann SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom NJ. Movement system impairment-based categories for low back pain: stage 1 validation. *J Orthop Sports Phys Ther.* 2003;33:126-142.
28. White AA, Panjabi MM. *Clinical Biomechanics of the Spine.* Philadelphia, PA: Lippincott-Raven; 1990.

Appendix

Description of procedures for the 10 rotation-related impairment items and the associated operational definitions for responses to the alignment or movement impairments assessed with each test.

GENERAL PROCEDURES

Initial Marker Placement

Adhesive markers are placed over the spinous process of L1, L5, and S2 at the beginning of the examination for the examiner to use as a visual cue regarding anatomical landmarks. For all marker placements the patient stands behind a table or chair and assumes his natural standing position, while the examiner sits behind the patient viewing the lumbopelvic region.

L5 Marker The examiner palpates the most superior aspect of the iliac crests. The examiner then moves his hands centrally to the L4-5 interspace and palpates the spinous process just below the interspace. A marker is placed over the spinous process.

S2 Marker The examiner palpates the posterior superior iliac spines (PSISs) and then moves his hands to the spinous process located between the PSISs. A marker is placed over the spinous process.

L1 Marker The patient places his hands on the support in front of him. The examiner places the web space of his hands on the superior aspect of the iliac crests so that the thumbs are on the lumbar region and aligned parallel with the floor. The patient then is instructed to bend forward putting the weight of his trunk into his arms, relax his back muscles, and round his lumbar region. Once the L4-5 interspace is found, the examiner counts up the lumbar spinous processes until he reaches the spinous process of L1. A marker is placed over the spinous process.

SPECIFIC TEST PROCEDURES AND OPERATIONAL DEFINITIONS FOR IMPAIRMENTS

Initial Position Standing

All tests in standing are performed while the patient stands with his feet shoulder width apart and his arms positioned at his sides. The examiner is positioned behind the patient so that the patient's pelvis and lumbar region are at eye level for the examiner.

Test Alignment of lumbar region in standing. The examiner places a hand on each side of the lumbar region (area between L1 and L5 markers) to palpate tissue spanning from the spinous processes to 5.08 cm lateral to either side of the spinous processes. A judgment is made by the examiner based on information obtained visually (posterior view of the lumbar region), as well as through palpation of the lumbar region tissue.

Impairment Rotation of the lumbar region. The patient displays a difference in the prominence of the tissue in the lumbar region of 1.28-cm or greater difference when both sides are palpated simultaneously.

Test Active lateral bending in standing. The examiner aligns a straightedge, such as a pencil, vertically over the lumbar region aligning the inferior aspect of the visual marker at the center of the S1 marker. The patient is instructed to easily laterally bend his trunk to 1 side as far as he can sliding his hand along his thigh and then return to the starting position. The patient is instructed to avoid rotating or bending his trunk forward or backward with the lateral bend motion. The examiner observes the movement of the lumbar region during the lateral bending motion from a posterior view, and assesses the final lumbar curve at completion of the lateral bend, right versus left.

Impairment Asymmetrical lumbar region motion with lateral bending, right versus left. The patient displays a difference in lateral bending as exhibited by either (1) a difference of 1.28 cm or greater between the vertical location of the apex of the curve with lateral bending to one side versus the other, or (2) a difference of 1.28 cm or greater in the amount of lateral excursion of L1 from the initial starting alignment with lateral bending to one side versus the other.

Initial Position Sitting

All tests in sitting are initiated from a position in which the patient's hips are at a 90° angle of flexion, the femurs are horizontal on the table and positioned in neutral abduction-adduction and rotation, and the lumbar spine is neutral.

Test Active knee extension in sitting. The examiner places a hand on each side of the lumbar region to palpate tissue spanning from the spinous processes to 5.08 cm lateral to either side of the spinous processes. The patient actively extends each knee separately throughout the range of motion without cueing from the examiner.

Impairment Rotation of the lumbopelvic region. Presumed rotation of one or more of the lumbar

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vertebrae or rotation of the pelvis is evidenced by tissue asymmetry, which can be seen and palpated when the subject actively extends either knee. Significant tissue asymmetry is defined as 1.28-cm or greater difference in the prominence of the tissue to either side of the lumbar spine and sacrum at the end of the knee motion.

Initial Position Partial Hook Lying

All tests in partial hook lying are initiated from a back lying position in which one lower extremity (LE) is extended while the contralateral LE is positioned in hip and knee flexion and the foot positioned flat on the table.

Test Active hip lateral rotation and abduction in partial hook lying. While the examiner palpates the anterior-superior iliac spine on the side opposite the moving LE, the patient actively allows the flexed extremity to move out into the available hip lateral rotation-abduction range of motion.

Impairment Rotation of the lumbopelvic region. Rotation of the pelvis and lumbar region occurs if, within the first 50% of the available hip abduction-lateral rotation motion, the patient displays 1.28-cm or greater motion of the anterior superior iliac spine contralateral to the moving LE.

Initial Position Prone

All tests in prone are initiated from a face lying position in which the patient's LEs are positioned in neutral adduction-abduction and rotation, arms are positioned at his sides, and the head is positioned in whichever position is most comfortable. The examiner places his hand over the sacrum so that a line through the metacarpophalangeal joints are coincident with the long axis of the sacrum, and the long axis of the hand and sacrum are perpendicular to each other.

Test Active knee flexion in prone. A lower extremity movement in which the patient actively bends each knee separately to 90° of flexion, and then returns it to the starting position.

Impairment Rotation of the lumbopelvic region. Rotation of the pelvis and lumbar region occurs if, when using the tips of the fingers of the hand as a visual reference for pelvic motion, 1.28-cm or greater of motion occurs relative to the starting position.

Test Active hip rotation in prone. A lower extremity movement in which the patient actively flexes each knee separately to 90°, and then medially and laterally rotates the hip through the available range of motion while the knee remains flexed.

Impairment 1 Rotation of the lumbopelvic region. Rotation of the pelvis and lumbar region occur if, when using the fingertips of the hand as a visual reference for pelvic motion, 1.28-cm or greater motion occurs relative to the starting position.

Impairment 2 Asymmetrical lumbopelvic region rotation, right versus left. Using the fingertips of the hand as a visual reference for pelvic motion, 1.28-cm or greater difference in movement of the pelvis must occur with rotation of one hip versus the other. The amount of pelvic movement is relative to the starting position.

Initial Position Quadruped

The patient assumes a quadruped position without verbal or physical cueing from the examiner.

Test Alignment of lumbar region in quadruped. In quadruped, the examiner places a hand on each side of the lumbar region to palpate tissue spanning from the spinous processes to 5.08 cm lateral to either side of the spinous processes, and then makes a judgment about the lumbar region alignment.

Impairment Rotation of the lumbar region. In quadruped, the subject displays 1.28-cm or greater difference in depth in the prominence of the tissue in the lumbar region.

Standardized Quadruped Position

A position the patient assumes that includes the following segmental alignments: (1) lumbar spine horizontal to supporting surface without lumbar region rotation, pelvic rotation, or lateral pelvic tilt; (2) hip joint angle at 90°; (3) hip joint aligned over knee joint so the hip is in 0° of abduction-adduction; (4) neutral hip rotation; (5) ankles plantar flexed; and (6) shoulders positioned in 90° of flexion. The examiner places a hand on each side of the lumbar region to palpate tissue spanning from the spinous processes to 5.08 cm lateral to either side of the spinous processes.

Test Active arm lifting in quadruped. An upper extremity movement in which the patient lifts each arm separately flexing at the shoulder to a maximum of 180° while keeping the elbow extended. The movement is initiated from the standardized quadruped position.

Impairment Asymmetrical rotation of the lumbar region, right versus left. Using the hands as a visual reference for presumed spinal motion, 1.28-cm or greater difference in movement of the hands must occur with arm lifting on one side versus the other. The amount of hand movement is relative to the starting position.

Test Active rocking back in quadruped. A movement initiated from the standardized quadruped position, in which the patient flexes their knees, hips, and spine while the hands remain in the starting position, until he is sitting on his heels, resulting in upper extremity flexion. The examiner places a hand around each iliac crest so that the thumbs are pointed toward the midline.

Impairment Pelvic rotation or pelvic tilt. Using the thumbs of the hands around the iliac crests as a visual reference for pelvic motion, 1.28-cm or greater rotation or tilt must occur during rocking back relative to the initial standardized quadruped position to be significant.