Journal of Orthopaedic & Sports Physical Therapy
Official Publication of the Orthopeadic and Sports Physical Therapy Sections of the American Physical Therapy Association

Differences in Measurements of Lumbar Curvature Related to Gender and Low Back Pain

Barbara J. Norton, PT, PhD[1]
Shirley A. Sahrmann, PT, PhD, FAPTA[2]
Linda R. Van Dillen, PT, PhD[3]

Study Design: Cross-sectional.
Objectives: To test the assumption that postural alignment and gender have a bearing on the specific type of low back pain (LBP) a person manifests.
Background: Measurements of static sagittal lumbar curvature are used by clinicians in the management of patients with LBP, but no investigator has reported differences in curvature related to specific categories of LBP.
Methods and Measures: We used a computer-interfaced, 3-D, electromechanical digitizer to derive curvature angles for the region of the spine between T12-L1 and S2. Trained clinicians examined the subjects and determined their LBP diagnoses. We used *t* tests to examine differences in curvature between women and men, those with and those without LBP, and those in 4 different categories of LBP. We used χ^2 to examine the relationship between gender and LBP category.
Results: Lumbar curvature angle (lordosis) was 13.2° larger for women than for men ($t = 6.74$; $P<.01$). There was no difference in lumbar curvature between people with undifferentiated LBP and people without LBP. There were differences in lumbar curvature between people in various categories of LBP, for example, subjects in the lumbar-rotation-with-extension category had 8.4° more lumbar curvature than subjects in the lumbar-rotation-with-flexion category ($t = 2.16$; $P<.05$). Based on the frequency distributions, there was a significant relationship between gender and LBP category ($\chi^2 = 10.19$; $P<.01$).
Conclusions: Measurements of lumbar curvature should be expected to differ between men and women and may be related to different types of low back pain. *J Orthop Sports Phys Ther 2004;34:524-534.*

Key Words: *lordosis, lumbar curvature, posture, spine*

Measurements of static sagittal spinal curvature in erect standing are used by many types of clinicians to aid in establishing a diagnosis, formulating a treatment plan, and assessing outcomes in patients with low back pain (LBP).[35] The measurements can be most useful in patient care if clinicians have access to evidence regarding (*a*) variation in the measurements among healthy individuals, (*b*) the relationship between curvature measurements and dysfunction, and (*c*) the relationship between spinal curvature and other subject characteristics. In fact, the evidence is limited and the findings are inconsistent.[35] Thus, clinicians have little basis for making judgments based on measurements of static sagittal spinal curvature. The focus of this report is on the relationship between measurements of static sagittal lumbar spinal curvature and 2 specific subject characteristics: gender and LBP category. The clinically relevant question is whether physical therapists should expect to see the same amount of static sagittal lumbar spinal curvature in everyone, regardless of gender and LBP category.

The relationship between gender and spinal curvature has been studied to a limited extent. In our search of the literature, we found 43 articles in which sagittal plane measurements of lumbar spinal curvature were reported. Only 14 of the reports included any data or analyses related to differences between women and men.[1,9,12,15,17,18,23,34-38,43,44] Curva-

[1] *Associate Professor and Associate Director for Postprofessional Studies, Washington University School of Medicine, Program in Physical Therapy, St Louis, MO.*
[2] *Professor, Washington University School of Medicine, Program in Physical Therapy, St Louis, MO.*
[3] *Assistant Professor, Washington University School of Medicine, Program in Physical Therapy, St Louis, MO.*
This work was funded in part by Grant 94R-03-NOR-02 from the Foundation for Physical Therapy Inc. The protocol for this study was approved by the Human Studies Committee of Washington University, School of Medicine, St Louis, MO. The authors of this study affirm that they have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.
Address correspondence to Dr Barbara J. Norton, Washington University School of Medicine, Program in Physical Therapy, 4444 Forest Park Blvd, Box 8502, St Louis, MO 63108. E-mail: nortonb@wustl.edu

ture measurements were obtained using noninvasive devices in only 3 of the 12 studies.[1,43,44] Because physical therapists do not always have access to roentgenograms, we will focus on studies in which noninvasive devices were used. Bergenudd et al[1] used a pantograph to obtain measurements of spinal curvature from 575 subjects, 252 women, and 323 men; 30% of the women and 28% of the men had LBP. A tangent method was used to derive the angle data from tracings of the curves. The mean lordosis angle was 38° in women and 27° in men; the difference was not tested statistically. In the study reported in 1996 by Youdas et al,[44] lumbar curvature (T12-S2) measurements of 90 subjects, 45 women and 45 men, were obtained using a flexible curve (ruler) and a tangent method. The mean curvature angle was 52.7° for women and 37.5° for men; the difference was not tested statistically. In 2000, Youdas et al[43] reported the results of testing 60 patients with chronic LBP. The mean curvature angle for those with LBP was 55.5° for women and 39° for men; the difference was not tested statistically. Using the published means and standard deviations, we calculated a *t* ratio for each of the studies. In all 3 studies, the difference in curvature between women and men was significant at the 0.05 level. In sum, static sagittal lumbar curvature appears to be greater in women than in men, but the curvature angles differ across studies. Given the disparity across studies in the specific curvature measurements, additional testing is needed to provide clinicians with data that can be used in making clinical judgments. We want to expand on previous work by measuring the lumbar curvature of a substantial number of women and men using a method that permits comparison among approaches.

The relationship between static sagittal lumbar spinal curvature and LBP category has also been examined to a limited extent. Of the 43 articles we reviewed, 17 included a comparison between groups of patients with LBP and controls.[1,4,6,11,13-16,18,23,24,27,28,36,37,42,43] Curvature measurements were obtained using noninvasive devices in only 6 of the studies.[1,4,6,24,27,43] Day et al[6] tested 32 healthy subjects and 15 patients with chronic LBP using the Iowa Anatomical Positioning System; they found no difference in depth of the lumbar curve between the groups. Bergenudd et al[1] used a pantograph to measure lumbar curvature in 575 subjects, 25% of whom had LBP. They found no difference in static sagittal lumbar curvature between subjects with LBP and those without LBP. Christie et al[4] used a photographic method to study 59 subjects. They did find a significant difference of 7° between patients with chronic LBP and controls. By contrast, they did not find a difference between patients with acute LBP and controls. In 2000, Youdas et al[43] reported data for 60 patients with LBP and cited previously reported data for 90 individuals without LBP. On the average, both women and men with LBP had more lumbar lordosis than those who did not have LBP, but the differences between the means were small (3° for women, 1.5° for men) and were not tested statistically. Nourbakhsh and Arab[27] tested 600 subjects using a flexible ruler and the method described by Youdas et al[43]; they found no difference in lumbar curvature between 300 patients with LBP and 300 controls. Most recently, Ng et al[24] used an inclinometer to measure the lumbar curvature of 30 men, 15 with LBP and 15 without LBP. Subjects in the 2 groups were matched for age, height, obesity, and physical activity; there was no significant difference between the groups in amount of lumbar lordosis. Given the evidence reviewed regarding lumbar curvature and LBP category, we could conclude that lumbar curvature measurements are not consistently either larger or smaller in patients with LBP than in individuals without LBP. However, none of the studies included a comparison among individuals with different types of LBP other than acute and chronic. If we assume different types of LBP problems do exist, then we must conclude that the available evidence is incomplete.

Several authors have suggested that different types of LBP problems do exist and a number of systems for categorization of LBP have been developed.[2,3,7,8,20-22,29,31-33,40] Unfortunately, none of the systems has been tested extensively. The system of movement-related categories we have been testing was developed by Sahrmann,[30] primarily on the basis of clinical observation. In previous studies, we provided some empirical evidence in support of the construct validity of the categories proposed by Sahrmann[39] and the reliability of items used to categorize patients with LBP.[40] Of relevance to this report is Sahrmann's assumption that different categories of LBP are associated with specific alignments and movement strategies.[30] In particular, we want to know if the amount of static sagittal spinal curvature differs, depending on the category of LBP problem. Given the anticipated differences in static sagittal spinal curvature between women and men, we also want to know if there is a relationship between gender and LBP category.

In sum, the purpose of this study was to test the following hypotheses: (*a*) the angle representative of static sagittal spinal curvature reflects a more lordotic curve for women than for men, (*b*) there is no difference in lumbar curvature between individuals with and without LBP, (*c*) there is a difference in lumbar curvature between individuals in different movement-related categories of LBP, and (*d*) there is a relationship between gender and LBP category.

METHODS

Sample Description

As part of a study involving both clinical and laboratory measurements, a convenience sample of 227 adult volunteers was recruited. The sample included both individuals with low back pain (LBP group) and individuals without low back pain (NoLBP group). Subjects were recruited (*a*) from the patient populations of 6 local outpatient physical therapy clinics, (*b*) from the pool of families and friends of the patients, and (*c*) by means of advertisements placed at various locations on the medical center campus and the university campus. Subjects were eligible for the LBP group if they had symptoms related to LBP in either the low back or in a combination of the low back and the lower extremity (proximal or distal). Subjects were excluded from the LBP group if they had any of the following: a history of spinal surgery within the previous 3 months, multiple previous surgical procedures, pending spinal surgery, the presence of severe kyphosis or scoliosis, rheumatoid arthritis, ankylosing spondylitis, or neurological disease. Individuals were excluded from the NoLBP group if they had an episode of LBP in the year prior to testing, that either affected daily activities for more than 3 days or required medical attention. Pregnant women were excluded from both groups.

The primary focus of this report is on the laboratory measurements obtained with the Metrecom. Of the 227 subjects tested, we were able to fully process Metrecom-derived data for 188 subjects. Equipment failures and operator errors resulted in the loss of parts of the data for the other 39 subjects. Overall, the mean age of the 188 subjects was 41.1 years (SD, 13.4 years; range, 19-73 years). There were 103 women and 85 men in the sample. The mean age was 40.3 years for the women and 42.1 years for the men; the difference was not statistically significant ($t = .95$; $P > .05$). The sample included 128 individuals with LBP and 60 without LBP. The mean ages of those in the LBP and NoLBP groups were 42.0 and 39.3 years, respectively; the difference was not statistically significant ($t = 1.34$, $P > .05$). The proportion of women and men in the LBP and NoLBP groups was similar (approximately 55% women and 45% men). The duration of symptoms prior to testing was greater than 7 weeks for 72% of the subjects with LBP; thus the condition could be categorized as chronic[33] for most of the subjects with LBP. Prior to testing, each subject read and signed an informed consent document that had been approved by the Institutional Review Board of Washington University's School of Medicine.

Instrumentation

We used the Metrecom Skeletal Analysis System (Metrecom) to acquire the data required to derive measurements of lumbar curvature. The Metrecom (FARO Technologies, Inc, Lake Mary, FL) is a computer-interfaced, electromechanical digitizer that provides x, y, and z coordinates of points in space. The mechanical arm of the Metrecom consists of a series of 3 metal rods and a terminal probe interspersed with proprietary rotary transducers at the junctions between adjoining rods. The output from all of the transducers is combined by the Metrecom's hardware and software to derive 3-D coordinate values for the location at the tip of the Metrecom's probe. The 2 primary modes of operation are referred to as the point mode and the stream mode. In point mode, data for a single point is acquired each time the switch is depressed. By contrast, in stream mode, data for a continuous stream of points is acquired with a fixed sampling rate of 10 samples per second. The measurements of the x, y, and z coordinates are precise to 0.1 mm.

We previously reported results of intrarater reliability testing for Metrecom measurements of inanimate objects[25] and measurements of lumbar curvature.[26] In all cases, the intraclass correlation coefficients (ICCs) were greater than 0.88.

Methods for Characterizing Curvature of Back

One of the methods we used for characterizing the curvature of the low back is referred to by Youdas et al[45] as the trigonometric method. Based on the trigonometric method, measurements of curvature are derived by using the formula, $\theta = 4\arctan(2d/l)$, where d is the depth of the curve at its midpoint and l is the length of the line connecting the end points of the curve.[41] In Figure 1, the curved line represents the surface of the back from point A to point B, where point A represents the T12-L1 interspace and point B represents S2. (Note: the curve is exaggerated in this figure to accommodate demonstration of the different angles.) The line l connects points A and B. The line d is constructed perpendicular to l at the midpoint of l. The angle θ is the angle at the center of the circle formed by the radii to points A and B.

For ease of visualization, we also calculated another angle based on the depth and length of the curve. The second angle, α, is defined by the following formula: $\alpha = 2\arctan(0.5l/d)$. The angle α is formed by the chords connecting points A and B to the point on the curve at which the line d intersects the curve. Note that as the curve becomes flatter, the values of θ approach 0°, whereas the values of α approach 180°. Thus, if a 180° is preferred as a frame of reference for a flat curve, then the α curvature angles should be used.

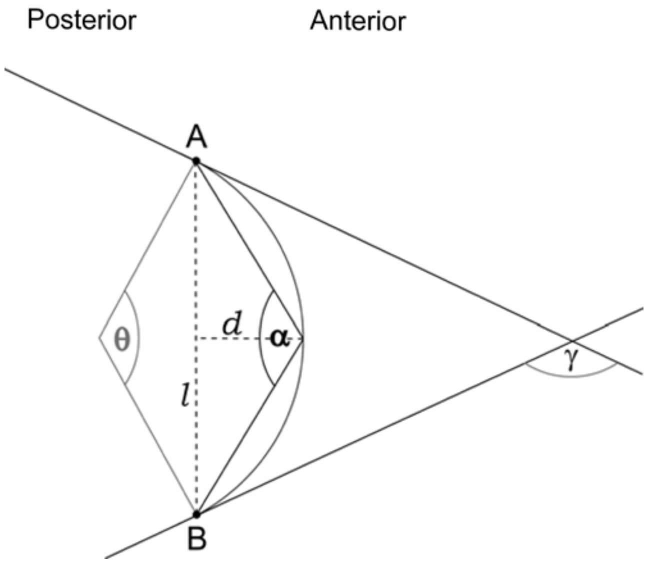

FIGURE 1. Schematic drawing of 3 curvature angles calculated. Points A and B represent the endpoints of the curve at the T12-L1 interspace and S2 spinous process, respectively. *l* is the length of the curve and *d* is the depth of the curve. θ, α, and γ are the 3 calculated curvature angles.

For the purpose of comparing our results to those reported previously by other investigators, we also used the method originally described by Loebl.[19] The method is referred to by Youdas et al[45] as the tangent method. As depicted in Figure 1, the angle (γ) used to quantify the curvature of the back using this method is formed by the intersection of tangents to the curve drawn at points A and B.

Method for Acquiring Examination Data and LBP Category

Five therapists were trained to perform the specific clinical examination items included in this study. The details of the training and examination procedures have been reported previously.[40] Briefly summarized, each of the 5 therapists was required to do the following prior to testing subjects: (*a*) study a detailed procedure manual, (*b*) take a written examination based on the manual, (*c*) score at least 90% on the written examination, (*d*) view a videotape containing examples of several patients performing the tests, and (*e*) attend training sessions in which the tests were performed on a variety of subjects by each of the examiners. The clinical examination included tests presumed to permit categorization of LBP problems. Typical items required the subject to either assume a position or perform a movement. For 28 of the items, subjects were asked to report the status of their symptoms after assuming the posture or performing the movement requested. For the remaining 25 items, the examiner made a judgment related to alignment or movement.

A pair of examiners tested each subject. For each subject, 1 of the examiners read instructions to the subject and palpated landmarks. Both examiners observed the patient's performance at the same time, but they independently recorded test results for each item. The order in which items were tested was identical for all subjects. After completing the clinical examination, the examiners independently selected a diagnostic category for the patient's LBP condition that was considered consistent with the preponderance of the test results. The names of the 3 categories relevant to this report are lumbar extension (Ext), lumbar rotation with flexion (RotFlx), and lumbar rotation with extension (RotExt). A brief description of the categories is provided in the Appendix.

Procedures for Metrecom Measurements

Subjects were asked to remove their shoes and outer clothing, don loosely fitting pants or shorts, and, in the case of women, don a gown. The examiner palpated the subject to locate 2 spinal landmarks, the spinous process of S2 and the T12-L1 interspace; the examiner then marked each landmark with a self-adhesive marker. The spinous process of S2 was located by palpating the posterior superior iliac spines (PSIS) bilaterally and then locating the spinous process in the midline of the back that was closest to the same vertical level as the PSIS. The T12-L1 interspace was located by successively palpating each of the spinous processes superior to S2 until the first lumbar (L1) and twelfth thoracic (T12) spinous processes were identified. The marker was placed over the midpoint of the space between the 2 spinous processes. After both landmarks were marked, subjects were asked to stand adjacent to the supporting column of the Metrecom. The yoke of the Metrecom was adjusted to the level of each subject's waistline. The subjects were instructed to stand comfortably erect with their arms resting at their sides (Figure 2). After the subject had assumed a comfortable position, a stabilizing rod that projects from the support column of the Metrecom was placed in contact with the lateral aspect of the subject's neck to minimize postural sway.

Using the tip of the Metrecom's probe, the examiner pointed to each of the markers and depressed the point mode switch. The examiner then used the tip of the probe to trace along the spine from a location slightly superior to the T12-L1 marker to a location slightly inferior to the S2 marker, while depressing the stream mode switch. The examiner repeated the tracing of the spine twice for a total of 3 measurements. After the measurements were completed, subjects stepped off the platform and relaxed for approximately 2 minutes. Then, the entire measurement process was repeated using the original markers.

RESEARCH REPORT

FIGURE 2. Photograph of subject positioned for testing with Metrecom.

Data Processing and Analysis

After testing was completed, the 3 angles of curvature (θ, α, and γ) were calculated using the *x*- and *y*-coordinate data from the Metrecom and computer algorithms described previously by Norton et al.[26]

Descriptive statistics were calculated for all 3 measurements of curvature: θ, α, and γ. Cohen's kappa[5] was used to estimate reliability for examiner judgments regarding LBP category. Differences across the levels of the grouping variables, gender and LBP category, were tested using *t* tests. Due to the low prevalence in several back pain categories, we tested for differences only between specific pairs of categories. We used a *t* test to examine the difference between RotExt and NoLBP because (*a*) we wanted to test the hypothesis that the individuals in the RotExt category have more lumbar lordosis than individuals in the NoLBP group, and (*b*) the sample sizes were relatively equivalent. We used a *t* test to examine the difference between RotExt and RotFlx because we wanted to test the hypothesis that the subjects in the RotExt category are more lordotic than those in the RotFlx category. We tested the difference between individuals in the RotExt and Ext categories with a *t* test to confirm the expectation that the groups did not differ. For the 2 categories, RotExt and RotFlx, we also tested for the interaction between LBP category and gender using a 2 × 2 between-groups ANOVA. Based on frequency data, the relationship between gender and LBP categories was tested using χ^2. The alpha level was set at .05 for all primary tests.

RESULTS

Reliability

The percent agreement between raters for the LBP categorization judgment was 78%; the kappa value was 0.57.

Gender-Related Differences in Measurements of Curvature

Summaries of the curvature measurements are provided separately for women and men in Table 1 and in Figure 3. Data for all 3 curvature angles—θ, α, and γ—are included in Table 1 and analogous tests of differences were conducted for all 3 curvature angles. The results of the analyses for a given grouping variable were always consistent; either all were significant or none was significant. Thus, in the interest of brevity, details in this and all subsequent sections will be noted only for the analyses involving curvature angle θ. The mean lumbar curvature angle θ was 13.2° larger in women than in men; the difference was significant ($t = 6.74$, $P<.01$).

Diagnosis-Related Differences in Measurements of Curvature

The mean (±SD) lumbar curvature angle θ was 40.2° (±14.8°) for those subjects in the NoLBP group

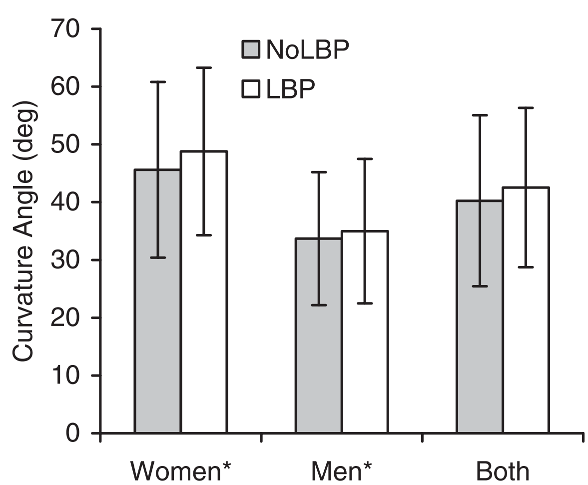

FIGURE 3. Bar graph of θ curvature measurements (mean ± SD) for women and men in low back pain (LBP) and no low back pain (NoLBP) groups.
*Significant difference between women and men; $P<.05$.

TABLE 1. Means (SDs) of lumbar curvature measurements for all women and men (n = 160).

Curvature Variable	Women	Men	*t*	*P*
θ-trigonometric	47.8° (14.8°)	34.6° (12.1°)	6.74	<.01
α-trigonometric	156.1° (7.4°)	162.7° (6.1°)	6.74	<.01
γ-tangent (Loebl)	31.7° (8.4°)	24.3° (7.1°)	6.53	<.01

TABLE 2. Means (SDs) of lumbar curvature (θ) by gender and low back pain (LBP) category.

Diagnostic Category	Women	Men	Both
No LBP (n = 60)	45.6° (15.2°)	33.7° (11.5°)	40.2° (14.8°)
LBP (all categories)	48.8° (14.5°)	35.0° (12.5°)	42.5° (15.2°)
Rotation with extension (n = 62)	50.5° (14.7°)	39.7° (12.3°)	46.7° (14.7°)
Rotation with flexion (n = 18)	47.0° (9.7°)	34.9° (14.4°)	38.2° (14.1°)
Extension (n = 20)	46.2° (17.5°)	35.0° (7.4°)	43.4° (16.2°)

TABLE 3. Frequency distribution of women and men across 3 low back pain categories.

Diagnostic Category	Women (n = 60)	Men (n = 40)	Total (n = 100)
Rotation with extension	40	22	62
Rotation with flexion	5	13	18
Extension	15	5	20

and 42.5° (±15.2°) for those in the LBP group. The difference between the groups was not significant (t = 0.98, P>.05).

Summary statistics for curvature measurements of subjects in the 3 LBP categories, across which differences were tested, are provided in Table 2. The only diagnostic group with a sample size similar to that of the NoLBP group (n = 60) was the RotExt group (n = 62). The difference between the means of the NoLBP group and the RotExt group for θ was 6.4°; the difference was significant (t = 2.41, P<.02). Of the remaining LBP categories, only 2 included enough subjects to warrant even a preliminary analysis: the RotFlx and the Ext categories. We compared each category to the RotExt category. The difference between the means of the RotExt group (n = 62) and the RotFlx group (n = 18) for θ was 8.4°; the difference was significant (t = 2.16, P<.04). The difference between the means for RotExt group (n = 62) and the Ext group (n = 20) for θ was 3.3°; the difference was not significant (t = 0.08, P>.05).

Relationship Between Gender and Diagnostic Category

In the sample studied, 78% of the 128 subjects with LBP were categorized as having 1 of 3 LBP diagnoses: RotExt, RotFlx, and Ext. The frequency distribution is summarized in Table 3 and in Figure 4. Of the 128 subjects with LBP, 48% were diagnosed as having a RotExt problem; the analogous percentages for the RotFlx and Ext categories were 14% and 16%, respectively. For both women and men, the most prevalent category was RotExt. However, there was also a significant relationship between gender and LBP category, as evidenced by differences in the distribution of women and men across the 3 categories (χ^2 = 10.19, df = 2; P<.01). Specifically, the percentage of women in the RotExt (65%) and in the Ext (75%) categories was greater than the percentage of men in each category. Conversely, the percentage of men in the RotFlx category (72%) was greater than the percentage of women in the category.

In terms of the θ lumbar curvature measurements, we noted earlier the significant effects for both gender and LBP category. For the comparison between RotExt and RotFlx, we also tested for the interaction effect between gender and LBP category; the interaction was not significant ($F_{1,76}$ = 0.03, P>.05). Please note in Table 2 and Figure 5, however, that both men and women in the RotExt category were more lordotic than their counterparts in the RotFlx category, but that the men were not as lordotic as the women in either category. By contrast, women in the RotFlx category, were less lordotic than women in the RotExt category, but were more lordotic than the men in either category.

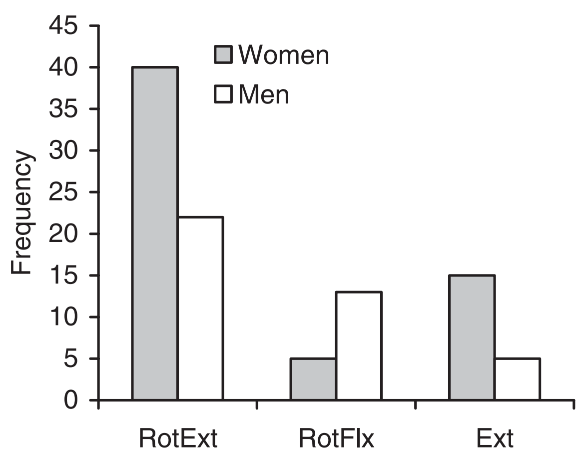

FIGURE 4. Bar graph demonstrating frequency distribution of women and men across 3 low back pain (LBP) categories: rotation with extension (RotExt), rotation with flexion (RotFlx), and extension (Ext). The difference in distribution of women and men across the LBP categories was significant; P<.05.

RESEARCH REPORT

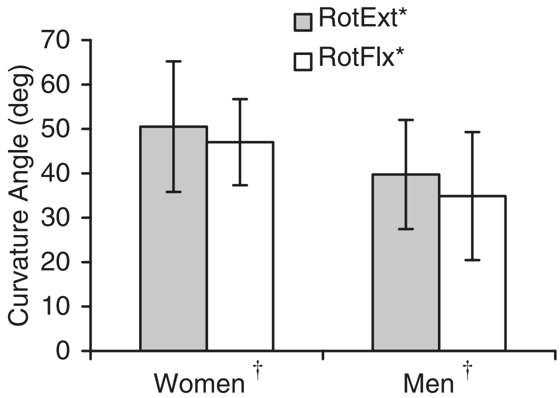

FIGURE 5. Bar graph of θ curvature measurements (mean ± SD) for women and men in rotation with extension (RotExt) and rotation with flexion (RotFlx) categories.
* Significant difference between RotExt and RotFlx; $P<.05$.
† Significant difference between women and men; $P<.05$.

DISCUSSION

Gender-Related Differences in Measurements of Curvature

As predicted, the angle representative of static sagittal spinal curvature reflected a more lordotic curve for women than for men. On the average, the difference between women and men in curvature angle was 13.2° based on the θ-trigonometric method, 7.4° based on the γ-tangent method, and 6.6° based on the α-trigonometric method. The differences between women and men reported by other investigators range from 11° to 16.5°.[1,42,43] Although different measurement devices and different methods were used across studies, the curvature measurements consistently reflected a more lordotic curvature in standing for women than for men.

Although there are similarities across studies in the magnitude of the gender-related differences, the actual curvature measurements are not all identical. The measurements we obtained using the γ-tangent method (women, 31.7°; men, 24.3°) were most similar to those reported by Bergenudd et al[1] (women, 38°; men, 27°), even though different devices and methods were used in the studies. Bergenudd et al[1] used a pantograph, a mechanical parallelogram device, to trace along the surface of the back from C7 to L5 and produced a representation of the back's curve on a piece of paper. Then they drew "three tangents at a maximum deviation from the vertical line" and measured the angles formed at the intersection of adjacent pairs of lines. The lumbar curvature was defined as the angle formed between the 2 distal tangent lines. Based on our inspection of Figure 2 of their paper,[1] it appears that the tangents were drawn along individually selected segments of the curve rather than at points on the curve associated with specified landmarks. The device we used, the Metrecom, permitted us to trace the spine in a fashion similar to the pantograph, reproduce the shape of the back as a curved line consisting of a series of points, and use computer software to calculate curvature angles based on several methods using specific landmarks. The fact that Bergenudd et al[1] did not draw the tangents at specific landmarks makes it difficult not only to reproduce the results, but also to compare the results to those reported in other studies. In addition, there were differences in the samples studied. In our study, the sample consisted of 188 Americans (75% Caucasian, 22% African American), 55% women, with an overall point prevalence for LBP of 68%. By contrast, Bergenudd et al[1] studied 575 Swedes (56% men), with an overall point prevalence for LBP of 29%. Thus, it is difficult to account for the similarity in our curvature measurements.

By contrast, the measurements we obtained using the θ-trigonometric method were closest to those reported by Youdas et al.[43,44] Youdas et al[44] used a flexible curve (ruler) to conform to the shape of the back between T12 and S2. They traced the curve on a piece of poster board and placed marks on the curve at T12, L4, and S2. Then they constructed tangents to the curve at all 3 marks and measured the angles formed at the intersections of the 2 pairs of adjacent tangents. They defined lumbar curvature as the sum of the 2 angles formed by the intersecting tangents. We used the T12-L1 interspace and S2 as the end points of the lumbar region and calculated angles using both a trigonometric method and a tangent method similar to that used by Youdas et al.[43,44] Based on our previous[26] and current results, we would have expected closer agreement between 2 similar tangent methods than between the 2 different methods, tangent and trigonometric. In an earlier study,[26] we compared Metrecom-derived measurements based on the tangent method to those based on the trigonometric method; the tangent-based measurements were approximately 12° less than the trigonometric-based measurements. We also compared measurements obtained with an inclinometer to those obtained with the Metrecom. The inclinometer measurements were similar to the tangent-based measurements and were approximately 10° less than the trigonometric-based measurements. In the current study, the trigonometric-based measurements were again larger than the tangent-based measurements. Thus, the similarity of Youdas et al's[43,44] tangent method results to our trigonometric method results, rather than our tangent method results, is puzzling. Differences in the characteristics of the samples studied may be relevant. On the average, their subjects were 55 years old and our subjects were 41 years old. The ratio of women to men was similar across studies (109:77 and 103:85), but Youdas et al[43,44] tested more controls (n = 90) than patients with LBP (n = 60), and we tested more patients with LBP (n = 128) than controls (n = 60). Additional testing is required to disentangle the contributions of sample characteristics and measurement methods to differences in the results.

Diagnosis-Related Differences in Measurements of Curvature

As predicted, there was no significant difference in lumbar curvature for individuals with LBP compared to those without LBP. Our results are consistent with the results from 5[1,6,24,27,43] of the 6 studies in which noninvasive devices were used. One plausible explanation for not finding a difference is that lumbar curvature is not related to LBP. Another possible explanation is that the amount of lumbar curvature may differ, depending on the type of LBP present, and the differences cannot be discerned in an undifferentiated sample. In previous studies, no one has tested for differences in curvature across subtypes of LBP based on anything other than acuity.

In this study, we did test for differences between individuals with different categories of mechanical LBP. Given the distribution of subjects encountered in our sample, we were not able to test for differences among all of the categories described. We did, however, find significant differences between (*a*) those in the RotExt category compared to those without LBP (NoLBP) and (*b*) those in the RotExt category compared to those in the RotFlx category. In both cases, those in the RotExt category had a more lordotic curve in standing than those in the comparison groups of NoLBP and RotFlx. These findings suggest that observation of the amount of lumbar curvature present in standing may be useful in understanding the nature of a patient's LBP problem.

Relationship Between Gender and Diagnostic Category

The most prevalent category for both women and men was RotExt. However, there were differences in the percentages of women and men categorized as having extension-related (RotExt and Ext) compared to flexion-related problems (RotFlx). Only 8% of the women in the 3 most prevalent categories were in the RotFlx category; whereas, 92% were in the RotExt and Ext categories. By contrast, 33% of the men were in the RotFlx category and only 67% were in the extension-related categories (RotExt and Ext). As noted earlier in this report, women had significantly more static sagittal lumbar curvature than men. Taken together, these findings suggest that there is a relationship between gender, amount of lumbar curvature, and LBP category. The fact that the gender × LBP category interaction effect was not significant may mean that either LBP category is not completely dependent upon gender or that the relatively low prevalence, especially of women, in the RotFlx category may have attenuated the results. Recall, however, that (*a*) both men and women in the RotExt category had more lordosis than their counterparts in the RotFlx category, (*b*) both men and women in the RotFlx category had less lordosis than their counterparts in the RotExt category, (*c*) in the ExtRot category, men had less lordosis than women, and (*d*) in the RotFlx category, women had more lordosis than the men. Additional testing with a larger number of subjects in all categories is needed to clarify the relationships. The issue of gender-specific differences in type of movement-related LBP category has not been addressed previously.

The clinical implication of these findings is that knowing the gender of a patient and the amount of lumbar curvature may aid in diagnosis of the patient's movement-related LBP problem and, potentially, in decisions about management. For example, it is reasonable for clinicians to anticipate seeing (*a*) a preponderance of extension-related problems in women, but a more equivalent number of flexion-related and extension-related problems in men, and (*b*) less static sagittal spinal curvature (lordosis) in men than in women, regardless of the LBP category. It is also reasonable to anticipate that the focus of treatment and expected outcomes may differ, depending on the type of LBP and gender. For example, if clinicians think it is important to modify a patient's lumbar curvature, they should carefully consider whether they want all patients with LBP, regardless of gender or type of LBP, to focus on increasing lumbar lordosis or whether it would be more appropriate to have some types of patients focus on decreasing lumbar lordosis. Clinicians should also carefully consider whether they want women and men to strive for identical amounts of lumbar curvature.

Study Limitations

One limitation of this study was the uneven distribution of subjects across the LBP categories. Subjects were not screened according to LBP category prior to enrollment in the study, because the primary study was aimed at testing the construct validity of the categories. We tested all subjects who met the general inclusion criteria in this cross-sectional study. Future studies should include similar numbers of subjects in the categories across which comparisons are to be made.

A second potential limitation of the study is level of reliability achieved by the clinicians for the categorization judgments. Ideally, the reliability coefficient would be closer to 1.00. Although the percent agreement was 78%, the skewed distribution of subjects across categories may have contributed to attenuation of the kappa value. Nonetheless, the reliability achieved is comparable to the results reported by Fritz and George[10] for a similar task. Furthermore, based on the results reported, it is apparent that measurement error was not large enough to nullify all significant effects.

Finally, the results of this study are not definitive. Additional testing is needed (*a*) to define expectations for the amount of static sagittal lumbar curvature in various categories of people, (*b*) to clarify the relationship between gender and LBP category, and (*c*) to propose specific guidelines for intervention. Clearly, specific guidelines for intervention cannot be advocated in the absence of randomized clinical trials designed to test the effects of various intervention approaches for the women and men in the different categories of LBP.

CONCLUSIONS

Consistent with the preponderance of previous studies, women have more static lumbar sagittal curvature (lordosis) than men during stance and there is no difference in static lumbar sagittal curvature between those with undifferentiated LBP and those without LBP. There are, however, newly documented differences in static lumbar sagittal curvature related to subcategories of LBP. Patients categorized as having either a rotation-with-extension or extension diagnosis have more static lumbar sagittal curvature than those categorized as having a rotation-with-flexion diagnosis. In addition, women are more likely than men to be categorized as having a rotation-with-extension diagnosis; conversely, men are more likely than women to be categorized as having a rotation-with-flexion diagnosis. A clinical implication of these findings is that knowing the gender of a patient and the amount of lumbar curvature may aid in diagnosis of the patient's movement-related LBP problem.

ACKNOWLEDGMENTS

We wish to acknowledge the individuals who participated as examiners in this study: Nancy Bloom, PT, DPT, Cheryl Caldwell, PT, DPT, Mary Kate McDonnell, PT, DPT, and Debra Fleming, MSPT. We also wish to acknowledge the contribution of Dequan Zou, DSc, in writing the computer program used to calculate the curvature angles.

REFERENCES

1. Bergenudd H, Nilsson B, Uden A, Willner S. Bone mineral content, gender, body posture, and build in relation to back pain in middle age. *Spine.* 1989;14:577-579.
2. Bernard TN, Jr., Kirkaldy-Willis WH. Recognizing specific characteristics of nonspecific low back pain. *Clin Orthop.* 1987;266-280.
3. Binkley J, Finch E, Hall J, Black T, Gowland C. Diagnostic classification of patients with low back pain: report on a survey of physical therapy experts. *Phys Ther.* 1993;73:138-150; discussion 150-135.
4. Christie HJ, Kumar S, Warren SA. Postural aberrations in low back pain. *Arch Phys Med Rehabil.* 1995;76:218-224.
5. Cohen J. A coefficient of agreement for nominal scales. *Educ Psychol Meas.* 1960;20:37-46.
6. Day JW, Smidt GL, Lehmann T. Effect of pelvic tilt on standing posture. *Phys Ther.* 1984;64:510-516.
7. 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;75:470-485; discussion 485-479.
8. DeRosa CP, Porterfield JA. A physical therapy model for the treatment of low back pain. *Phys Ther.* 1992;72:261-269; discussion 270-262.
9. Fernand R, Fox DE. Evaluation of lumbar lordosis. A prospective and retrospective study. *Spine.* 1985;10:799-803.
10. Fritz JM, George S. The use of a classification approach to identify subgroups of patients with acute low back pain. Interrater reliability and short-term treatment outcomes. *Spine.* 2000;25:106-114.
11. Frymoyer JW, Newberg A, Pope MH, Wilder DG, Clements J, MacPherson B. Spine radiographs in patients with low-back pain. An epidemiological study in men. *J Bone Joint Surg Am.* 1984;66:1048-1055.
12. Gelb DE, Lenke LG, Bridwell KH, Blanke K, McEnery KW. An analysis of sagittal spinal alignment in 100 asymptomatic middle and older aged volunteers. *Spine.* 1995;20:1351-1358.
13. Hansson T, Bigos S, Beecher P, Wortley M. The lumbar lordosis in acute and chronic low-back pain. *Spine.* 1985;10:154-155.
14. Harrison DD, Cailliet R, Janik TJ, Troyanovich SJ, Harrison DE, Holland B. Elliptical modeling of the sagittal lumbar lordosis and segmental rotation angles as a method to discriminate between normal and low back pain subjects. *J Spinal Disord.* 1998;11:430-439.
15. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. *Spine.* 1994;19:1611-1618.
16. Jackson RP, Peterson MD, McManus AC, Hales C. Compensatory spinopelvic balance over the hip axis and better reliability in measuring lordosis to the pelvic radius on standing lateral radiographs of adult volunteers and patients. *Spine.* 1998;23:1750-1767.
17. Korovessis P, Stamatakis M, Baikousis A. Segmental roentgenographic analysis of vertebral inclination on sagittal plane in asymptomatic versus chronic low back pain patients. *J Spinal Disord.* 1999;12:131-137.
18. Korovessis PG, Stamatakis MV, Baikousis AG. Reciprocal angulation of vertebral bodies in the sagittal plane in an asymptomatic Greek population. *Spine.* 1998;23:700-704; discussion 704-705.
19. Loebl WY. Measurement of spinal posture and range of spinal movement. *Ann Phys Med.* 1967;9:103-110.
20. McKenzie RA. *The Lumbar Spine: Mechanical Diagnosis and Therapy.* Waikanae, New Zealand: Spinal Publications, Ltd; 1989.
21. Moffroid MT, Haugh LD, Henry SM, Short B. Distinguishable groups of musculoskeletal low back pain patients and asymptomatic control subjects based on physical measures of the NIOSH Low Back Atlas. *Spine.* 1994;19:1350-1358.

22. Mooney V. The syndromes of low back disease. *Orthop Clin North Am.* 1983;14:505-515.
23. Murrie VL, Dixon AK, Hollingworth W, Wilson H, Doyle TA. Lumbar lordosis: study of patients with and without low back pain. *Clin Anat.* 2003;16:144-147.
24. Ng JK, Kippers V, Richardson CA, Parnianpour M. Range of motion and lordosis of the lumbar spine: reliability of measurement and normative values. *Spine.* 2001:26(1):53-60.
25. Norton BJ, Ellison JB. Reliability and concurrent validity of the Metrecom for length measurements on inanimate objects. *Phys Ther.* 1993;73:266-274.
26. Norton BJ, Hensler K, Zou D. Comparisons among noninvasive methods for measuring lumbar curvature in standing. *J Orthop Sports Phys Ther.* 2002;32:405-414.
27. Nourbakhsh MR, Arab AM. Relationship between mechanical factors and incidence of low back pain. *J Orthop Sports Phys Ther.* 2002;32:447-460.
28. Pope MH, Bevins T, Wilder DG, Frymoyer JW. The relationship between anthropometric, postural, muscular, and mobility characteristics of males ages 18-55. *Spine.*1985;10:644-648.
29. Porter RW. Mechanical disorders of the lumbar spine. *Ann Med.* 1989;21:361-366.
30. Sahrmann SA. *Diagnosis and Treatment of Movement Impairment Syndromes.* 1st ed. St Louis, MO: Mosby, Inc; 2002.
31. Saunders HD. Classification of musculoskeletal spinal conditions. *J Orthop Sports Phys Ther.* 1979;1:3-15.
32. Sikorski JM. A rationalized approach to physiotherapy for low-back pain. *Spine.* 1985;10:571-579.
33. Spitzer WO, Dupuis M, Leblanc FE, Abenhaim L. Scientific approach to the assessment and management of activity-related spinal disorders: a monograph for clinicians. Report of the Quebec Task Force on Spine Disorders. *Spine.* 1987;12:S16-S21.
34. Stagnara P, De Mauroy JC, Dran G, et al. Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. *Spine.* 1982;7:335-342.
35. Troyanovich SJ, Cailliet R, Janik TJ, Harrison DD, Harrison DE. Radiographic mensuration characteristics of the sagittal lumbar spine from a normal population with a method to synthesize prior studies of lordosis. *J Spinal Disord.* 1997;10:380-386.
36. Tsuji T, Matsuyama Y, Sato K, Hasegawa Y, Yimin Y, Iwata H. Epidemiology of low back pain in the elderly: correlation with lumbar lordosis. *J Orthop Sci.* 2001;6:307-311.
37. Tuzun C, Yorulmaz I, Cindas A, Vatan S. Low back pain and posture. *Clin Rheumatol.* 1999;18:308-312.
38. Valkenburg HA, Haanen HCM. The epidemiology of low back pain. In: White AA, Gordon SL, eds. *Symposium on Idiopathic Low Back Pain.* Miami, FL: CV Mosby; 1980:9-22.
39. 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.
40. 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.
41. Walker ML, Rothstein JM, Finucane SD, Lamb RL. Relationships between lumbar lordosis, pelvic tilt, and abdominal muscle performance. *Phys Ther.* 1987;67:512-516.
42. Wood KB, Kos P, Schendel M, Persson K. Effect of patient position on the sagittal-plane profile of the thoracolumbar spine. *J Spinal Disord.* 1996;9:165-169.
43. Youdas JW, Garrett TR, Egan KS, Therneau TM. Lumbar lordosis and pelvic inclination in adults with chronic low back pain. *Phys Ther.* 2000;80:261-275.
44. Youdas JW, Garrett TR, Harmsen S, Suman VJ, Carey JR. Lumbar lordosis and pelvic inclination of asymptomatic adults. *Phys Ther.* 1996;76:1066-1081.
45. Youdas JW, Suman VJ, Garrett TR. Reliability of measurements of lumbar spine sagittal mobility obtained with the flexible curve. *J Orthop Sports Phys Ther.* 1995;21:13-20.

Appendix

Summary of Signs and Symptoms Associated With the Diagnoses*

Rotation with extension

a) Movement: lumbar spine tends to move toward rotation and extension during movements of the trunk and lower extremities

b) Alignment: lumbar spine tends to be extended and rotated compared to neutral

c) Symptoms: increase with movements and postures associated with lumbar extension and rotation; decrease with restriction of lumbar extension and rotation

Rotation with flexion

a) Movement: lumbar spine tends to move toward rotation and flexion during movements of the trunk and lower extremities

b) Alignment: lumbar spine tends to be flexed and rotated compared to neutral

c) Symptoms: increase with movements and postures associated with lumbar flexion and rotation; decrease with restriction of lumbar flexion and rotation

Extension

a) Movement: lumbar spine tends to move toward extension during movements of the trunk and lower extremities

b) Alignment: lumbar spine tends to be extended compared to neutral

c) Symptoms: increase with movements and postures associated with lumbar extension; decrease with restriction of lumbar extension

* For detailed descriptions, please refer to Sahrmann[30] and to Van Dillen et al.[39]