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Classification of the Normal Variation in the Sagittal Alignment of the Human Lumbar Spine and Pelvis in the Standing Position

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Study Design. A prospective radiographic study of 160 volunteers without symptoms of spinal disease was conducted.

Objectives. The objective of this study was to describe, quantify, and classify common variations in the sagittal alignment of the spine, sacrum, and pelvis.

Summary of Background Data. Previous publications have documented the high degree of variability in the sagittal alignment of the spine. Other studies have suggested that specific changes in alignment and the characteristics of the lumbar lordosis are responsible for degenerative changes and symptomatic back pain.

Methods. In the course of this study, anteroposterior and lateral radiographs of 160 volunteers in a standardized standing position were taken. A custom computer application was used to analyze the alignment of the spine and pelvis on the lateral radiographs. A four-part classification scheme of sagittal morphology was used to classify each patient.

Results. Reciprocal relationships between the orientation of the sacrum, the sacral slope, the pelvic incidence, and the characteristics of the lumbar lordosis were evident. The global lordotic curvature, lordosis tilt angle, position of the apex, and number or lordotic vertebrae were determined by the angle of the superior endplate of S1 with respect to the horizontal axis.

Conclusions. Understanding the patterns of variation in sagittal alignment may help to discover the association between spinal balance and the development of degenerative changes in the spine.

Key words: lordosis, kyphosis, sagittal balance, spinal alignment, sacral slope, classification system. **Spine 2005; 30:346–353**

The coronal alignment of the human spine is well understood. It is normal when straight, and pathologic when curved. Many classification systems address the different types of coronal deformities, providing surgeons with a common language for discussing pathology, treatment, and clinical results.[1–4] In contrast, the sagittal alignment of the spine is not as well understood. The sagittal profile of the spine is usually characterized as being kyphotic between T1 and T12, and lordotic between L1 and L5, but this is not necessarily the case. The differences between normal and pathologic curvatures are less clear in the sagittal plane than the coronal plane.[5] Many techniques have been published for measuring sagittal alignment, but a comprehensive classification system of variations in the sagittal morphology of the spine that includes a description of the orientation of the pelvis has not emerged. This is unfortunate, since the majority of degenerative disease occurs in spines that are well aligned in the coronal plane but exhibit highly variable morphology in the sagittal plane.

In an effort to systematically describe normal variations in sagittal alignment of the spine and the association between the lumbar spine and the pelvis, a custom computer application for analyzing spinal anatomy on digitized radiographs was developed (Optimage, Lyon, France). This application is able to construct a 3-dimensional curve that approximates the anterior aspect of the vertebral bodies after a trained user has identified various radiographic points along the spine and pelvis. Geometric parameters that describe the characteristics of the thoracic and lumbar curvatures, and the association between the lumbar spine, sacrum, and pelvis, are then calculated automatically, stored in a database, and can be retrieved for analysis.

The computerized modeling of the thoracic and lumbar curvatures of the spine with this application is independent of the anatomic location of the thoracolumbar junction at T12–L1. Instead, the "thoracic" curve is defined as existing between the anterior aspect of T1 and the inflection point where the association between adjacent vertebral bodies changes from kyphosis to lordosis. In a similar fashion, the "lumbar" curve is defined by the inflection point and the anterior superior corner of S1. This technique for modeling the sagittal profile of the spine is essentially identical to describing coronal abnormalities with the Cobb method. It creates an accurate description of the limits of each sagittal curve, the total degrees of included curvature, and the number of vertebral bodies in kyphosis and lordosis.

To document normal variations in the sagittal alignment of the human spine, a cohort of 160 normal patients without symptoms of spinal disease was enrolled in a prospective radiographic study. Full-length radiographs of the spine in the anteroposterior and lateral

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planes were made, extending from the base of the skull to the proximal femora. The radiographs were digitized and analyzed by a team of researchers. Variations in the sagittal morphology of the spine and the lumbosacral junction were classified using a four-part classification system developed by the senior author to describe common patterns of reciprocal relationships between the orientation of the sacrum and the characteristics of the lumbar lordosis.

■ Materials and Methods

A total of 160 adult volunteers were enrolled in this study. Consent was obtained from each patient and the local Institutional Review Board approved the study. The average age of the cohort was 27 years, with a range from 18 to 48 years of age, and consisted of 86 females and 74 males. The volunteers were mainly of medical students, physical therapists, nurses, and other allied health professionals affiliated with the medical center where the study was performed. The entire population was of European heritage and drawn from the area surrounding Lyon, France. At the time of enrollment, patients were questioned about their medical history. Those patients who were free of current or historical symptoms suggestive of spinal or orthopedic disease were included in the study. Volunteers were excluded from this cohort of normal patients if they had a history of chronic back pain, deformity, significant orthopedic disease, or an obvious radiographic abnormality such as spondylolysis, spondylolisthesis, scoliosis, or Scheuermann's kyphosis. Slightly wedged vertebrae in the thoracic spine were accepted as being within the range of normal variation.

For the radiography of the spine, each patient was asked to stand in an erect but comfortable posture. The hands were placed on supports and the knees held in extension (Figure 1). Two 30 cm × 90 cm exposures from the base of the skull to the proximal femora in the posterior to anterior plane and left to right lateral plane were made. The distance from the radiographic source to the film was maintained at 230 cm for all exposures. The edges of the radiographic film were square with respect to the horizontal and vertical axes. The films were digitized with a commercially available optical scanner (VIDAR VXR-8, Vidar Systems Inc). Digital copies of the radiographs in either JPEG or bitmap format at a minimum of 75 dots per inch were stored in a computer database. A custom computer application (Softimage Spine, Optimage) was used to analyze the association between various radiographic points along the spine and pelvis. This application is written in visual basic and runs on a standard desktop PC with a Windows operating system. Digital copies of the radiographs were imported into the application for analysis. A trained user manually marked the following points on the sagittal view: the center of the femoral heads; the anterior and posterior limits of the superior endplate of S1; the four corners of the L5 vertebral body; the anterior superior corner of the T1 vertebral body; the apex of the lumbar lordosis and the thoracic kyphosis; and the inflection point where the lumbar lordosis transitions into a thoracic kyphosis (Figure 2). If there was slight ambiguity about the location of the lumbosacral junction due to the possible presence of a transitional vertebrae, the sacral slope was marked at the superior endplate of the apparent fixed portion of the sacrum, corresponding to the functional lumbosacral junction. If there was significant ambiguity about the anatomic landmarks, the patient was excluded from further review.

Figure 1. A lateral radiograph of the spine and pelvis is made with the subject in a controlled standing position. The hands are placed on rests, and the patient is asked to stand in a comfortable but erect posture.

The software has the capability to magnify and enhance the visual details in individual regions of interest in order to improve the accuracy of locating certain points on the film. Using the points marked by the user, the software application constructs a line along the anterior aspect of the vertebral bodies between T1 and L5. The technique of computerized modeling of the profile of the spine as a series of tangent arcs of circles has been previously described. The "thoracic" segment of the spine is located between T1 and the inflection point where the spine transitions from kyphosis to lordosis. The "lumbar" segment exists between the inflection point and S1. This determination of kyphotic and lordotic segments is independent of the anatomic location of the thoracolumbar junction at T12–L1. At the inflection point, the thoracic and lumbar curves are tangent to a line that is simultaneously perpendicular to the inferior limit of kyphosis and the superior limit of lordosis. The thoracic and lumbar curves are further divided into two separate arcs of a circle, above and below the apex of the curve. Each arc is tangent to the vertical axis at the apex of the curve. The inferior limit of the lower arc of lumbar lordosis is tangent to a line perpendicular to the superior endplate of S1. The radius of each arc is independently determined by the association between the apex of the curve and the location of the limit of the arc. For example, the length and radius of the upper arc of the lumbar lordosis is determined by the association between the apex of the lumbar lordosis and the position of the inflection point. The length and radius of the lower arc of the curve are determined by the association between the apex and the sacral end. With this tech-

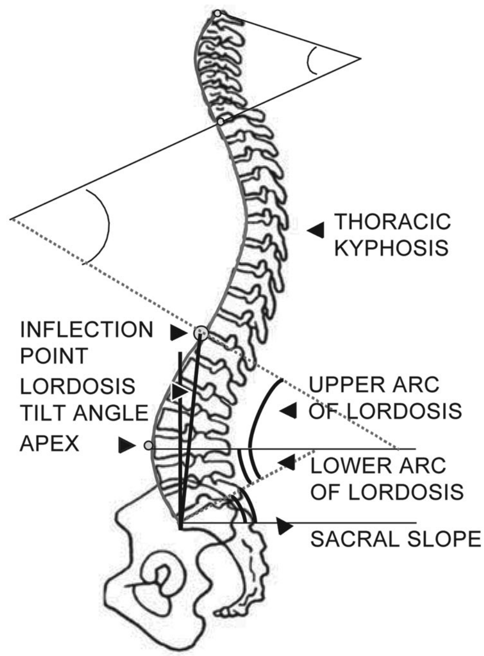

Figure 2. The geometric relationships between the arcs of lumbar lordosis and the sacral slope are shown. The location of the inflection point between kyphosis and lordosis, the lordosis tilt angle, position of the apex, and the degrees of curvature of the lower arc of lordosis are important determinants of sagittal morphology. In this geometric construction, the angle of superior endplate of S1 with respect to the horizontal axis (sacral slope) is equal to the lower arc of lumbar lordosis.

nique, the lower arc of lumbar lordosis is geometrically equal to the sacral slope (Figure 2). The angle between the anterior superior edge of S1 and the inflection point, which marks the limit of the lordotic segment of the spine, is defined as the lordosis tilt angle. By convention, this angle is expressed as a negative value if the limit of the lumbar lordosis is posterior to the anterior aspect of S1, and positive if it is anterior to S1.

The association between the alignment of the pelvis and the lumbar spine is an important determinant of sagittal balance. The radiographically identifiable points of the pelvis that are used to describe lumbopelvic anatomy include the superior endplate of S1, and the center of the femoral heads. Legaye *et al* have described three angles between these radiographic landmarks that regulate spinal sagittal curves.[6] These angles are called pelvic incidence, pelvic tilt, and sacral slope. Pelvic incidence is defined as the angle between the perpendicular to the sacral plate at its midpoint and a line connecting the same point to the center of the bicoxofemoral axis. The measurement of this angle does not change with the position of the patient, and it is considered an anatomic constant after the cessation of growth. Pelvic tilt is defined as the angle between a vertical line originating at the center of the bicoxofemoral axis and a line drawn between the same point and the middle of the superior endplate of S1. The angle of pelvic tilt describes the amount of rotation of the pelvis around the femoral heads. Sacral slope is defined as the angle between the superior endplate of S1 and the horizontal axis. Sacral slope and pelvic tilt are positional parameters that can be affected by changes in the alignment of the lower extremities. Pelvic incidence is a shape parameter that is not affected by changes in the alignment of the lower extremities. These angles are geometrically related, such that pelvic incidence is equal to the sum of the angles of sacral slope and pelvic tilt: pelvic incidence = sacral slope + pelvic tilt.

The correlations between the geometric parameters of pelvic and lumbar alignment were determined using the Pearson correlation coefficient. The pelvic parameters included in this analysis were the sacral slope, pelvic incidence, and pelvic tilt. The lumbar parameters included in this analysis were the position of the apex, inflection point, lordosis title angle, angle of global lordosis, total number of lordotic vertebra, and the angle and number of vertebrae in the upper and lower arcs of lordosis. A classification system that takes into consideration the position of the apex of the thoracic and lumbar curves, the position of the inflection point, the number of vertebral bodies in each curvature, total kyphosis and lordosis in degrees, lordosis tilt angle, and angle of the sacral slope was established to classify each patient as one of four types. This classification system was created by the senior author (P.R.) and is based on the observation that there are characteristic sagittal profiles that occur as a consequence of the orientation of the pelvis, sacrum, and lumbosacral junction. Reciprocal relationships between the sacral slope and the characteristics of the lumbar curvature are considered an essential component of overall sagittal alignment. Variations in the lower arc of lordosis are determined by the sacral slope. When the sacral slope increases, the lower arc of lordosis increases, and the global curvature of lordosis increases as well. When the sacral slope decreases, two reciprocal changes in the lower arc of lordosis can occur: the lower arc of lordosis can decrease as the apex moves inferiorly, or the lower arc of lordosis can flatten as the radius of curvature increases.

Type 1 Lordosis. The sacral slope is less than 35°, which is usually associated with a low pelvic incidence (Figure 3). The apex of the lumbar lordosis is located in the center of L5 vertebral body. The lower arc of lordosis is minimal, decreasing toward zero as the sacral slope approaches the horizontal. The inflection point is low and posterior, creating a short lordosis with a negative lordosis tilt angle. The upper spine has a significant kyphosis of the thoracolumbar junction and thorax.

Type 2 Lordosis. The sacral slope is less than 35° (Figure 4). The apex of the lumbar lordosis is located at base of the L4 vertebral body. The lower arc of lordosis is relatively flat. The inflection point is higher and more anterior, decreasing the lordosis tilt angle but increasing the number of vertebral bodies included in the lordosis. The entire spine is relatively hypolordotic and hypokyphotic.

Type 3 Lordosis. The sacral slope is between 35° and 45° (Figure 5). The apex of lumbar lordosis is in the center of the L4 vertebral body. The lower arc of lordosis becomes more prominent. The inflection point is at the thoracolumbar junction, and the lordosis tilt angle is nearly zero. An average of four vertebral bodies constitute the arc of lordosis. The spine is well balanced.

Type 4 Lordosis. The sacral slope is greater than 45°, which is associated with a high pelvic incidence (Figure 6). The apex of the lumbar lordosis is located at the base of the L3 vertebral body or higher. The lower arc of lordosis is prominent, and the lordosis tilt angle is zero or positive. The number of vertebrae in a lordotic orientation is greater than 5, and a state of segmental hyperextension exists.

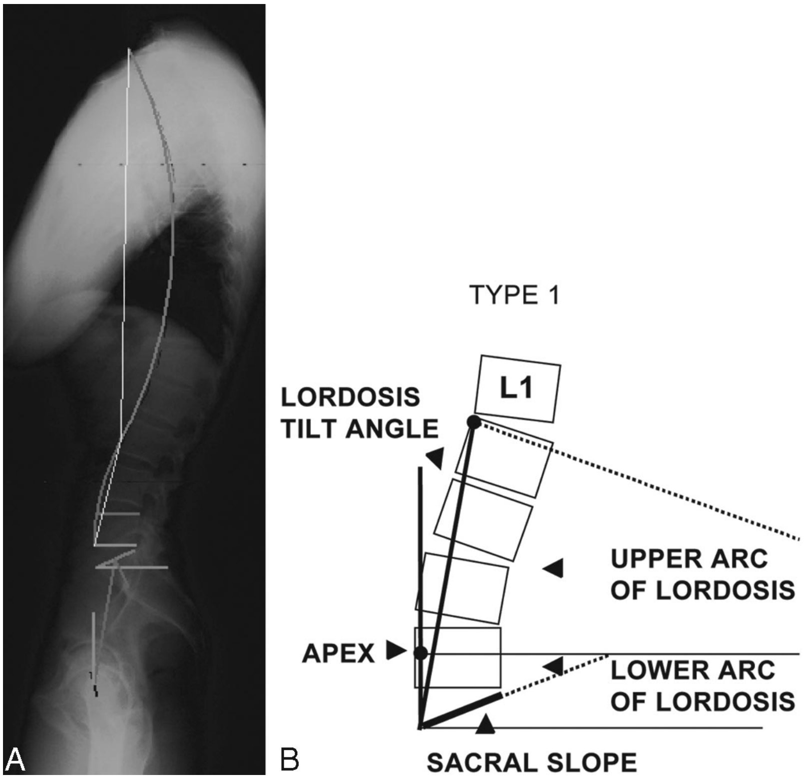

Figure 3. A, A lateral radiograph of a patient with Type 1 lordosis. B, Shown schematically, the sacral slope is less than 35°. The apex of the lumbar lordosis is located in the center of L5 vertebral body. The lower arc of lordosis is minimal, decreasing toward zero as the sacral slope approaches the horizontal. The inflection point is low and posterior, creating a short lordosis with a negative lordosis tilt angle.

■ Results

With the use of a custom computer application, predetermined radiographic locations used to describe and quantify spinal and pelvic alignment were identifiable in 160 sequential radiographic examinations of the spine. A complete determination of spinal and pelvic sagittal alignment was completed for each case. Significant variations in the parameters describing lumbar and pelvic alignment were present. These data describing all the parameters for each patient was automatically saved to an Excel (Microsoft Corp., Redmond, WA) spreadsheet and retrieved for analysis. The classification of each case as one of four types of sagittal alignment was completed. The patients were unevenly distributed among the differ-

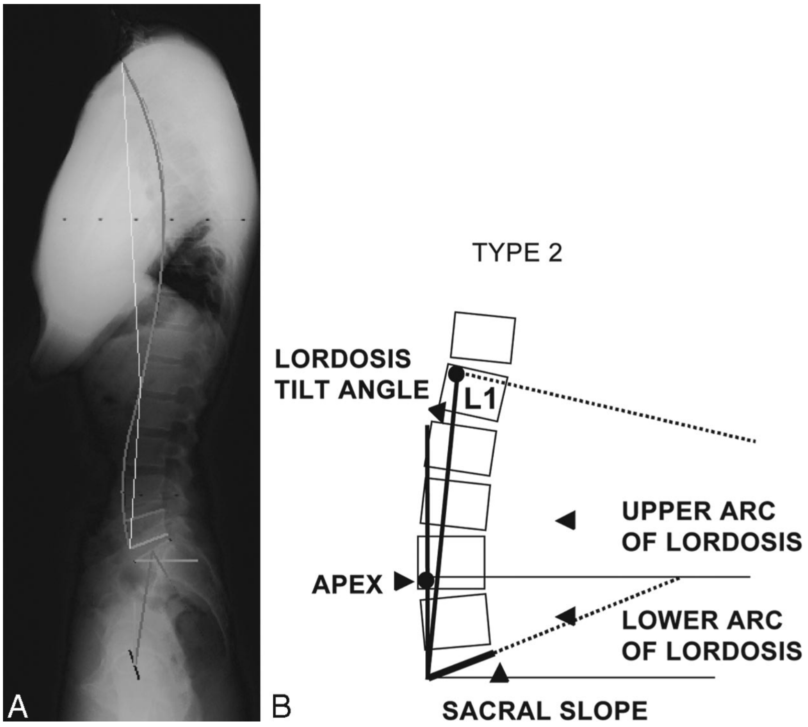

Figure 4. A, A lateral radiograph of a patient with Type 2 lordosis. B, The sacral slope is less than 35°. The apex of the lumbar lordosis is located at base of the L4 vertebral body. The lower arc of lordosis is relatively flat. The inflection point is higher and more anterior, decreasing the lordosis tilt angle, but increasing the number of vertebral bodies included in the lordosis. The entire spine is relatively hypolordotic and hypokyphotic.

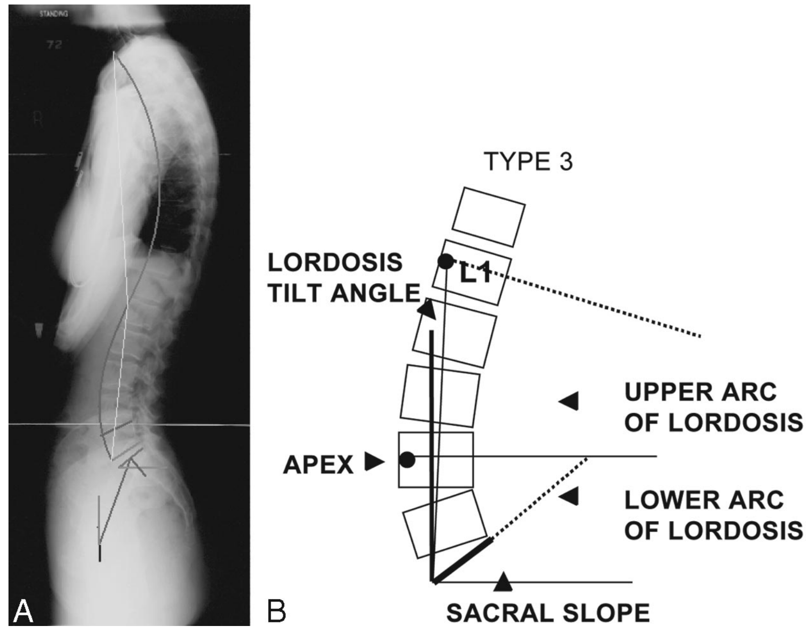

Figure 5. A, A lateral radiograph of a patient with Type 3 lordosis. B, The sacral slope is between 35° and 45°. The apex of lumbar lordosis is in the center of the L4 vertebral body. The lower arc of lordosis becomes more prominent. The inflection point is at the thoracolumbar junction, and the lordosis tilt angle is nearly zero. An average of four vertebral bodies constitute the arc of lordosis.

ent categories. The least common category (Type 2) contained 18 patients, whereas the most common category (Type 3) contained 60 patients.

In this cohort of normal volunteers, the sagittal alignment of the spine varied significantly. The average value for the global kyphosis of the thoracic curvature was 46.4° with a range of 22.5° to 70.3°. The inflection point where the spine transitioned from kyphosis to lordosis was located, on average, in the center of the L1 vertebral body, near the thoracolumbar junction (Table 1). However, this transition was noted to occur as proximally as the T10 vertebral body, and as distally as the L4 vertebral body. The average value for global lordosis of the lumbar curvature was 61.4° with a range from 41.2° to 81.9°. The apex of lumbar lordosis was located, on average, in the center of the L4 vertebral body, with a range from the center of L2 proximally to the base of L5 distally. The angle of the superior endplate of S1 with respect to the horizontal axis averaged 39.9°, with a range from 21.2° to 65.9°. Pelvic incidence averaged 51.9°, with a range of 33.8° to 83.7°. Pelvic tilt, defined as the included angle between a line drawn from the center of the hip axis to the center of the superior endplate of S1 and the vertical axis, averaged 12.0°, with a range from −5.1° to 30.6°.

The statistical correlations between the geometric parameters of lumbar and pelvic alignment are listed in

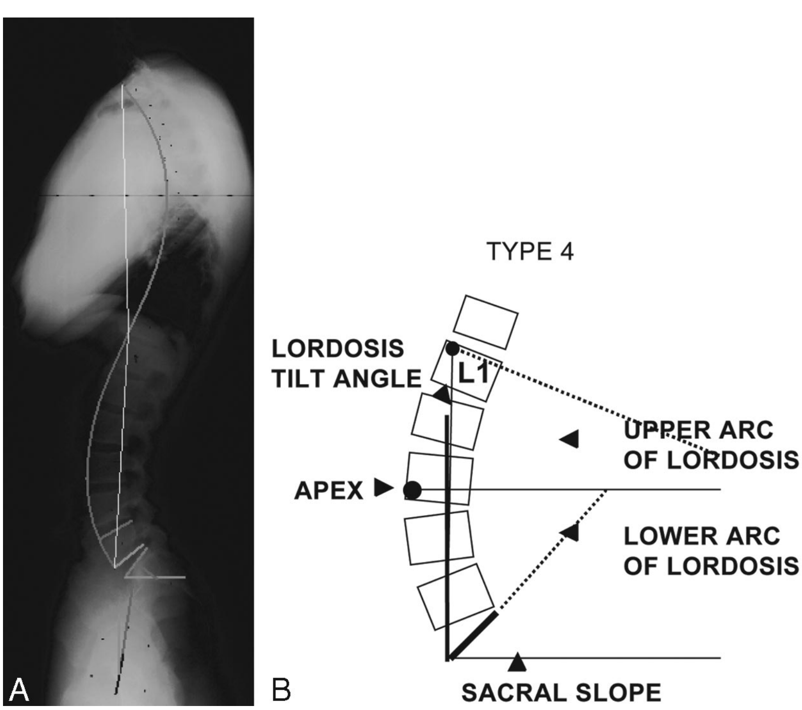

Figure 6. A, A lateral radiograph of a patient with Type 4 lordosis. B, The sacral slope is greater than 45°, which is associated with a high pelvic incidence. The apex of the lumbar lordosis is located at the base of the L3 vertebral body or higher. The lower arc of lordosis is prominent, and the lordosis tilt angle is zero or positive.

Table 1. The Geometric Parameters Describing Sagittal Alignment for the Entire Cohort

Parameter	Label	Average (°)	SD (°)	Minimum (°)	Maximum (°)
Pelvic incidence	PI	51.91	10.71	33.75	83.72
Sacral slope	SS	39.92	8.17	21.22	65.90
Pelvis tilt	PT	11.99	6.46	−5.06	30.59
Apex	1	Center of L4	1 vertebra	Base L5	Center of L2
Inflection point	2	Center of L1	1 vertebra	Center of L4	Center of T10
Lordosis tilt angle	3	−5.71	4.59	−16.15	10.76
Global lordosis	4	61.43	9.72	41.22	81.94
No. of lordotic vertebrae	5	4.50	0.90	1.50	7.50
Upper arc	6	21.50	5.02	7.00	35.00
No. of vertebrae	7	3.00	0.80	0.50	5.50
Lower arc	8	39.92	8.17	21.22	65.90
No. of vertebrae	9	1.50	0.60	0.00	3.50

Table 2. The correlation between the sacral slope and global lordosis (R = 0.86) indicates that the total amount of lordosis is determined by the association of the superior endplate of S1 with respect to the horizontal axis. Global lordosis increases as the sacral slope becomes more vertical, demonstrating a reciprocal association between the orientation of the sacrum and the characteristics of the lumbar lordosis. There is also a strong correlation between sacral slope and pelvic incidence (R = 0.80). Statistically significant correlations between pelvic incidence and global lordosis (R = 0.64), sacral slope and position of the apex (R = 0.52), sacral slope and lordosis tilt angle (R = 0.53), and position of the apex and lordosis tilt angle (R = 0.72) also exist (Table 3).

Discussion

This study demonstrates that sagittal alignment of the human spine and pelvis in a standardized standing position is highly variable in different individuals. For example, in this cohort of 160 normal subjects, the angle of the superior endplate of S1 with respect to the horizontal axis varied between 20° and 65°, the angle of global lumbar lordosis varied between 41° and 82°, and the number of vertebral bodies in a lordotic orientation varied from 1 to 8. These data suggest that the widely accepted generalization that the spine is kyphotic between T1 and T12 and lordotic between L1 and L5 may be overly simplistic. The correlations between the various parameters of lumbar and pelvic alignment indicate that characteristics of the lumbar lordosis are most dependent on the orientation of the sacral slope and the pelvis. The upper arc of lumbar lordosis remains relatively constant, with an average value of approximately 20° in all proposed types of sagittal alignment. In contrast, the lower arc of lordosis is the most important determinant of the global lordosis: lordosis tilt angle, position of the apex, and number of lordotic vertebrae. A sacral slope less than 35° and a low pelvic incidence are associated with a relatively flat, short lumbar lordosis. A sacral slope greater than 45° and a high pelvic incidence are associated with long, curved lumbar lordosis. This reciprocal association between the orientation of the sacrum and the characteristics of the lumbar lordosis is an important component of overall sagittal alignment (Table 3).

Prior studies have also remarked on the large degree of normal variability in the sagittal alignment of the spine in young, healthy patients,[5] in middle- and older-

Table 2. The Statistical Correlations Between the Pelvic and Spinal Geometric Parameters Determined Using the Pearson Correlation Coefficient

	I	SS	PT	1	2	3	4	6	7	9
Incidence (I)		0.80*	0.65*	0.52*	0.28*	0.59*	0.64*	−0.05	−0.07	0.52*
Sacral slope (SS)			0.06	0.55*	0.32*	0.53*	0.86*	0.03	−0.06	0.55*
Pelvis tilt (PT)				0.17†	0.07	0.31*	−0.02	−0.13	−0.05	0.17†
Apex (1)					0.52*	0.72*	0.38*	−0.17†	−0.17†	1*
Inflection point (2)						0.20†	0.22*	−0.08	0.75*	0.52*
Lordosis tilt angle (3)							0.16†	−0.55*	−0.32*	0.72*
Global lordosis (4)								0.54*	−0.03	0.38*
Upper arc (6)									0.03	−0.17†
No. of vertebrae in UA (7)										−0.17†

* Significant with $P < 0.001$ (Pearson test).
† Significant with $P < 0.005$ (Pearson test).

Table 3. The Characteristics of the Lumbar Lordosis as a Function of the Type of Sagittal Morphology

Sacral Slope	No.	Incidence [mean (range)] (°)	Apex	Lordosis Tilt Angle [mean (range)] (°)	Global Lordosis [mean (range)] (°)	No. of Lordotic Vertebrae [mean (range)] (°)	Upper Arc [mean (range)] (°)
<35° (mean, 30°; range, 21°–35°)	34	41 (34–54)	Middle L5	−9 (−3–−15)	52 (41–64)	4 (1.5–6)	22 (13–29)
<35° (mean, 32°; range, 28°–35°)	18	44 (38–57)	Base L4	−5 (−1–−9)	52 (44–58)	5 (4–7.5)	19 (11–26)
35° < PS < 45° (mean, 39°)	60	51 (36–65)	Middle L4	−6.5 (10–−16)	61 (43–76)	4.5 (3–6.5)	22 (7–35)
PS > 45° (mean, 50°; range, 45°–66°)	48	63 (43–83)	Base L3	−2.5 (6–−12)	71 (61–82)	5 (3.5–6)	21.5 (13–32)

aged patients,[7] and in patients with back pain.[8,9] In one of the earliest studies on sagittal alignment, Stagnara *et al* concluded that the "span of possible values of maximum kyphosis and lordosis in subjects with no spinal disease is considerable. . . It is therefore unreasonable to speak of normal kyphotic or lordotic curves."[5]

Despite this variability, several subsequent studies have demonstrated that sagittal alignment can be accurately measured and that these measurements are repeatable when the same subject is examined at two different points in time.[10,11] Furthermore, these studies have also demonstrated that there are characteristic changes in sagittal alignment that occur with aging,[7] the development of symptomatic back pain,[8] and in adjacent segment degeneration following a lumbar spine fusion.[9] For example, Vendantam *et al* demonstrated that the mean sagittal vertical axis moved anteriorly with age, from a point located 5.6 cm posterior to the anterior aspect of the sacrum in adolescence, to a mean of 3.2 cm in the middle-aged and elderly.[12] Evcik and Yucel reported that patients who had chronic low back pain were statistically more likely to have a vertically oriented sacrum and less lumbar lordosis than age- and sex-matched controls who had acute back pain.[13] An iatrogenic loss of lumbar lordosis accompanied by an anterior shift of the sagittal vertical axis creates a constellation of symptoms and problems with spinal alignment that is difficult to treat.[14–17] Many authors have commented on the negative consequences of "flat back syndrome" and the importance of preserving lumbar lordosis during arthrodesis of the lumbar spine. In a review of the 83 consecutive lumbar spine fusions, an anterior shift in the C7 plumb line and a vertically oriented sacrum was found to be a statistically significant predictor of surgical treatment for adjacent segment degeneration within 5 years.[9] The negative effects of iatrogenic changes in the sagittal alignment of the spine after arthrodesis of the lumbar spine have been well established, but the link between native states of potential malalignment and degenerative changes remains to be determined.

In summary, prior publications have suggested that there appears to be an association between the loss of lordosis, an anterior shift in the sagittal vertical axis, and the development of symptomatic back pain and degenerative changes in the spine. Further research on the strength of this association is needed. The computer-aided measurement of sagittal alignment is reasonably fast and has acceptable interobserver and intraobserver reliability in determining points of reference.[18,19] In a study on the reliability of this method to accurately measure sagittal alignment of the spine and pelvis in 30 randomly selected lateral radiographs of the spine, the interobserver reliability in locating the anatomic points of interest varied between 0.92 and 0.99, while the intraobserver reliability varied between 0.93 and 0.99.[19] The application used in this study permits the efficient analysis of large numbers of radiographs by automatically collating and saving the recorded measurements of sagittal alignment. With the classification system proposed here, we have demonstrated that each patient is classifiable as one of four types. It should be noted that a spectrum of variation in the alignment and characteristics of the sagittal curves of the spine exists. In each type of sagittal alignment proposed in this study, there are examples of patients who clearly manifest the definitive characteristics of each category. As with any classification scheme, there are also patients who are hard to classify because the measurements describing their sagittal alignment fall between two different categories. The categories that we have proposed are intended to identify certain morphologic features that may have an effect of the pathogenesis of back pain, deformity, and the results of certain surgical interventions. We think that the identification of recurring characteristic alignments, such as the reciprocal association between sacral slope and lumbar lordosis, and sacral slope and pelvic incidence, will facilitate a better understanding of how sagittal alignment is related to degenerative changes.

We have completed this study to establish an initial cross-sectional data set describing sagittal spinal alignment in healthy, young volunteers. An attempt will be made to prospectively follow these patients in a longitudinal fashion to determine if native sagittal alignment influences the development of subsequent symptoms, disc pathology, or spinal deformity. Concurrently, we also plan to proceed with an analysis of the sagittal morphology of patients who initially present with symptoms of discopathy, spinal stenosis, and pain secondary to spinal deformity. We speculate that the frequency of each type of spinal alignment is dependent on the average age of the cohort since there are characteristic changes, such as a loss of lumbar lordosis, that occur with aging. We have also made several preliminary observations regarding certain types of sagittal alignment that are more frequently associated with symptomatic back pain or degenerative diseases. For example, we have noted that patients with symptomatic disc herniations are most commonly classified as Type 1 or 2, patients with spinal stenosis are most commonly classified as Type 4, and we rarely see patients with significant complaints who are classified as Type 3. While this data set has certain inherent limitations because it is represents the range of sagittal alignment in young, healthy patients, we think that the ongoing collection and analysis of similar data in normal volunteers and patients seeking consultation for spinal disease will help to explore the association between native sagittal alignment and the relative risk of developing degenerative changes and pain in the lumbar spine.

Key Points

- Previous publications have documented a high degree of variability in the sagittal alignment of the human spine.
- Specific changes in sagittal alignment and the characteristics of the lumbar lordosis are potentially responsible for degenerative changes and symptomatic back pain.
- A comprehensive classification scheme for describing the alignment of the lumbar spine and pelvis was used to classify the lateral radiographs in 160 normal volunteers.
- Understanding the patterns of variation in sagittal alignment may help to discover the relationship between spinal balance and the development of degenerative changes in the spine.

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