Sagittal alignment of the lumbar spine in a Turkish population

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ABSTRACT

Objective: To understand the normal lumbar spine in the sagittal plane, and the range of lumbar lordosis.

Methods: This study was carried out in the Department of Anatomy, School of Medicine, Duzce University, Duzce, Turkey in the year 2005. We retrospectively reviewed T1-weighed sagittal spin-echo MRIs of the lumbar spine in 413 individuals (188 male, 225 female) aged between 13-82 years, and evaluated the angle of lumbar lordosis (ALL), sacrohorizontal angle (SHA), and lumbosacral angle (LSA).

Results: The ALL and SHA were significantly greater in females than in males (p<0.05). Weak, but significant correlations were detected between age and ALL, SHA, and LSA for females (p<0.05). The LSA was significantly greater for individuals over 41 years (p<0.05) when the entire study group was considered, and it was also significantly greater for individuals over 51 years in females (p<0.05). The LSA was significantly greater in the 7th decade than in the 3rd decade (p<0.05).

Conclusions: The results of this study provide insight into the sagittal alignment of the lumbar region for a Turkish population, and can serve as a reference for further clinical studies to improve the planning of spinal surgery.

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The sagittal balance of the spine is maintained by lordosis between L1 and L5 and kyphosis between T1 and T12. These curvatures allow the spine to absorb energy effectively and increase the efficiency of the spinal muscles, contributing to the erect posture of humans. The importance of the sagittal plane contour in the normal function of the spine and in its various pathological conditions is receiving increasing recognition.[1-7] In recent years, the increasing number of spinal deformities treated surgically has emphasized the importance of examining spine contours in the frontal, transverse, and sagittal planes.[1-3,7] While the coronal alignment of the human spine is well understood, namely, its being normal when straight and pathological when curved, however, the sagittal alignment of the spine is not.[6] The lumbar lordotic curve plays an important role in maintaining sagittal spinal alignment.[7,8] Although the exact effects of an increase or decrease in lumbar lordosis are not clear, many researchers have suggested that a reduced lumbar lordosis after spinal surgery, also known as a flat-back deformity, has a negative effect.[1,7,9,10] In addition, its relationship to low back-pain has also been emphasized.[8,11,12] Therefore, it is important to avoid subjectively evaluating the increase or decrease in lordosis and to determine the normal limits of the lumbar lordosis angle (ALL). However, there is no reported standardized technique for measuring the ALL, and the variation in the selection of the upper and lower vertebrae used to measure lumbar lordosis is responsible for the variation in the lordosis range. Magnetic resonance imaging (MRI) offers a new perspective for examining the lordosis of the spine. The MRI is a noninvasive method of examining the lumbar spine in great detail and has shown that the variation in the lumbar spine may or may not be related to reported symptoms.[13] Therefore, we determined the lumbosacral angle (LSA), ALL, and sacrohorizontal angle (SHA) using sagittal plane lumbar MRI. Knowledge of the normal values for age and sex will be important to provide objective reference values for planning spinal surgery.

Methods. This study was carried out in the Department of Anatomy, School of Medicine, Duzce University, Duzce, Turkey in the year 2005. The study was approved by the local ethics committee of Duzce Medical School. We retrospectively reviewed T1-weighed sagittal spin-echo MRIs of the lumbar spine of individuals who had low back pain. A total of 413 patients (188 male, 225 female) aged between 13-82 years met the inclusion criteria. Scoliosis, spondylolisthesis, spinal tumors, congenital anomalies, previous lumbar surgery, and radiotherapy were exclusion criteria. The equipment used had a 1.5-Tesla field strength (Intera Nova, Philips, Best, The Netherlands). The slice thickness for sagittal images was 4 mm, with a 1-mm inter-slice gap. The ALL, SHA, and LSA were evaluated using DicomWorks v1.3.5 software. The ALL was measured from the superior end plate of L1 to the superior end plate of S1,[2,11,14] according to Cobb's method. The SHA was measured from the superior end plate of S1 to the horizontal line of the sacral end plate tip.[1,3] The LSA was measured from the inferior end plate of the L5 to the superior end plate of S1[1,4,11,12] (**Figures 1a, 1b, & 1c**).

The statistical analysis was performed using SPSS for Windows release 11.01. Gender differences were analyzed using the independent samples test. The correlation of age with the aforementioned angles was analyzed using Pearson correlation analysis. These angles were compared according to decade using the Mann-Whitney U-test. For all analyses, statistical significance was defined using a probability level of $p<0.05$.

Results. The mean ALL and SHA were significantly greater in females than in males ($p<0.05$). The mean LSA was greater in females than in males, but the difference was not significant ($p>0.05$) (**Table 1**). A weak, but significant correlation was observed between age and the ALL (r=0.184), SHA (r=0.142), and LSA (r=0.243) for females ($p<0.05$), but no such correlations were detected for males (**Table 2**). The LSA was significantly greater for individuals over 41 years ($p<0.05$) when the entire study group was considered. Although the ALL, SHA, and LSA were greater for individuals over 41 years in both males and females, the differences were not statistically significant ($p>0.05$) (**Table 3**). The ALL, SHA, and LSA were greater for individuals over 51 years in the entire study group and males, but the differences were not statistically significant ($p>0.05$). In females, the LSA was significantly greater for individuals over 51 years ($p<0.05$) (**Table 4**). The distributions of the angles according to decade in both sexes are shown in **Table 5**. As bone maturation was not complete in the 2nd decade, the 3rd decade was used as the reference for comparing decades. As there were too few individuals in the 8th and 9th decades, they were not included in the analysis. The LSA in the 7th decade was significantly greater than in the 3rd decade (Mann–Whitney U-test, $p<0.05$) for the entire study group. However, when males and females were evaluated separately, the differences were not statistically significant (Mann–Whitney U-test, $p>0.05$).

Discussion. The orientation of the spine varies with subject age, gender, and weight. Physiologically, an aligned spine is an essential component of the

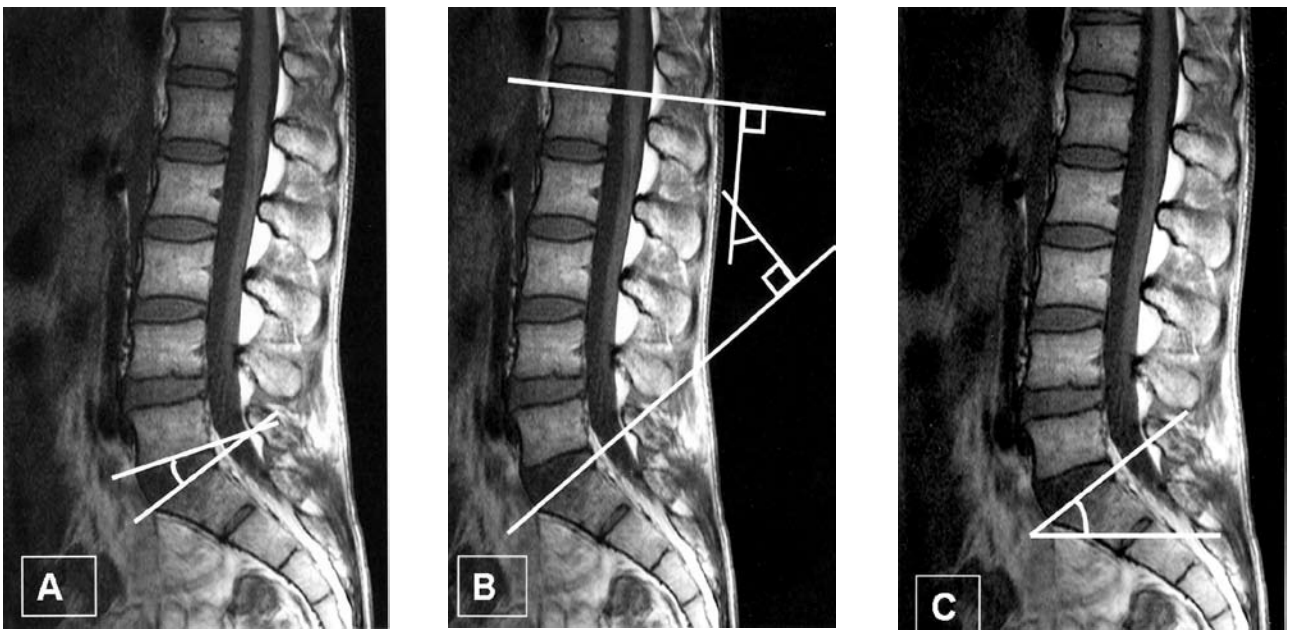

Figure 1 - Magnetic resonance image showing **a**) The LSA was measured from the inferior endplate of L5 to the superior endplate of S1. **b**) The ALL was measured from the superior endplate of L1 to the superior endplate of S1. **c**) The SHA was measured from the superior endplate of S1 to the horizontal line of the sacral endplate tip. LSA - lumbosacral angle, ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle.

Table 1 - Mean angle measurement in both genders.

Parameter	Female (n=225)		Male (n=188)		Whole Study group (n=413)	
	Mean	SD	Mean	SD	Mean	SD
Age	45.22	14.43	41.90	16.34	43.71	15.40
ALL*	47.24	11.16	40.94	10.11	44.37	11.14
SHA*	37.06	8.37	34.68	7.72	35.98	8.16
LSA	11.61	4.90	11.20	5.01	11.42	4.95

independent samples test *p<0.05, ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle, LSA - lumbosacral angle

Table 2 - Correlation of angles with age in both genders.

Parameter	Statistical method	Female (n=225) Age	Male (n=188) Age
Age	Pearson Correlation	1	1
	Sig. (2-tailed)	-	-
ALL	Pearson Correlation	0.184	0.003
	Sig. (2-tailed)	0.006	0.967
SHA	Pearson Correlation	0.142	0.025
	Sig. (2-tailed)	0.033	0.736
LSA	Pearson Correlation	0.243	0.125
	Sig. (2-tailed)	0.000	0.086

ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle, LSA - lumbosacral angle

Table 3 - Comparison of angles according to age in both genders (age <40 and age >41).

Parameter	n	Mean	SD	n	Mean	SD
	Age <40			Age >41		
Female						
ALL	88	46.32	10.372	137	47.83	11.641
SHA	88	36.34	8.478	137	37.53	8.299
LSA	88	11.06	4.762	137	11.97	4.969
Male						
ALL	97	40.38	8.721	91	41.53	11.432
SHA	97	34.46	6.802	91	34.91	8.625
LSA	97	10.58	4.725	91	11.86	5.240
Whole						
ALL	185	43.21	9.969	228	45.32	11.941
SHA	185	35.36	7.682	228	36.48	8.509
LSA*	185	10.81	4.736	228	11.93	5.068

Independent samples test *p<0.05, ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle, LSA - lumbosacral angle

Table 4 - Comparison of angles according to age in both genders (age <50 and age >51).

Parameter	n	Mean	SD	n	Mean	SD
	Age <50			Age >51		
Female						
ALL	148	46.15	10.127	77	49.34	12.733
SHA	148	36.40	8.298	77	38.34	8.416
LSA*	148	11.09	4.774	77	12.61	5.011
Male						
ALL	128	40.84	9.350	60	41.15	11.659
SHA	128	34.56	7.286	60	34.93	8.635
LSA	128	11.11	4.771	60	11.38	5.521
Whole						
ALL	276	43.68	10.111	137	45.75	12.891
SHA	276	35.55	7.884	137	36.85	8.649
LSA	276	11.10	4.764	137	12.07	5.256

Independent samples test *p<0.05, ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle, LSA - lumbosacral angle

Table 5 - Distribution of angles according to decades in both genders.

Decade	Female				Male				Whole Study Goup			
	n	ALL	SHA	LSA	n	ALL	LSA	SHA	n	ALL	LSA	SHA
		Mean ± SD				Mean ± SD				Mean ± SD		
2nd	9	43.00± 9.84	36.00±6.91	7.56±4.67	16	42.31±10.63	34.56±9.50	12.12±6.22	25	42.56±10.15	35.08±8.53	10.48±6.03
3rd	24	47.04± 9.76	36.79±7.92	10.88±4.90	34	41.21± 7.64	35.26±5.58	9.68±4.57	58	43.62± 8.98	35.90±6.63	10.17±4.71
4th	52	47.12±10.66	36.48±9.07	11.83±4.62	42	39.26± 8.54	34.00±6.38	10.74±4.04	94	43.61±10.48	35.37±8.04	11.34±4.38
5th	55	45.53±10.01	36.20±8.04	11.18±4.60	35	41.26±10.99	34.09±8.37	12.23±4.65	90	43.87±10.55	35.38±8.19	11.59±4.63
6th	48	45.73± 9.91	36.35±7.51	11.27±5.16	30	41.93±10.89	35.03±8.56	10.00±4.96	78	44.27±10.39	35.85±7.90	10.78±5.09
7th	26	50.38±14.15	39.15±9.26	13.04±5.02	20	38.95±12.37	34.15±9.42	12.85±6.71	46	45.41±14.45	36.98±9.56	12.96±5.75
8th	8	59.63±15.78	44.25±9.45	15.63±3.58	11	44.36±12.89	37.55±8.72	13.27±4.05	19	50.79±15.78	40.37±9.41	14.26±3.94
9th	3	59.00± 5.29	42.33±5.51	16.33±3.06	0	-	-	-	3	59.00± 5.29	42.33±5.51	16.33±3.06

ALL - angle of lumbar lordosis, SHA - sacrohorizontal angle, LSA - lumbosacral angle appearance and function of the human body. It is necessary to restore the spinal contours in pathologies such as Scheuermann's kyphosis or spondylolisthesis, in which spinal misalignment can be followed in the sagittal plane, or in idiopathic scoliosis, which can deform the spine in all 3 planes. When the spine needs to be reshaped in the sagittal, transverse, and coronal planes, it is important to know the normal contours for these curvatures.[2,7,15] The differences between normal and pathological curvatures are less clear in the sagittal plane than in the coronal plane.[6]

The radiological method used to examine the spinal contours must be reliable and repeatable. Although Cobb's method is used to measure the ALL, there is no standard for measuring lordosis. The lack of standardization between reports causes difficulty in making exact comparisons. The selection of the upper and lower vertebrae used for measurement is one of the crucial factors leading to variation during examination. Sagittal plane analysis of the spine in adults and adolescents has been studied thoroughly, and normative data for lumbar lordosis have been reported.[1-7,9,15,16] Tuzun et al[11] suggested that the angles between the planes of the superior end plate of the first lumbar vertebra and the inferior end plate of the fifth lumbar vertebra for lumbar lordosis reflect the physiological curvature of the lumbar region better. Some studies have emphasized the need to measure segmental lumbar lordosis, as well as the global lordosis angle, in order to avoid variation in the results.[1] In this study, the lordosis angle was measured from the superior end plate of L1 to the superior end plate of S1.

Roussouly et al[6] made a different grouping and defined 4 types of lordosis. They reported that the number of vertebrae showing lordosis varies from 1-8 and with the help of these data, the widely accepted generalization that the spine is kyphotic between T1 and T12 and lordotic between L1 and L5 may be overly simplistic. A study in which the lower arch lordosis was stated to be the most important indicator of global lordosis reported that the average value for global lordosis was 61.4º. Anatomically, the L5–S1 angle is an important source of lordosis in the lumbosacral spine, and approximately two-thirds of L1–S1 lordosis are distributed below L4.[3] Okcu et al[1] reported a LSA of 11.65±5.56°. We also established the normal interval for the LSA (11.42±4.95°), which is reported to form two-thirds of the total global lordosis, and determined its variation according to age and sex.

The average values of lumbar lordosis in various age groups have been described, which tends to reach a maximum after puberty, with a precipitate decrease after the 7th decade of life.[3] Gelb et al[17] reported that the lordosis angle value varies from –38 to –84 and demonstrated characteristic changes in sagittal alignment that occurs with aging. Tuzun et al[11] reported a moderate, significant correlation of age with lumbar lordosis. Cheng et al[16] reported that there was no relationship between aging and ALL. We found that the LSA in the 7th decade was significantly greater than in the 3rd decade for the entire study group. However, when males and females were evaluated separately, the differences between the 7th and 3rd decades were not significant. Tuzun et al[11] reported that there was no significant correlation between age and SHA. Reported values for the angle between the superior end plate of S1 and horizontal line of sacral end plate tip are 33.15±9.60°,[1] 34.6°,[3] 39.7±4.1°,[4] and 33.6±9.9°.[11] We measured the SHA from the superior end plate of S1 to the horizontal line of the sacral end plate tip to be 35.98±8.16° for the entire study group (**Table 1**). We found a weak but significant correlation of age with SHA for females only (**Table 2**), and the mean values for lumbar lordosis and SHA differed between women and men. Gelb et al,[17] Legaye et al,[9] and Vialle et al,[7] came to the same conclusion for ALL. In contrast, lumbar lordosis was independent of gender in other studies.[5,11,16]

Consequently, posture, age, and gender has an important effect on evaluating the ALL. In the literature, we find a very wide normal range for the lordosis angle arising from this variation. Our study was a cross-sectional clinical study, which can be considered as a limitation for this study; the obtained results provide reference values for a Turkish population sample and can serve as a guide for spinal surgery.

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