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Original Article

Assessment of the Lumbosacral Lordosis Angle for Sexual and Age-related Deviations in Cadaveric Lumbar Spines in Sikkim

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Abstract

Introduction: The role of optimal lumbar lordosis is unparalleled in the balancing the upright posture and management of spinal ailments. However, incongruities concerning the actual lordosis angle as well as the optimal range remain unresolved. The lumbosacral lordosis (LSL) angle formed between the central axis of third through fifth lumbar vertebrae and that of first sacral vertebra is contemplated as the true lumbosacral angle (LSA) by several authors. Data defining the standard parameters of this angle for regional and gender variances and their association among each other and age is unavailable in our population. Therefore, we estimated the LSL angle, the sacral disk angle (SDA), and the LSA in midsagittal cadaveric spines for regional variability and sexual dimorphism and the correlation among them and with age. Our results will not only compute the normal reference range in our population but will provide unsurmountable data in accomplishing the goal of the optimal lordosis angle in lumbar instrumentation and rehabilitative therapy.

Purpose: Analysis of the LSL, lumbosacral, and SDAs in cadaveric lumbar spines and their correlation with age and gender.

Materials and Methods: Forty midsagittal lumbar spines, consisting of equal number of males and female aged between 18 and 65 years were included in the study. Measurements were made using stainless steel goniometers.

Results: The mean age, LSL angle, SDA, and LSA is 47.85 (11.97), 143.9 (4.2), 20.0 (4.03), and 42.35 (3.4) in males and 42.95 (12.36), 139.85 (6.78), 17.35 (4.24), and 40.1 (3.37) in females.

Conclusion: The LSL angle (P = 0.015), SDA (P = 0.029) and the LSA (P = 0.047) are significantly higher in males. The lumbosacral scoliotic list LSL and SDA were positively correlated with each other and age in both males (r = 0.75) and females (r = 0.72).

Key words: Lordosis, Lumbosacral lordosis angle, Sacral disk angle, Lumbosacral angle

INTRODUCTION

The cognizance of evaluation of the lumbar lordotic curvature is unparalleled in the diagnosis and treatment of spinal ailments. The sagittal alignment of the spine stabilities the erect posture and determines the mechanical forces acting on the vertebral bodies.[1] Its alteration is the biggest offender for lumbosacral disintegration and pain.[2] Achieving the precise lumbar lordosis angle is the ultimate goal in deterrence of spinal degeneration and recreation of appropriate lumbar lordosis defines the success of reconstructive spinal surgery and rehabilitative therapy. However, the mystification of the true lumbosacral angle (LSA) and methods of assessment remain unsolved as the lordosis angle as well as the optimal range is still unspecified.[3,4] Lumbar lordosis is an evolutionary adaptation of human spine on attaining the erect posture where the lumbar spine arches forward to compensate for sacral inclination thus balancing the upper torso and preventing kyphosis.[5] Some authors consider the lumbosacral lordosis (LSL) angle formed at the center of L5 vertebrae by an axis joining the lower three lumbar vertebrae and that of first sacral vertebra as the true LSA.[6-9] Lordosis of the spine occurs at the cervical and

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lumbar region where the itinerant segments meet the almost immobile masses.[10,11] To the best of our knowledge, the evaluation of this angle for sexual dimorphism or regional variance and its correlation with age and other sagittal angles remains unexplored in our region. Most investigators have assessed either the Cobb's angle or the Ferguson's angle as the angle of lumbar lordosis.[4,5,12-17] The major inadequacy of the Cob's method is its sheer disregard for small segmental malformations as it includes the whole lumbar spine and the wide range of normal lordosis angle (30°–80°) that it defines. Furthermore, a single Cob's angle gives two varying lordotic curvatures.[4,17] All these limitations are overcome by the evaluation of the lumbosacral scoliotic list (LSL) which is static as the angle between two fixed vertical centroid axes is measured. Our study provides the unmatched morphometric analysis of the lumbar spine as it deliberates the lowest lumbar segment, most prone to ordeal of instability and contributing to 40% of lumbar lordosis and the lumbosacral junction most susceptible to trauma of flexibility.[4,10,11,18-20] With long fusions involving the lower lumbar segments and sacropelvic fixation gaining recognition for caudal strengthening in spinal surgeries the evaluation of LSL will deliver the most accurate reference ranges for deterrence of degeneration of the spine and circumvent iatrogenic or age associated flatback syndrome.[5,21] The sagittal spinal angles are influenced by several factors such as ethnicity, age, gender, and diseases.[5,22-41] Inconsistent observations prevail where most researchers reported higher values of lumbar lordosis in females.[21-26,34] While others found no variance.[7,15,17,30] Numerous researchers also validate that the aging spine exhibits loss of lordosis which manifests as flat back syndrome and gait anomalies.[10,22,31-33] While many observed no association between age and loss of lordosis.[11,14,29,34] Contradictory statistics exists regarding ethnicity, where some studies demonstrated bigger lordosis angles in Caucasians than Native Americans and Europeans.[35] While others reporting higher lordosis angles in African-Americans than Caucasians while some reported otherwise.[36-38] Moreover, yet others demonstrated similar angles between African-Americans and Caucasians and Europeans and Chinese.[39,40] Differences are observed even among two groups of same ethnicity.[41] Restoration of the perfect lumbar lordosis is the goal of lumbar fusion surgeries that averts adjacent segment degeneration and revised surgeries.[1,41-46] Although Cob's method is most preferred for assessment of lordosis, it increases the misperception about the precise angle of lumbar lordosis. All the deterrents of the Cob's method such as obtaining two varying angles from a single angle of lordosis, its neglect of segmental deformities and the large variation of the normal range of lordosis (30–80°) are overcome when evaluating the LSL angle which is fixed at the center of L3 vertebrae. Besides the above benefits our study also defines the standard reference range of lumbar lordosis for our population for the management of spinal ailments.

MATERIALS AND METHODS

Forty cadaveric mid sagittal lumbar spines sections were studied ranging from 18 years to 65 years in the department of anatomy, Sikkim Manipal Institute of Medical Sciences. Midsagittal sections were made taking care not to displace or damage the disks and vertebral bodies. Measurement of the LSL angle (LSL) sacral disk angle (SDA) and LSA was undertaken as mentioned by Yachom and Rowe. Spines with irregularities of the vertebra or disks, deformities like scoliosis, kyphosis and prolapsed disk, and those above 65 years likely to have extensive degenerative changes were excluded from the study. Small modifications were made to measure the angles directly. Transparency sheets were placed over the spinal sections and all important land marks and lines were drawn on these sheets and measurements were taken. The SDA was measured using the 360º stainless steel goniometer at the lumbosacral junction where the angle between a line passing through lower endplate of L5 vertebra and another line passing through the upper endplate of the first sacral vertebra were measured. The LSL angle (LSL) and the LSA were measured using the 180° goniometer. The LSL angle is open posteriorly and formed at the center of fifth lumbar vertebrae by an axis joining the lower three lumbar vertebrae and the axis of the first sacral vertebrae. The first line connects the centers of the L3 through L5 vertebral bodies and second line extends from the center of body of S1 vertebra to the center of L5 body. The center of the vertebral bodies is constructed by joining the anteroinferior with the posterosuperior angles and the anterosuperior with posteroinferior angle of vertebral bodies.

The LSA or the Ferguson's angle was measured between the upper end of sacrum and the horizontal plane. Data were analyzed using Windows SPSS version 20 (IBM Corp, USA). The data were tested for normality using the Kolmogorov–Smirnov test and were found to be normally distributed. The mean angles were tested using Student's t test for means. The association between various angles with each other and age was assessed using Pearson's correlation coefficient. The test results were within a confidence interval of 95%. A $P < 0.05$ was considered statistically significant.

RESULTS

The study was conducted on 40 mid-sagittal lumbar spinal sections without anatomical malformations. Equal number of male and female spines (20 each) was included in the study. The LSL angle LSL formed at the center of fifth lumbar vertebrae was measured [Figure 1].

The overall mean age (SD) was 45.5 (12.26). The mean age was 42.9 (12.3) for females and 47.8 (11.9) in males with no significant difference ($t = 1.28$, $P = 0.20$).

The total mean LSL angle observed was 141.9° (±5.9) with a range of 125°–150°. The LSL was significantly greater in males 143.9 (4.17) as compared to females 139.85 (6.78), ($P = 0.015$) demonstrating that females have higher lordotic spines [Table 1]. This is in agreement to similar findings of most referred literature in our study. The overall mean LSL was lower than that perceived by Yachum and Rowe (145°, range 124–162°) and Saraste but comparable to Naidoo's inferences in asymptomatic Indian females.[6-8] The lower mean LSL observed in our samples is congruous with other studies on cadaveric samples who also established significant differences compared to spines of living participants.[34] The variances demonstrated in our study could be credibly influenced by ethnicity and environmental factors as this includes samples from the sub Himalayan belt. We established that there is a loss of lumbar lordosis with advancing age as the LSL angle was is higher in older spines. The highest angles were reported in the sixth decade of life while the lowest in the second decade. It is further evident in our study that the SDA and LSL showed positive correlation with each other. A weak positive correlation between LSL and LSA was observed but was not significant. However, no correlation was established between LSA and SDA [Table 2].

Figure 1: Measurement of lumbosacral lordosis angle using goniometer

A significant positive correlation between LSL as well as SDA and age are observed in both females and males ($r = 0.85$, $P = 0.0026$) and ($r = 0.830$, $P = 0.0029$) and ($r = 0.68$, $P < 0.05$), ($r = 0.81$, $P \leq 0.05$) respectively. However, sexual dimorphism is observed in Pearson's correlation between age and LSA where a weak positive correlation between LSA and age ($r = 0.26$, $P = 0.01$) is observed in females whereas a negative correlation between LSA ($r = -0.40$, $P = 0.52$) and age is observed in males [Table 3].

DISCUSSION

The orientation of sagittal spinal alignment determines the shear and compressive forces acting on the anterior, vertebral body, and iv disk and posterior elements of vertebral column.[1] Studies have perceived that altered lumbosacral sagittal alignment leads to spinal disintegration and pain. Conservation of the optimal lumbar lordosis is the primary goal of rehabilitative therapy and lumbar fusion surgery.[2,4-7] However, considerable ambiguity exists regarding the definite angle of lordosis itself and the average normal standards. The posteriorly open LSL angle formed at the center of L5 vertebral body between the axis joining the centers of L3 through L5 and the axis of first sacral vertebral bodies is contemplated as the true LSA by some authors but there is scant available data regarding its morphometry.[5,6] We assessed the LSL angle (LSL), the SDA and the LSA in 40 midsagittal lumbar sections for regional and gender variances and their correlation with age. Some major shortfalls of Cob's method of assessment of lordosis angle is its sheer disregard of smaller segmental malformations as it includes the whole of the lumbar spine from upper surface L1 to upper surface of S1 and that a single Cob's angle provides two varied lordotic curvatures.[3,4,16] This can be overcome by the assessment of the LSL, which is more specific as its land marks are fixed on the central axis of the lumbar and sacral vertebrae. It also limits the extent of patients' exposure to hazardous irradiations where images of the pelvis itself will offer adequate information. The LSL being confined to the lumbosacral junction, region subjected to extreme insult of compressive forces provides important the most reliable statistics for the investigations of spinal ailments.[20] Mangione demonstrated that with the loss of lordosis in old age the center of gravity shifts anteriorly and this leads to progressive imbalance of sagittal spinal configuration and verticalization of sacrum.

Table 1: Mean sagittal angles by gender

Variable	Total	Male		Female		*t*-test
	Mean (SD)	Mean (SD)	Range	Mean (SD)	Range	P value
Age	45.4° (±12.2)	47.85 (±11.9)	25–64	42.95 (±12.36)	20–64	0.21
LSL	141.9° (±5.9)	143.9° (±4.2)	135–151°	139.9° (±6.8)	125–148°	0.015
SDA	18.73° (±4.3)	20.02° (±4.03)	10–25°	17.45° (±4.34)	13–26°	0.029
LSA	41.5° (±3.16)	42.2° (±3.9)	35–48°	40.1° (±3.7)	34–46°	0.047

Table 2: Comparison of combined mean lumbosacral lordosis angle of present study with other studies

STUDY	Mean LSL(SD)	Range	*P*-value
Yachum and Rowe 2005	146°	124–162°	<0.05
Naidoo 2008 (females)	143.2° (±5)	135–155°	0.22
Present study 2021 combined	141.9° (±5.9)	125–151°	<0.05
Present study females with Naidoo (Females)	139.85 (±6.78) Females	125–149	0.04

Table 3: Age wise mean lumbosacral lordosis angle observed in the present study

Group	Age	Male *n*	Mean (SD) LSL	Female *n*	Mean (SD) LSL	*t*-stats	*P*
1	21–30	3	136.7°±1.52	4	130.0°±4.54	2.7	0.01
2	31–40	3	143.0°±3.00	4	137.25°±5.12	1.86	0.06
3	41–50	5	144.2°±3.34	6	142.83°±3.18	0.69	0.97
4	51–60	6	145.5°±2.25	4	144.5°±3.41	0.51	0.60
5	61–70	3	148.6±1.52	2	146.5±2.12	1.2	0.4

This causes excessive stress upon the osteoporotic hips and knees which trigger the gait abnormalities in the aged.[32] Hasday *et al*. (1983) predicted that iatrogenic flat back and gait abnormalities are common complications of Harrington's instrumentation.[43] The recreation of optimal lumbar lordosis angle in the lower lumbar segment and prevention of iatrogenic flat back is the desired objective in lumbar fusion surgeries. This reduces the complications of Harrington's instrumentation such as adjacent segment degeneration and gait anomalies and averts revision surgery.[3,42-46] Our inclusion of sections without any anatomical deformities assumes immense importance as the inferences will not only compute the standard normal reference parameters for our population and provide the pre-operative blueprint to formulate the above goal of restoration of the appropriate lumbar lordotic angle for reconstructive spinal surgery and therapy [Figure 2].

We observed an overall mean LSL angle of 141.9° (±5.9) with a range of 125°–151°, which is significantly lower than the mean angle of 146° ($P < 0.001$) range 124°–162°, demonstrated by Yachum and Rowe.[7] Saraste observed a mean LSL of 135° in patients of spondylosis and 145° in the control group. The mean LSL observed in our study is significantly lower than that observed by Saraste ($P < 0.05$) in the controls without spondylosis.[8] Interestingly the combined mean LSL in our sample corresponds to the mean LSL 143.3° ± 5, ($P = 0.22$) established by Naidoo in her sample of young to middle aged females. Nevertheless, we observed lower mean LSL in our female samples 139.9° (±6.78) ranging between 125 and 148° as compared to Naidoo.[9] The lower mean LSL observed in our sample could be ascribed to this being a cadaveric study. As our study is carried out in a population in the sub Himalayan belt the lower values obtained in our study could also be on account of ethnicity. However, to endorse this, further assessment with bigger samples in the forthcoming years is essential. Similarly, variations from the usual findings were reported by Farni and Truman (1965) in cadaveric samples.[36]

Gender Discrepancies

Data regarding the normal morphometry of the LSL or gender dimorphism and its association with age in our region is unavailable. We observed significantly greater LSL in males 143.9 (4.17) as compared to females 139.85 (6.78), $P = 0.015$. This substantiates the studies by Vialle, Ferdinand and Fox, Bryan, Amonoo-Koufi, Damasceno, and Youdas who observed greater lordosis in females.[22-28,34] Similar findings were reported by Hay *et al*. who observed that female spines demonstrated greater lordotic curvatures caudally with the peak between the L4 and L5 vertebrae.[27] These changes are ascribed to the adaptation of female spines to the forward thrust of the center of gravity during pregnancy as perceived by Whitcome *et al*. in their study.[28] While others Skaf and Okpala (2014), Onyemaechi (2018), and Kalichman (2011) observed no discrepancy between genders.[5,14,15,29,30]

Interestingly, the mean LSL angle of 139.85 (±6.78) obtained in our female samples is significantly (SEM = 1.52, t = 2.2032, P = 0.04) lower than that demonstrated by Naidoo in her sample of asymptomatic females.[9] Our sample included spines without anatomical malformations of the disk or the vertebrae or the canal. The mean values obtained will provide the most accurate reference range for normal LSL this region.

Age and Lumbosacral Lordois Angle

So far, there is no available record in literature regarding the correlation of the LSL with age. Most of the literature cited have either measured the lordosis by the Cob's method and have given inconsistent reports. Skaf *et al*. measured the lumbar lordosis by Cob's method reported a significant decrease of lumbar lordosis with age.[5] Similarly, Aaro, Murata, Potter, Magione, and Oyakhire established that lumbar curvature decreased with age as the lordotic angle increased.[5,9,21,30,31] Whereas, Hellems, Okpala, Kalchiman, and Youdas showed no difference with age.[12,15,29,34] Our study is in agreement with many of the above-mentioned studies showing loss of lumbar lordosis with age. The lowest mean LSL angle of 130° (±4.54) in females and 136.7° (±1.52) in males was observed in Group 1 (21–30) years. While the highest mean LSL of 146.5° (±2.12) in females and 148.6° (±1.52) in male was observed in Group 5 (61–70 years) [Table 3] A strong positive correlation (r = 0.83) between age and LSL is observed in our study [Table 4]. The results are in agreement with Skaff and Mangione, Von Lockum who demonstrated that loss of lordosis favored disk degeneration and shifts the center of gravity anteriorly leading to kyphotic spines and gait anomalies of old age.[5,32,38] Similarly, Ergun *et al*. (2010) also observed that a more vertical lumbosacral spine favored disk degeneration and herniation even in young adult women.[2] The higher LSL in old age observed in our study confirms that older spines portrayed loss of lordosis which further leads to degenerative changes of the disk and vice versa [Figure 3].

Indigenous Variablity

Innumerable authors have reported variability in the lumbar lordotic curvatures among various populations. Atta-Alla *et al*. (2014) in their study of Lebanese females observed that Lebanese women had straighter backs compared to Egyptians.[35] Fahrni and Trueman (1965) in their study of cadavers observed smaller lordotic angles in Native Americans compared to Caucasians.[36] Hanson (1998) observed that African-Americans had greater lordosis angles than Caucasians.[37] While Maduforo (2012), Oyakhire *et al*. (2013) observed lower angles in Africans than Caucasians as observed by Von Lockum and Splithoff.[16,30,38,39] Goldberg (2001) observed similar lumbar lordosis angles in Caucasians and African-Americans.[40] Chen (1999) also did not report any difference in between Chinese and European population.[41] However, most of the above cited studies assessed either LSA, Ferguson's or Cob's angle.[16,30,36-41] The combined mean LSL angle of 141.9° (±5.9), (P < 0.05) is significantly lower than the mean angle of 146° demonstrated by Yachum and Rowe and Saraste who observed a mean LSL of 145° (P < 0.001) in his study in the control group as compared to those with spondylosis (135°).[7,8] The mean LSL angle observed our male samples is analogous to the mean LSL angle of 143.2° (±5°) in young to middle aged asymptomatic Indian females demonstrated by Naidoo *et al*. in the radiographic study of lumbar spines of. However, the observed mean LSL of 139.85 (±6.8) in female spines in our study is significantly (SEM = 1.52, t = 2.2032, P = 0.04) lower than that demonstrated by Naidoo in young Indian females without back ache.[9] The significantly lower mean LSL angle observed across all our samples has established that influence of ethnicity and regional factors are considerably

Table 4: Gender wise Pearson's correlation between age and angles

Gender	LSL	SDA	LSA
Male	r=0.83	r=0.81	r=-0.40
P-value	P<0.05	P<0.05	P=0.08
Female	r=0.85	r=0.68	r=0.26
P-value	P<0.05	P<0.05	P=0.13

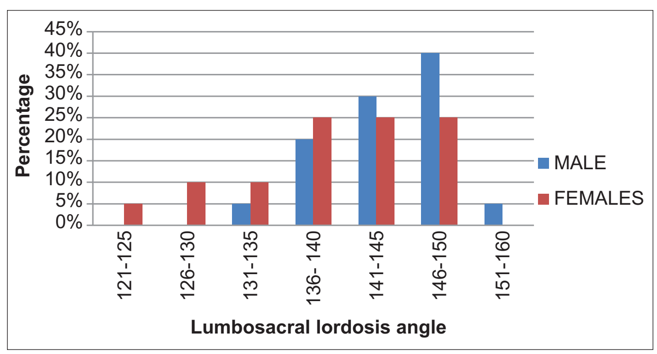

Figure 2: Frequency chart showing the lumbosacral lordosis angle between males and females

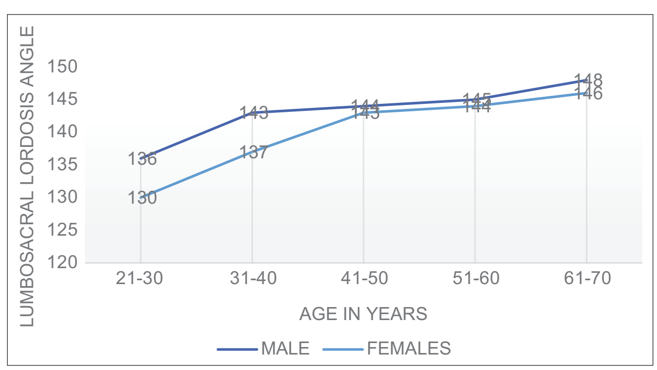

Figure 3: The correlation between age and lumbosacral lordosis

responsible for variances of the sagittal orientation of the lumbar lordosis of the spine. The present study corroborates that Indians, especiallly in the northeastern regions, have significantly lower sagittal spinal angles compared to other populations.

CONCLUSION

We observed LSL and lumbosacral disk angle and LSA were significantly higher in male samples. The smaller LSL in female leads to greater lordotic curvature of the spine which is an adaptation to balance the lumbar spines during pregnancy when the center of gravity shifts anteriorly. The LSL was positively correlated with age where the highest angle was observed in older spines. LSL was positively correlated with SDA in both males and females. Therefore, we concluded that spines showed significant loss of lordosis with age which conceivably induced the degenerative changes leading to flat back syndrome of aged spines. The measurement of the LSL angle presents the actual measurement between the itinerant lumbar spine and the immobile sacrum provides the most accurate reference data to evaluate spinal ailments and quantify the normal ranges. It also overcomes the shortfalls of the Cob's method by stipulating a single fixed angle over a short segment of spine with well-defined land marks. Our inclusion of spinal segments without anatomical incongruities will offer the ideal sagittal lumbar lordosis angle in reconstructive spinal surgeries and in devising lumbar support devices.

REFERENCES

1. Roaf R. Vertebral growth and its mechanical control. J Bone Joint Surg Br 1960;42-B:40-59.
2. Ergun T, Lakadamyali H, Sahin MS. The relation between sagittal morphology of the lumbosacral spine and the degree of lumbar intervertebral disc degeneration. Acta Orthop Traumatol Turc 2010;44:293-9.
3. Robertson PA, Armstrong WA, Woods DL, Rawlinson JJ. Lordosis recreation in transforaminal and posterior lumbar interbody fusion: A cadaveric study of the influence of surgical bone resection and cage angle. Spine (Phila Pa 1976) 2018;43:E1350-7.
4. Been E, Kalichman L. Lumbar lordosis. Spine J 2014;14:87-97.
5. Skaf GS, Ayoub CM, Domloj NT, Turbay MJ, El-Zein C, Hourani MH. Effect of age and lordotic angle on the level of lumbar disc herniation. Adv Orthop 2011;2011:950576.
6. Ebrall PS. Assessment of the Spine. 1st ed. Edinburg: Churchill Livingstone; 2004. p. 231-2.
7. Yochum TR, Rowe LJ. Essentials of Skeletal Radiology. 3rd ed., Vol. 1. Philadelphia, PA: Lippincott Williams and Wilkins; 2005. p. 53-70.
8. Saraste H, Brostom LA, Aparisi T. Axdorph radiographic measurement of the lumbar spine: A clinical and experimental study in man. Spine 1985;10:236-41.
9. Naidoo M. The Evaluation of Normal Radiographic Measurements of the Lumbar Spine in Young and Middle-age Indian Females in Durban. Master's Degree Dissertation at Durban University of Technology; 2008. p. 1-75. Available from: https://www.hdl.handle.net.
10. Harrison DD, Cailliet R, Janik TJ, Troyanovich SJ, Harrison DE, Holland B. Elliptical modelling of sagittal lumbar lordosis and segmental rotation angles as a method to discriminate between normal and low back pain subjects. J Spinal Disord 1998;11:430-9.
11. Cyriax JH. Lumbago mechanism of dural pain. Lancet 1945;246:427-9.
12. Hellems HK Jr., Keats TE. Measurement of normal lumbosacral angle. Am J Roentgenol Radium Ther Nucl Med 1971;113:642-5.
13. Ferguson AB. Clinical and roentgen interpretation of lumbosacral spines. Radiology 1934;22:548-58.
14. Onyemaechi NO. Evaluation of lumbar angles and their clinical correlates in a Nigerian population. Int J Res Med Sci 2016;4:2018-23.
15. Okpala FO. Measurement of lumbosacral angle in normal radiographs; a retrospective study in Southeast Nigeria. Ann Med Health Sci Res 2014;5:757-62.
16. Maduforo C, West O, Nwankwo N, Onwuchekwa R, Etawo US, Ongbulu D. Study of the lumbosacral angles of males in Port Harcourt, South-South, Nigeria. Niger Health J 2012;12:22-4.
17. Voutsinas S, Mac Ewen G. Sagittal profiles of the spine. Clin Orthop Related Res 1986;210:235-42.
18. Bogduk N, Twomey LT. Clinical Anatomy of Lumbar Spine. 2nd ed. New York: Churchill Livingstone; 1991. p. 45-7.
19. Abitbol MM. Evolution of the lumbosacral angle. Am J Phys Anthropol 1987;72:361-72.
20. Been E, Barash A, Marom A, Kramer PA. Vertebral bodies or discs: Which contributes more to human like lordosis? Clin Orthop Relat Res 2010;468:1822-9.
21. Potter BK, Lenke LG, Kuklo TR. Prevention and management of iatrogenic flatback deformity. J Bone Joint Surg Am 2004;86:1793-808.
22. Vialle R, Levassor L, Rillardon L, Templier A, Sakalli W, Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Joint Surg Am 2005;87:260-7.
23. Ferdinand R, Fox DE. Evaluation of lumbar lordosis: A prospective and retrospective study. Spine 1985;10:799-803.
24. Bryan GJ. Lumbar vertebrae. In: Diagnostic Radiography, A Concise Practical Manual. 4th ed. London: Churchill Livingstone; 1987. p. 152.
25. Damasceno LH, Catarin SR, Campos AD, Defino HL. Lumbar lordosis: A study of angle values of the vertebral bodies and intervertebral discs role. Acta Ortop Bras 2006;14:193-8.
26. Amonoo-Koufi HS. Changes in lumbosacral angle, sacral inclination and the curvature of lumbar Spine during aging. Acta Anat 1992;145:373-7.
27. Hay O, Dar G, Abbas J, Stein D, May H, Masharawi Y, *et al*. The lumbar lordosis in males and females, revisited. PLoS One 2015;10:e0133685.
28. Whitcom K, Shapiro L, Lieberman D. Fetal load and the evolution of lumbar lordosis in bipedal Hominins. Nature 2007;450:1075-8.
29. Kalchiman L, Li L, Hunter DJ, Been E. Association between computed tomography evaluated lumbar lordosis and features of spinal degeneration, evaluated in supine position. Spine J 2011;11:308-11.
30. Oyakhire M, Agi C, Didia BC, Yellow E. Assessment of the Spine in a healthy working population: A radiographic study of the lumbosacral angle in relation to occupation in Southern Nigeria. Asian J Med Sci 2013;5:99-5.
31. Aaro S, Ohlen G. The effect of Harrington instrumentation on sagittal configuration and motility of the spine in scoliosis. Spine 1983;8:570-5.
32. Mangione P, Senegas J. Sagittal balance of the spine. Rev Chir Orthop Reparat App Mot 1997;83:22-32.
33. Murat Y, UtsumiT, Hanaoka E, Takahashi K,Yamagata M, Moriya H. Changes in lumbar lordosis in young patients with low back pain during a 10 year priod. J Orthop Sci 2002;7:618-22.
34. Youdas JW, Garret TR, Harmsen S, Suman VJ, Carey JR. Lumbar lordosis and pelvic inclination of asymptomatic adults. Phys Ther 1996;76:1066-81.
35. Atta-Alla SS, Saab IM, El Shishtawy M, Hassan KH. Morphometric study of the lumbosacral spine and some of its related angles in Lebanese adult females. Ital J Anat Embryol 2014;119:92-105.
36. Fahrni WH, Trueman GE. Comparative radiological study of spines of a primitive population with North Americans and North Europeans. J Bone Joint Surg Br 1965;47:552-5.
37. Hanson P, Magnusson SP, Simonsen EB. Differences in sacral angulation and lumbosacral curvature in black and white young men and women. Acta Anat 1998;162:226-31.
38. Von Lockum HI. Lumbosacral region. J Am Med Assoc 1924;82:1109-14.
39. Splintoff CA. Lumbosacral junction roetgenographic comparision of

patients with and without backaches. J Am Med Assoc 1953;152:1610-3.
40. Goldberg C, Chairello CM. Lumbar sagittal plane mobility and lordosis in the well elderly as related to gender and activity level. Phys Occup Ther Geriatr 2001;19:17-34.
41. Chen YL. Geometric measurements of the lumbar spine in Chinese men during trunk flexion. Spine 1999;24:666-9.
42. Swank SM, Mauri TM, Brown JC. The lumbar lordosis below Harrington instrumentation for scoliosis. Spine 1990;15:181-6.
43. Hasday CA, Passof TL. Perry gait abnormalities arising from iatrogenic loss of lumbar lordosis secondary to Harrington instrumentation in lumbar fracture. Spine (Phila Pa 1976) 1983;5:501-11.
44. Kumar MN, Baklanov A, Chopin D. Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. Eur Spine J 2001;10:314-9.
45. Nakashima H, Kawakami N, Tsuji T. Adjacent segment disease after posterior lumbar interbody fusion: Based on cases with a minimum of 10 years of follow-up. Spine 2015;40:E831-41.
46. Heo Y, Park JH, Seong HY. Symptomatic adjacent segment degeneration at the L3-4 level after fusion surgery at the L4-5 level: Evaluation of the risk factors and 10-year incidence. Eur Spine J 2015;24:2474-80.

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