Normal Pediatric Lumbar Lordosis: Measurement of Magnitude and Age of Maximum Development Using Three Radiographic Techniques

Francis Osita Okpala
Department of Radiology, Federal Teaching Hospital, Abakaliki, Ebonyi, Nigeria

Correspondence: Dr. Francis Osita Okpala, Department of Radiology, Federal Teaching Hospital, PMB 102 Abakaliki, Ebonyi, Nigeria.
E-mail: frankokp@yahoo.com

ABSTRACT

Background: A retrospective measurement of lumbar lordosis (LL) in normal supine lateral lumbosacral spine radiographs of 27 children aged 0.04–14.00 years. Measurement of the LL may aid in the early diagnosis and management of some pediatric conditions before irreversible neurologic change occurs. They include spondylolisthesis (congenital or acquired); achondroplasia and muscular dystrophies are less common. The sagittal radiographic lumbar lordotic angle is poorly documented in normal pediatric population. **Objective:** To evaluate the magnitude and age of maximum development of the normal pediatric LL using three different radiographic techniques. **Methods:** Ferguson (for lumbosacral angle [LSA]), Cobb (for Cobb angle) and tangential radiologic assessment of LL (for TRALL angle) were the methods used. Data were analyzed with SPSS statistics version 20.0 (Chicago, IL, USA). $P < 0.05$ was considered significant. **Results:** LSA varied from 15° to 62°, Cobb angle 15–65° and TRALL angle 20–46°. The mean (standard deviation) of LSA, Cobb, and TRALL angles were 35.8 (10.3)°, 35.6 (13.7)°, and 32.3 (7.3),° respectively; the 0.95 confidence interval for the LSA was 27.6–44.5°, Cobb angle 27.2–50.7°, and TRALL angle 26.8–40.1°. Each angle showed no significant gender difference. The major part of estimated adult LL was gained during the first 5 years of life; the second peak occurred in the 11–14 years age-group. **Conclusion:** In children under 15 years, poor management of pathologies affecting LL can cause irreversible neurologic damage arising from spinal deformity.

Key words: Age of maximum development; lumbar lordosis; magnitude

Introduction

The vertebral spine presents regional curves on a sagittal plane designed to absorb impact, reduce its longitudinal stiffness, and intensify muscular function.[1] At the lumbar level, this curve is convex anteriorly and is known as the lumbar lordosis (LL).[2] Early in the fetal period, the thoracic and sacrococcygeal regions of the spine form an almost continuous curve that represents the sagittal curvature.[3] Later, the cervical and LLs appear as secondary or compensatory curves; muscle action and fetal movement appear to influence their development.[4,5] After birth, the spinal sagittal curves undergo changes during the growth period.[6] As an infant starts to stand, usually between 12 and 18 months of age, LL continues to develop until the completion of spinal growth, normally between 13 and 18 years.[7]

Although the various methods that have been used to quantify the lumbar lordotic curve include goniometry,[8,9]

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radiography,[10-16] flexible rulers,[17-21] software methods,[22] spinal mouse,[23] spinal pantograph,[24] and inclinometer;[25,26], radiography remains the gold standard and LL can be measured accurately in a supine lateral lumbosacral spine radiograph.[27-29] Some of the radiographic angular measures of LL include lumbosacral angle (LSA), Cobb, and tangential radiologic assessment of lumbar lordosis (TRALL) angles.

Measurements of the LL may aid in the early diagnosis and management of some pediatric conditions before irreversible neurologic change occurs. Spondylolisthesis (congenital or acquired) is a relatively common pathology that may affect the LL; less common conditions include achondroplasia and muscular dystrophies. Alterations in spinal alignment are commonly of cosmetic concern to the patient and family. Sequelae from progressive spinal deformities include pain and a loss of sitting balance (nonambulators).[30]

The sagittal radiographic lumbar lordotic angle is poorly documented in normal pediatric population, and data in our geographic area is virtually nonexistent. This study was therefore, aimed at quantifying the normal value of this angle using three different measuring techniques.

Methods

A radiographic retrospective study in 27 children (15 males and 12 females) to determine LL in the supine lateral lumbosacral spine was conducted. The children were aged 0.04–14.00 years; mean (standard deviation [SD]) was 6.5 (4.3) years. The radiographs were from the archives of a teaching hospital from the southeast part of Nigeria and spanned from 2012 to 2014. The study center routinely does its lateral lumbosacral spine X-rays in the recumbent posture and the usual technique is as follows: Patient lies in true lateral position in the center of the X-ray couch, focus-film distance is 90 cm (36 inches), and X-ray beam is centered at 3rd lumbar vertebra with the X-ray tube at right angle to the film. Exposure is done without Bucky with 60–65 kVp and 10–15 mAs. Uncooperative children are usually restrained by an adult wearing a protective lead apron. Ethical clearance was obtained. The apparent low number of the studied radiographs was due to the difficulty in finding truly normal films as most of the archival films had vertebral pathology. Inclusion criteria were: (a) Normal X-ray films: Defined as those obtained for suspected disorder but with no abnormalities detected [Figure 1] by the radiologist and (b) patients aged between 0 and 14 years. Films from patients above 14 years or that were of poor quality, or showing any vertebral pathology, were excluded. Films from patients above 14 years were excluded to ensure that only those that have not attained spinal maturity were studied.

Though a prospective study using normal subjects would have been ideal in this study, a retrospective method was adopted to avoid the ethical issue of patient's irradiation.

Figure 1: Normal pediatric lateral lumbosacral spine radiograph

Even if some of the studied radiographs belonged to subjects that presented with back complaints, low back pain without any radiographically demonstrable vertebral pathology have been reported not to significantly affect the degree of normal LL.[31,32]

Lordotic angles were measured by: (a) Mounting each radiograph on a viewing screen with good illumination; (b) drawing measurement lines (using appropriate landmarks) with a 30 cm long transparent ruler and pencil; and (c) measuring the angles in degrees with a protractor. All measurements were made by the author in order to remove the inter-observer error.

LSA is the angle formed between a horizontal line and a line through the plane of the superior margin of S1 [Figure 2]. Cobb angle is between perpendiculars from the superior end plate of L1 and the superior end plate of S1 [Figure 3]. TRALL angle was measured as described by Chernukha *et al*.[14] [Figure 4a-c]. Along the posterior vertebral bodies: (a) A curved line was drawn from the superior end plate of L1 to the inferior end plate of S2 (Arc line); (b) a line connecting the superior end plate of L1 and the inferior end plate of S2 was drawn (chord line), and the greatest perpendicular distance between the Arc line and the chord line was determined; and (c) from the point where the greatest perpendicular distance is touching the Arc line, two lines were drawn, one to L1 (upper part of chord line) and the other to S2 (lower part of chord line); the intersection of these two lines is the TRALL angle.

Data analysis was done with SPSS statistics version 20.0 (Chicago, IL, USA). $P < 0.05$ was considered significant. Some of the statistical methods employed included mean and SD, test of significance, confidence interval (CI), and graphs.

Results

A total of 27 normal lateral supine lumbosacral spine radiographs were assessed (15 males; 12 females). The mean age (SD) of the patients was 6.5 (4.3) years; 6.5 (4.7) years for the males, and 6.5 (4.1) years for the females [Table 1]. There was no significant difference between the mean ages of the males and females ($P = 0.98$, $P > 0.05$) [Table 1]. The LSA was 35.8 (10.3)° (range = 15–62°; CI = 31.2–40.4°); Cobb angle was 35.6 (13.7)° (range = 15–65°; CI = 29.4–41.8°); and TRALL angle was 32.3 (7.3)° (range = 20–46°; CI = 29.4–35.2°) [Table 1]. There was no significant difference between the LSA and Cobb angle ($P = 0.943$, $P > 0.05$); significant differences, however exist between the LSA and TRALL ($P = 0.033$, $P < 0.05$), and between the Cobb and TRALL angles ($P = 0.043$, $P < 0.05$) [Table 2]. All the angles showed no significant sex difference [Table 1]. In all the three angles studied, the magnitude of LL significantly increased from the age-group 0–14 years [Table 3 and Figure 5a-c]. Furthermore, the major part of estimated adult LL was gained during the first 5 years of life while the second peak occurred in the 11–14 years age-group [Table 3 and Figure 5a-c].

Figure 2: Lumbosacral angle measurement lines

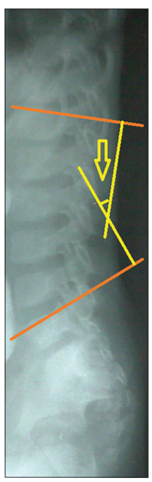

Figure 3: Cobb angle measurement lines

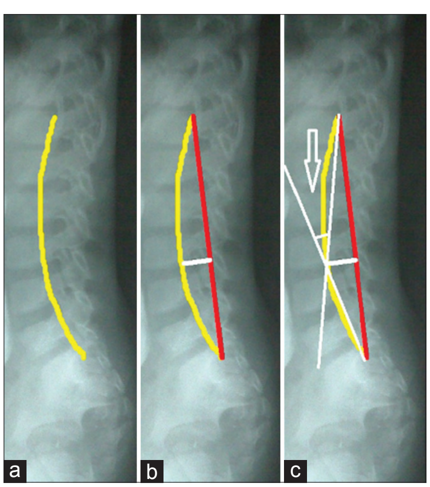

Figure 4: Tangential radiologic assessment of lumbar lordosis angle measurement lines (a) initial line; (b) next lines; and (c) final lines)

Discussion

It used to be the thinking that LL develops in children during the 1st year of life, in response to new biomechanical loads (which influence the growth of the vertebrae) as they begin to pull themselves up into standing postures prior to taking their first steps. However, recent research suggests that there may be a genetic component to the morphology because LL is evident in up to 60% of human fetuses.[33] Children who never assume the erect position develop a LL to the same degree and at the same time as other children while growth retardation delays its emergence.[34] As an infant starts to stand, usually between 12 and 18 months of age, LL continues to develop until the completion of spinal growth, normally between 13 and 18 years.[7] The children whose radiographs were assessed in this study have not attained spinal maturity (i.e., their LL is still developing) because their age range was 0.04–14.00 years.

A small degree of LL is normal and tends to make the buttocks appear more prominent; too much LL is called hyperlordosis. Children with significant LL will have a large space underneath the lower back when lying supine on a hard surface. Some children have more pronounced LL which most often fixes itself as the child grows. This is called benign juvenile LL. If the lordotic curve is flexible (when the child bends forward the curve reverses itself), it is generally not a concern; but if the curve seems "fixed" (not bendable), medical evaluation and treatment are needed and tests that may be indicated include lumbosacral spine X-rays, spinal magnetic resonance imaging, and some laboratory tests.[30]

The methods of quantifying the curve of LL can be grouped into radiographic and nonradiographic; however, the radiographic method remains the gold standard despite some of the benefits of the nonradiographic methods.[27-29] While the radiographic method uses ionizing radiation with its associated risks, the nonradiographic methods do not involve the use of ionizing radiation. The nonradiographic methods include goniometry,[8,9] flexible rulers,[17-21] software methods,[22] spinal mouse,[23] spinal pantograph,[24] and

Table 1: Mean age and angles (LSA, Cobb, and TRALL) according to gender

Variable	Number	Range		Age (in years) Angles (in degrees)		*t*-test: Male versus female	95% CI of the mean	
		Minimum	Maximum	Mean	SD		Minimum	Maximum
Age								
Males	15	0.04	14	6.49	4.7	0.98		
Females	12	0.08	14	6.54	4.1	*P*>0.05		
Total	27	0.04	14	6.51	4.3			
LSA								
Males	15	15	62	35.9	12.6	0.95	31.2	40.4
Females	12	22	45	35.6	7.2	*P*>0.05		
Total	27	15	62	35.8	10.3			
Cobb								
Males	15	16	65	36.9	15.1	0.56	29.4	41.8
Females	10	15	47	33.6	11.7	*P*>0.05		
Total	25	15	65	35.6	13.7			
TRALL								
Males	14	20	46	32.8	8.1	0.72	29.4	35.2
Females	9	22	40	31.6	6.3	*P*>0.05		
Total	23	20	46	32.3	7.3			

LSA – Lumbosacral angle; SD – Standard deviation; CI – Confidence interval; TRALL – Tangential radiologic assessment of lumbar lordosis

Table 2: Assessment of possible statistical difference between LSA, Cobb, and TRALL angles

Lordotic angles	One sample *t*-test (to assess for statistical difference between LSA, Cobb, and TRALL angles; *P*<0.05 is significant) Mean
LSA *n*: 27 Range: 15-62° Mean: 35.8° SD: 10.3° Variance: 106.99	Test value=35.8° A versus B (*P*=0.943; *P*>0.05) A versus C (*P*=0.033; *P*<0.05)
Cobb *n*: 25 Range: 15-65° Mean: 35.6° SD: 13.7° Variance: 188.25	Test value=35.6° B versus C (*P*=0.043; *P*<0.05)
TRALL *n*: 23 Range: 20-46° Mean: 32.3° SD: 7.3° Variance: 53.54	

LSA – Lumbosacral angle; SD – Standard deviation; TRALL – Tangential radiologic assessment of lumbar lordosis

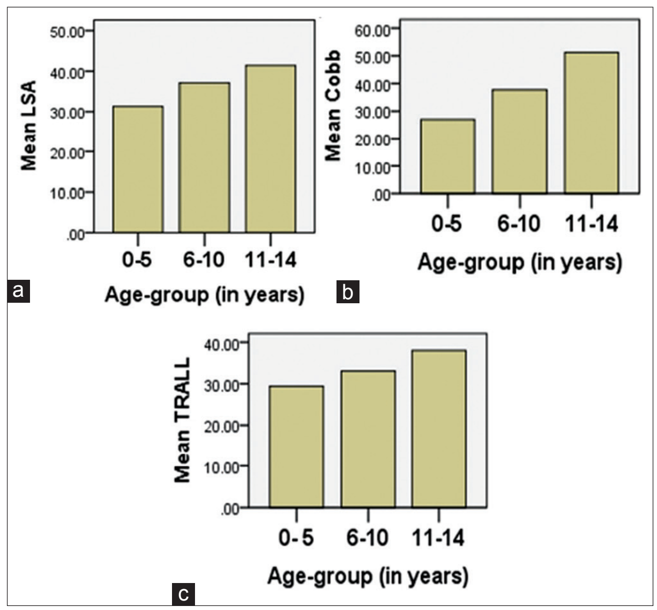

Figure 5: (a) Bar graphs of mean lumbosacral angle, (b) Cobb, and (c) tangential radiologic assessment of lumbar lordosis angles by three age-groups

inclinometer[25,26]. One of the nonradiographic methods is the use of surface topography; and its advantage include imaging of the patients in their normal, habitual posture, and avoiding some of the unnatural changes in posture-induced by positioning the patient in front of the X-ray machine.[35] Two early systems, Integrated Shape Imaging System, and Quantec, developed computer models that estimated radiographic Cobb angles using surface topography data. Correlations were good (r = 0.8 and tended to be within 10° of the radiographic measurements).[36]

Using a Quantec Spinal Image System (QSIS) that uses computerized raster stereography technology to acquire three-dimensional measurements of back contour, Thometz *et al*. investigated 40 normal children (mean age = 9.1 years) in the erect posture; and within a 95% CI, sagittal-plane QSIS angle ranged from 36.8° to 44.8°, that is, 40.8° mean value.[37] There is no significant difference between the radiographic Cobb angle obtained in this study and the computer model-estimated Cobb angle (QSIS) reported by Thometz *et al*. (P = 0.07, P > 0.05) in the erect posture [Table 4]. The Cobb angle also showed no significant difference (P = 0.12,

Table 3: Variation of the mean LSA, Cobb, and TRALL angles by three age-groups

Age-group (in years)	Data	LSA	Cobb	TRALL	*t*-test of mean angles across age-groups (*P*<0.05 is significant)		
					LSA	Cobb	TRALL
0-5	Mean	31.30	27.00	29.40	A versus B *P*=0.20	A versus B *P*=0.03	A versus B *P*=0.26
	n	10	10	10			
	SD	8.17	8.06	5.54			
6-10	Mean	37.13	37.73	33.06	B versus C *P*=0.48	B versus C *P*=0.10	B versus C *P*=0.32
	n	12	11	9			
	SD	11.76	12.44	8.00			
11-14	Mean	41.40	51.25	38.00	A versus C *P*=0.04	A versus C *P*=0.001	A versus C *P*=0.04
	n	5	4	4			
	SD	8.38	14.34	7.53			
Total (0-14)	Mean	35.76	35.60	32.32			
	n	27	25	23			
	SD	10.3	13.7	7.3			

LSA – Lumbosacral angle; SD – Standard deviation; TRALL – Tangential radiologic assessment of lumbar lordosis

Table 4: Comparison of the mean Cobb and TRALL angles with some literature values

One sample *t*-test: Present study versus literature					
Angle (in degrees)	Present study (Okpala FO)	Literature			
		Sagittal-plane QSIS, erect posture (A computer model that estimates radiographic Cobb angle using surface topography data) (2000)	Radiographic, retrospective, erect, Cobb angle by Propst-Proctor and Bleck (1983)	Radiographic, retrospective, recumbent, Cobb, and TRALL angles by Chernukha *et al.* (1998): Derived from their data of 1-10 years age-group	
				Cobb	TRALL
Test value		40.8°	40.0°	38.7°	39.5°
Cobb	35.6°	*P*=0.070; *P*>0.05	*P*=0.122; *P*>0.05	*P*=0.264; *P*>0.05	
TRALL	32.3°				*P*=0.000; *P*<0.001

QSIS – Quantec Spinal Image System; TRALL – Tangential radiologic assessment of lumbar lordosis

P > 0.05) with the radiographic Cobb angle reported by Propst-Proctor and Bleck; they had reported the normal mean radiographic Cobb angle of 40.0° (range 31.0–49.5°) in their retrospective study involving 104 normal children in the erect posture[38] [Table 4]. Since the Cobb angle obtained in this study compared favorably with two literature values obtained respectively by QSIS and radiographic Cobb technique, this suggests that the values of the LSA and TRALL angle obtained in this study are likely reliable. Furthermore, since in the current study, X-ray films taken in the recumbent posture were assessed while the cited literature values were obtained in the erect posture, it implies that posture has no significant effect on the value of LL; this agreed with the observation of Reichmann and Lewin that children who never assume the erect position develop LL to the same degree and at the same time as other children.[34]

When the work of Chernukha *et al*. is studied, it can be derived from their Table 3 that from 51 subjects aged 1–10 years (mean = 6.0 years), the mean (SD) of the Cobb and TRALL angles were 38.7 (7.8)° and 39.5 (5.7),° respectively.[11] The 1–10 years age-group was chosen in order to march their study with the current study for age; the mean age of the current study is 6.5 years. Chernukha *et al*. did a retrospective study of 199 normal radiographs (of subjects aged 1–30 years) taken in the recumbent posture. In the present study, while the mean Cobb angle (35.6°) showed no significant difference from the 38.7° mean Cobb angle derived from the study of Chernukha *et al*. (*P* = 0.264, *P* > 0.05), the mean TRALL angle (32.3°) is only about 7° less than their mean TRALL angle of 39.5° (*P* = 0.001, *P* < 0.05) [Table 4]. Thus, the Cobb and TRALL angles obtained in this study compared favorably with all the cited literature values. The LSA obtained in this study could not be compared with literature values as there is paucity of data on the magnitude of this angle in the pediatric age-group; most literature data on LSA are on the adult population.

The LSA, Cobb, and TRALL angles obtained in this study showed no significant gender difference and this supports the observation of some authors that sex has no significant effect on the degree of LL in children[38-40] [Table 1].

One remarkable feature of this study is the simultaneous measurement of three different radiographic angles of LL; most literature studies of normal pediatric LL had centered on one method, usually the Cobb technique. Each of the angles can be independently applied in the evaluation of pediatric LL.

In this study, the total mean LSA was 35.8 (10.3)°, Cobb angle was 35.6 (13.7),° and TRALL angle was 32.3 (7.3)° [Table 1]. There was no significant difference between the LSA and

Cobb angle ($P = 0.943$, $P > 0.05$); significant differences however exist between the LSA and TRALL ($P = 0.033$, $P < 0.05$), and between the Cobb and TRALL angles ($P = 0.043$, $P < 0.05$) [Table 2]. Thus, it can be inferred that during the period of spinal growth, the LSA and Cobb angle have almost equal mean, SD, and range; also, the TRALL angle showed the least variance in SD and range [Table 2]. Chernukha *et al*. had reported the TRALL angle to be less variable than the Cobb.[14]

In the three angles studied, the magnitude of LL significantly increased from the age-group 0–14 years [Table 3 and Figure 5a-c]. Furthermore, the major part of estimated adult LL was gained during the first 5 years of life; the second peak occurred in the 11–14 years age-group and is most likely due to the structural changes caused by the pubertal growth spurt [Table 3 and Figure 5a-c]. These findings are almost similar to those of Chernukha *et al*. and are further proofs of the reliability of the values obtained in this study, notwithstanding the seeming small sample size.

The limitation in this study is the seeming small sample size arising from the difficulty in finding normal radiographs in the archives; most of the archival radiographs showed one pathology or the other, and were thus ineligible for study. Despite this, the study has given an idea of the value of pediatric LL by three different radiographic techniques. However, the fact that the Cobb angle obtained in this study showed no significance difference from three different literature values is noteworthy and increases the probability that the LSA and TRALL angle values are also reliable [Table 4].

Further study of the magnitude of normal pediatric LL using any of the easily available and less complicated nonradiographic methods is recommended in the long-term surveillance of spinal deformity. It could be used during every follow-up visit because patients would not be exposed to ionizing radiation. Thus, clinicians will detect spinal deformity earlier. Also, patients would be imaged in their normal, habitual posture, avoiding some of the unnatural changes in posture-induced by positioning the patient in front of the X-ray machine.

Conclusion

This study has established the magnitude and age of maximum development of the normal pediatric LL using three different radiographic angles (LSA, Cobb, and TRALL). There is no significant difference between the LSA and Cobb angle; significant differences, however, exist between the LSA and TRALL, and between the Cobb and TRALL angles. The TRALL angle showed the least variability in SD and range in comparison to the LSA and Cobb values. All three angles showed no significant gender difference. The major part of estimated adult LL was gained during the first 5 years of life; the second peak occurred in the 11–14 years age-group. In children under 15 years, poor management of any pathology that can affect LL may result in irreversible neurologic damage arising from a spinal deformity.

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Conflicts of interest
There are no conflicts of interest.

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