Original Article

Age-of-Cessation of Lumbar Lordosis Development as an Assessment Parameter

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Abstract

Background: In managing paediatric spinal deformities, the currently-in-use growth maturity assessment parameters (clinical or radiological) are based mostly on Caucasian populations. They may be adequate for general treatment planning but may not accurately predict the remaining growth potential. Some therapies (e.g. growing rod distractions or growth modulation surgeries) require more accurate predictions of remaining growth potential and race-specific values. Lumbar lordosis (LL) development ceases at spinal bone maturity. The age-of-cessation seems a more accurate predictor of remaining spinal bone growth potential, compared to currently-in-use growth maturity assessment parameters, but is rarely included in the growth maturity assessment parameters. **Aims and Objectives:** As a predictor of remaining spinal growth potential, age-of-cessation of LL development (Race-specific of Black populations) was quantified. **Materials and Methods:** In archival normal lateral lumbosacral radiographs of patients of a tertiary hospital in South-East Nigeria, LL development across five age groups (Birth– 9, 10–15, 16–20, 21–25 and 26–30 years) was quantified with lumbosacral joint angle (LSJA) in 215 (110 males, 105 females), and lumbosacral angle (LSA) in 238 (119 males, 119 females). Data were analysed with IBM SPSS Statistics 23.0 (NY, USA). $P \leq 0.05$ was considered statistically significant. **Results:** Both LSJA and LSA age groups' mean values progressively increased with age, and plateaued at 21–25 years range, with LSJA mean of 23.4 ± 1.3 years, and LSA mean 23.5 ± 1.3 years; the means difference was insignificant ($P = 0.680$). **Conclusion:** With ageing, there is progressive increment, and later, cessation of LL. Age-of-cessation indirectly infers spinal-maturity-age, and could indirectly be an assessment parameter of spinal-maturity-status.

Keywords: Age-of-cessation, assessment parameter, development, lumbar lordosis, spinal-maturity

Introduction

The three paediatric growth surges (in years) are pre-growth (2–9), growth (10–15) and post-growth (16–20);[1] the most rapid growth occurs at birth, 5 years and 10–15 years.[2,3]

Lumbar lordosis (LL), the anterior-ward convexity in the lumbar region of the vertebral column,[4] is functionally important for bipedal locomotion,[5] and is evident in about 60% of human foetuses.[5] Its development continues after birth, as an infant starts to stand.[6-10] In children who never assume the erect position, it develops to the same degree and at the same time as other children, while growth retardation delays its emergence.[11] The development ceases at spinal maturity (i.e. spinal bone maturity).[6,9,10] The gold standard for its accurate measurement is with a supine lateral lumbosacral radiograph[12-14] despite the availability of many non-radiographic methods. Some radiographic measures are the lumbosacral angle (LSA), lumbosacral joint angle (LSJA), Cobb and tangential radiologic assessment of LL (TRALL) angles.[15]

The LL may be altered by paediatrics spinal deformities (PSD) such as hyperlordosis, scoliosis and spondylolisthesis.[16] Alterations in spinal alignment are commonly of cosmetic concern to the patient and family. Sequelae from progressive PSD include pain and a loss of sitting balance (non-ambulators).[16]

In managing PSD, the currently-in-use growth maturity assessment parameters (based mostly on Caucasian populations)

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may be clinical or radiological. Clinical example is Tanner staging for Secondary sexual characteristics.[17] The radiological examples are bone age assessment methods and include the following. The Risser sign/grading scale (refers to the level of calcification of the iliac apophysis and ultimate fusion of the apophysis to the iliac crest),[18]

Tanner and Whitehouse II or III,[19] Greulich and Pyle method (using standard bone age atlas),[20] Sanders classification,[21] Distal radius and ulna classification,[22] and Sauvegrain method (Elbow apophysis score system).[23] Although these parameters may be adequate for general treatment planning, there are some significant limitations in their applications. For instance, the Risser sign and timing of menarche (in Tanner staging for secondary sexual characteristics) are mostly retrospective and lack strong predictive utility. Furthermore, inTanner staging, the breast and pubic hair development in girls, and scrotum and pubic hair in boys, are difficult to use by spine surgeons to accurately predict remaining growth potentials.[24] Some therapies of PSD (e.g. growing rod distractions, or growth modulation surgeries) require more accurate predictions of remaining growth potential and race-specific values.[24] Bone age assessments are more accurate parameters, but further research is required to determine inter-racial variations and develop their role in management decisions;[24] the Sanders staging (based on a single X-ray of the left hand, fingers and wrist) requires physeal assessment of all digits, which is complex and cumbersome to use in a busy clinic setting.[24]

Development of LL ceases at spinal maturity (i.e. spinal bone maturity);[6,9,10] the age-of-cessation is not one of the reported currently-in-use growth maturity assessment parameters (e.g. for managing PSD), though its use seems credible, simple and less time-consuming. Published data regarding this age are sparse;[6,9,10] also, race-specific values on this is sparse.[7]

The evaluation of age-of-cessation of LL development in this study was, therefore, to quantify it, assess its potential as an indirect spinal growth maturity assessment parameter (and if found credible, recommend its routine use), and add a race-specific (Black populations) value to literature.

Materials and Methods

In individuals aged ≤30 years, the LSJA and LSA were measured in supine lateral lumbosacral spine radiographs from the archive (2012–2017) of a tertiary hospital in South-East Nigeria, after the hospital's ethical clearance. While the LSJA was measured in 215 individuals (110 males and 105 females), the LSA was measured in 238 (119 males and 119 females).

The study centre routinely does lateral lumbosacral X-rays in the recumbent posture, using the global standard radiographic imaging technique for patients' position and exposure; this makes the study reproducible. The departmental imaging technique is as follows. In the centre of the X-ray couch, the patient is laid in the true lateral position, head supported with a pillow, non-opaque sponge roll placed under the thoracolumbar spine (to make the long axis of the spine parallel to the film), arms raised to the head, hips and knees flexed, legs placed comfortably using padding, and entire body immobilised. Uncooperative children are restrained by an adult wearing protective lead apron. Anatomical marker would be inserted. Over-couch X-ray beam would be collimated, centred to the midline, at the level of lower costal margin (corresponding to L3 spinous process), with the central X-ray vertical at 90° to the film, and X-ray exposure done in arrested respiration using appropriate exposure factors. Uncooperative children were watched and exposure was done at the end of inspiration.

From the patients' request forms (usually enclosed in the film jackets), demographic data and clinical information were obtained. Radiographs of ≤30-year-old individuals reviewed by the radiologist as normal were studied [Figure 1a]. Excluded radiographs were those with no indication of sex or age, poor quality, vertebral pathology and patient's age >30 years.

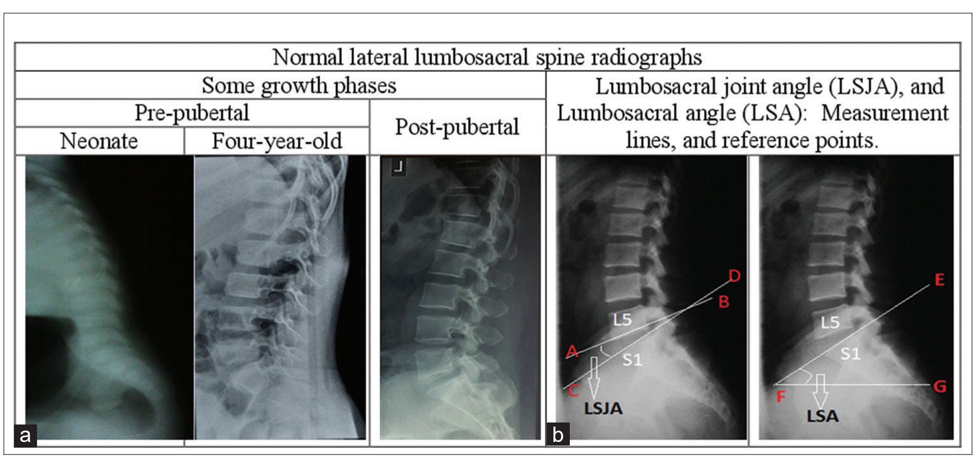

Figure 1: Normal lateral lumbosacral spine radiographs showing some growth phases (a), lumbar lordosis measurement lines and reference points (b)

Each radiograph was mounted on an illuminated viewing box and measurement lines are drawn (using appropriate reference points) with a 30 cm long transparent ruler and the LL angle (in degrees) was measured with a protractor. The LSJA was between a line through the inferior endplate of L5 (Line AB) and the second line through the superior endplate of S1 (Line CD) [Figure 1b],[15,25] while the LSA was between a line through the plane of the superior margin of S1 (Line EF) and a horizontal line (Line FG) [Figure 1b].[15,26] Measured radiographs were marked to avoid possible repeat measurement.

Data were analysed with IBM SPSS Statistics 23.0 (NY, USA) using the three growth surges (in years) of paediatric growth: Pre-growth (Birth–9), growth (10–15) and post-growth (16–20) spurts; the post-growth period was extended to 21–25 and 26–30 years groups to capture any possible extension of LL development beyond the 16–20 years period. The analyses include: (a) Descriptive statistics of mean ages, LSA and LSJA, and comparison of mean values with summary *t*-tests; (b) Comparison, in both LSJA and LSA groups, the mean LL angles across all age-groups, with *post hoc* tests using Fisher's least significant difference (LSD). The statistically significant *P* value was $P \leq 0.05$.

Results

Descriptive statistics of age, angular values of LL (LSA and LSJA) and Summary *t*-tests comparisons (in both LSJA and LSA groups) of mean ages and mean LL angles showed the following results. The age range of studied groups was 0.04–30 years, mean LSJA group (215) was 22.6 ± 6.8 years, and mean LSA group (238) was 22.3 ± 7.3 years; the 0.3 years mean difference was insignificant ($t = 0.451$; $P = 0.652$) [Table 1]. In the LSJA group, the male (110) mean age was 22.4 ± 7.0 years and 22.9 ± 6.8 years for the female (105); the gender mean difference of 0.5 years was insignificant ($t = -0.494$; $P = 0.622$). In the LSA group, the male (119) mean age was 22.0 ± 7.5 years and 22.6 ± 7.1 years for the female (119); the 0.6 year gender mean difference was also insignificant ($t = -0.635$; $P = 0.526$) [Table 1]. In angular values of LL, the male mean LSJA was 18.3 ± 5.9°, and 18.4 ± 5.6° for the female; the 0.1° mean difference was insignificant ($t = -0.199$; $P = 0.843$) [Table 1]. Furthermore, the male mean LSA was 42.3 ± 9.8°, and 44.3 ± 10.8° for the female; the 2.0° mean difference was statistically insignificant ($t = -1.480$; $P = 0.140$) [Table 1].

In each of the LSJA and LSA groups, the comparison of mean LL angles across all age groups with *post hoc* tests (using Fisher's LSD) showed the following. The mean LL angle (of both LSJA and LSA) progressively increased with age, plateaued (i.e., ceased) at 21–25 years age group [Table 2 and Figure 2], which in the LSJA group has mean of 23.4 ± 1.3 years, and 23.5 ± 1.3 years in the LSA group; the mean age difference of 0.1 year between both groups was insignificant ($t = -0.413$; $P = 0.680$) [Table 2]. Since both groups means have the same standard deviation of ± 1.3 years, the mean age-of-cessation of LL development for both groups were taken as 23.5 years.

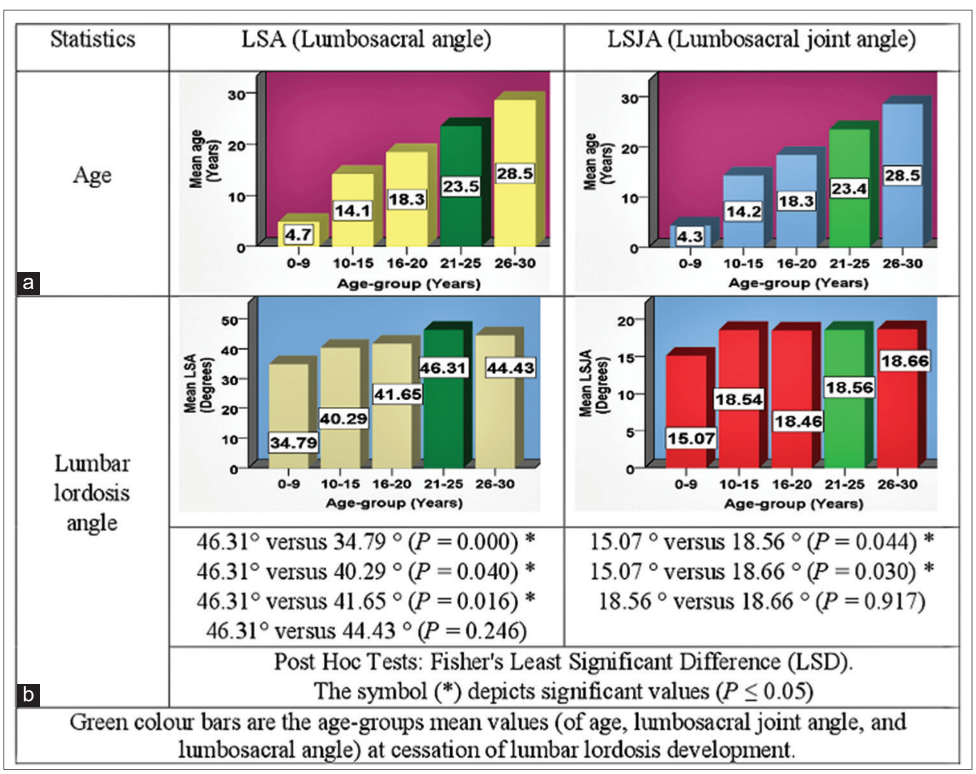

Figure 2: Bar graphs (three-dimensional) of mean values of age (a), and lumbar lordosis angles (b) across age groups

Table 1: Descriptive statistics of mean ages and lumbar lordosis angles (lumbosacral angle and lumbosacral joint angle)

Statistics	LSA			LSJA		
	Male	Female	Total	Male	Female	Total
Age						
Number of cases	119	119	238	110	105	215
Minimum (years)	0.04	0.08	0.04	2.0	0.08	0.08
Maximum (years)	30.0	30.0	30.0	30.0	30.0	30.0
Mean±SD (years)	22.0±7.5	22.6±7.1	22.3±7.3	22.4±7.0	22.9±6.8	22.6±6.8
Variance	55.8	49.8	52.7	48.3	45.7	46.9
Lumbar lordosis angle						
Number of cases	119	119	238	110	105	215
Minimum (°)	15.0	18.0	15.0	5.0	5.0	5.0
Maximum (°)	67.0	71.0	71.0	39.0	32.0	39.0
Mean±SD (°)	42.3±9.8	44.3±10.8	43.3±10.3	18.3±5.9	18.4±5.6	18.3±5.7
Variance	95.2	115.8	106.0	34.3	31.7	32.9

Comparison of mean values: Summary *t*-tests. Mean difference is significant at $P \leq 0.05$. Total age (years): LSA versus LSJA: 22.3 versus 22.6; t=0. 451; P=0.652. Gender age (years): LSA: Male versus female: 22.0 versus 22.6; t=−0.635; P=0.526. Gender age (years): LSJA: Male versus female: 22.4 versus 22.9; t=−0.494; P=0.622. Gender LSA (°): Male versus female: 42.3 versus 44.3; t=−1.480; P=0.140. Gender LSJA (°): Male versus female: 18.3 versus 18.4; t=−0.199; P=0.843. LSA: Lumbosacral angle, LSJA: Lumbosacral joint angle, SD: Standard deviation

Table 2: Lumbosacral joint angle and lumbosacral angle: Descriptive statistics and comparison of age groups' means differences

(a) *Post Hoc* tests

Variable	Number of cases	Age-groups' level	Age-groups' range (years)	Age-groups' mean age±SD, years	Age-groups' mean lumbar lordosis (°)	(a) *Post Hoc* tests: Fisher's LSD. Mean difference is significant at $P \leq 0.05$ Dependent variables: Age-group means LSJA and LSA Factor: Age-groups' level
LSJA	14	1	0-9	4.3±2.6	15.1	1 versus 2 (P=0.117)
	13	2	10-15	14.2±1.5	18.5	1 versus 3 (P=0.054)
	46	3	16-20	18.3±1.4	18.5	1 versus 4 (P=0.044)*
	54	4	21-25	23.4±1.3	18.6	1 versus 5 (P=0.030)*
	88	5	26-30	28.5±1.3	18.7	4 versus 5 (P=0.917)
	215		0-30	22.6±6.8	18.3	Other levels comparisons: P>0.05
LSA	21	1	0-9	4.7±2.9	34.8	1 versus 3 (P=0.009)*
	14	2	10-15	14.1±1.4	40.3	1 versus 4 (P=0.000)*
	46	3	16-20	18.3±1.4	41.7	1 versus 5 (P=0.000)*
	62	4	21-25	23.5±1.3	46.3	2 versus 4 (P=0.040)*
	95	5	26-30	28.5±1.3	44.4	3 versus 4 (P=0.016)*
	238		0-30	22.3±7.3	43.3	4 versus 5 (P=0.246) Other levels comparisons: P>0.05

(b) Summary data *t*-test of level 4 groups mean ages (years). LSJA (23.4) versus LSA (23.5): t=−0.413, P=0.680.

*Significant *P* values. LSJA: Lumbosacral joint angle, LSA: Lumbosacral angle, SD: Standard deviation, LSD: Least significant difference

Discussion

In both LSJA and LSA groups in this study, the most significant finding was that the mean lordotic angles across age-groups progressively increased with aging and plateaued at 21–25 years range (mean: 23.5 ± 1.3 years); the plateauing indicated cessation of LL development (spinal maturity) [Table 2 and Figure 2]. Spinal maturity is the maturation of the spinal bones. The LL development ceases at spinal maturity.[6,9,10]

This study has therefore quantified the age-of-cessation of LL development. It seems a credible and reliable spinal growth-maturity assessment parameter for the following reasons. It indirectly inferred spinal bone maturity[6,9,10] and occurred at a similar age in the two angular measures of LL (LSJA and LSA) used in this study. Furthermore, it is a clinical parameter but derived by radiography (using supine lateral lumbosacral radiographs, the gold standard of LL measurement.[12-14] Furthermore, its application (e.g. in managing PSD by spine clinicians) seems simple and less time-consuming, especially in busy out-patient clinics.

This study has therefore made a case for the use of age-of-cessation of LL development as an indirect spinal growth-maturity assessment parameter. The quantified age is also an addition of race-specific (African populations) value to literature; the currently-in-use literature values were based mainly on Caucasian populations.

This study's spinal maturity-age (range, 21–25 years; mean, 23.5 ± 1.3 years) was supported by some literature reports by Shefi *et al*.,[7] Chernukha *et al*.,[9] Cech and Martin,[10] and, Giglio and Volpon.[8] In Israel, Shefi *et al*., in a cross-sectional retrospective study on mid-sagittal reformatted images from 210 abdominal computed tomographic scans of children aged 2–20 years measured LL angle (with Cobb technique, L1–L5, among other three spinal parameters not relevant in this study) and reported progressive increment from 2 to 4 years age-group, to 17–20 years age group.[7] This progressive increment up to 20 years was similar to the current study's finding, but the 17–20 years range for the attainment of maximum LL angle was lower than the 21–25 years range observed in the current study, and this might be due to the fact that in the current study, individuals up to 30 years were studied. Perhaps, the results could have been the same if they had increased their study population age >20 years, to up to 30 years.

Chernukha *et al.* in a retrospective study in the United States of America, measured LL (using Cobb and TRALL methods) in 199 normal supine lateral lumbosacral radiographs of patients aged 1–30 years (mean, 14.8 years), and who were divided into five age groups (1–5, 6–10, 11–15, 16–20, and 21–30 years), and reported that both methods showed that LL development plateaued at 21–30 years (mean, 22.4 years).[9] This 22.4 years of a Caucasian population was just about 1 year earlier than the current study's mean age of 23.5 years of a black population. This suggests that spinal maturity occurs about 1 year earlier in Caucasians than in Black populations. Cech and Martin reported that skeletal maturity is attained when the epiphyseal plates close; this begins in childhood and is usually complete by 25 years of age.[10] Fusion of the vertebral arches occurs in the cervical spine in the 1st year of life and in the lumbar spine by 6 years; the vertebral arch and centrum fuses between 5 and 8 years of age. Secondary centres of ossification in the vertebrae do not unite until 25 years of age.[10] This report of Cech and Martin supports this study's spinal maturity age (range, 21–25 years; mean, 23.5 ± 1.3 years).

In Brazil, Giglio and Volpon used a pantograph (with a software and computer) to measure thoracic kyphosis (not studied in the current study) and LL in 718 normal children and adolescents (350 males and 368 females), aged 5–20 years, with no race selection. They reported linear LL increment from 5 to 20 years, with no significant gender differences.[8] These findings were similar to that of the current study in the effect on LL development, of both age and gender, up to 20 years of age. Perhaps, if they had increased their study populations' age >20 years, to up to 30 years, their 21–30 years results might also compare favourably to those of the current study.

This study's finding that LL development ceased at 21–25 years age group is contrary to the report by Oliver and Middleditch that spinal maturity is normally between 13 and 18 years.[6] The reason for this difference is unclear as they did not state how their reported age range was computed.

In both LSJA and LSA groups in this study, the other findings were the gender influence on age on the one hand, and on LL on the other. In each group, there was no significant gender difference either in the mean age, or in the mean LL angle [Table 1]; the latter suggests that sex had no significant effect on LL, and therefore insignificant effect on LL development. While the gender effect on LL results (for both LSJA and LSA) were supported by literature reports by Okpala,[15] Giglio and Volpon,[8] the LSA result was contrary to report by Bryan,[27] that females have higher LL value (LSJA was not studied by Bryan). However, the credibility of the present study's finding was heightened by the literature report that in comparison to LSA, the LSJA is a more reliable angular measure of LL.[15]

The possible limitations in this study were the retrospective approach (adopted to avoid the ethical issue of patients' irradiation) and supine position of the studied radiographs; a prospective approach with normal subjects in erect posture would have been ideal. However, in pre-pubertal (from birth to 9 years) children, erect position is impossible in babies and most infants that cannot stand, and most of the remaining children will not cooperate and will need restraining in a supine lateral position. Even if the restraining somehow affects the LL, the effect will most likely not be significant because LL development continues after birth[6-10] and ceases at spinal bone-maturity-age, which in this study was between 21 and 25 years; the main objective in this study was to quantify the age at which the development ceases. Thus, the supine radiographs adopted in this study addressed these concerns and enabled uniformity of posture across all age groups. Furthermore, it has been reported that: (a) LL is not significantly different in the recumbent and upright positions,[28,29] in healthy individuals, the tone of the spinal muscles was thought to be sufficient to prevent such an increase in the upright position;[9] (b) LL quantified by the retrospective method is not significantly different from that obtained by prospective method;[28] and (c) supine lateral lumbosacral film accurately measures LL and remains the gold standard.[12-14]

Conclusion

The mean age-of-cessation of LL development was 23.5 ± 1.3 years. Its application (as an assessment parameter of spinal maturity status) is simple and less time consuming, especially in busy out-patient clinics. Routine inclusion in growth-maturity assessment parameters is recommended. Furthermore, the quantified value is a race-specific addition to literature.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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