Cobb angle measurements on lateral lumbar radiographs obtained in the lateral recumbent position: A Ghanaian study

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Abstract

Background

Lumbar lordosis and its quantification are important for clinical consideration. The Cobb method is one of the important radiographic methods for estimating lumbar lordosis. Supine lateral lumbar radiographs remain the gold standard for accurate measurement of lumbar lordosis. This study aimed at measuring the average lumbar lordosis of Ghanaian patients using the Cobb method.

Methods

Using a goniometer, Cobb angle measurements were manually made on lumbar spine radiographs with no spinal deformities obtained from three study sites from April 2021 to June 2021. Subgroup analyses of lumbar lordotic angles (LLAs) were also conducted.

Results

The average LLAs obtained from the radiographs of the 118 patients were 27.18° (SD = 13.05°) for the L1-L5 and 43.56° (SD = 14.58°) for the L1-S1. The LLAs for females [L1-L5: 29.85° (SD = 11.59°), L1-S1: 47.076° (SD = 13.354°) were higher than males: L1-L5:24.32° (SD = 13.98°); L1-S1: 39.81° (SD = 15.05°). Younger patients had higher LLAs. There was a strong positive correlation between L1-S1 and L1-L5 values (*R* = 0.825) in the Ghanaian populace. The LLAs generally decreased with aging. Finally, LLAs are gender dimorphic among Ghanaians with higher values reported in females.

Conclusion

This study revealed the existence of an association between age and angle of lumbar lordosis and gender dimorphism in Ghanaian patients. Disc herniation occurs at higher levels of the spine as age increases and lumbar lordotic Cobb’s angle decreases. The LLA and age can therefore be assumed as predictors of the level of lumbar disc herniation.

Background

Lumbar lordosis is defined as the curvature assumed by the intact lumbar spine to compensate for the inclination of the sacrum, restore an upward orientation and consequently avoid forward inclination [1]. It is also the natural anterior convexity of the lumbar spine [2]. Lumbar lordotic curvature (LLC) is a unique structural characteristic of the normal human spine that is not apparent in the neonatal spine, but becomes progressively prominent as an individual develops and adopts an upright posture [3]. A deviation from normo-lordosis could mean a reduced lordotic curvature (hypolordosis) or an exaggerated lordotic curvature (hyperlordosis), with the former and/ or loss of kyphosis described also as flatback syndrome. The relationship between LLC and low back pain (LBP) has immense clinical significance because it serves as the basis of therapeutic exercises for treating and preventing low back pain [3].

The lumbar lordotic angle (LLA) associated with the LLC is found to increase with age and further correlates with intervertebral stress distribution. Disc herniation occurs at higher levels of the spine with high age and a low lordotic lumbar Cobb's angle. According to Porto & Okazaki [3], lumbar lordosis varies from 40° to 60°. The LLA is a clinical parameter whose value in a populace is significant. LLAs $\leq$ 40° indicate a rectification and those $\geq$ 60° implies hyperlordosis. Chun et al [4] found that patients with LBP had smaller LLAs than healthy controls. Imaging of the spine is very commonly done for LBP and the simplest modality is the plain x-ray of the lumbar spine. The anterior-posterior (AP) and lateral views of the lumbar spine on plain x-ray radiographs evaluate for lumbar alignment, vertebrae body and disk space size, bone space and architecture, and gross evaluation of soft tissue structures [5].

Cobb's method is one of the most common techniques for measuring spinal curvature using radiographs, and the most widespread method used for determining the degree of thoracic kyphosis and lumbar lordosis in the sagittal plane [6]. The Cobb angle is a standard measure of lumbar lordosis and is the angle between the sacral plate and the superior surface of the L1 vertebra [7]. Despite its significance, lumbar lordosis measurements among Ghanaian patients is extremely sparse as anecdotal evidence indicates no recent literature. This study was conducted to measure the average LLA of Ghanaian patients using the Cobb method and compare results with similar measurements obtained internationally.

Methods

Ethical approval and permission to conduct the study were respectively provided by the Ethics and Protocols Committee of the University of Ghana School of Biomedical and Allied Health Sciences (UG-SBAHS) (Number: SBAHS/AA/RAD/10673329/2020-2021) and the Radiology Department of the Korle Bu Teaching Hospital in Accra, Ghana. Patients' identities, anonymity of information and confidentiality were ensured.

Subjects

Due to radiation protection principles and ethical considerations on irradiating healthy subjects, a retrospective study approach using a non-probability, quota sampling method was adopted for this study, and was conducted at a teaching hospital (TH), polyclinic (PC) and a private imaging centre (PIC). The population consisted of 118 paediatric and adult lateral lumbar radiographs of Ghanaian patients (12 years and above) who reported to the study sites for lumbar examinations from April 2021 to June 2021. The patient characteristics (Table 1) and radiographic imaging data were retrospectively retrieved from completed radiology request forms.

There were more female (51.7%) lumbar radiographs than males (48.3%). The ages of the patients were categorized as adolescent (10–19 years), young adulthood (20– 39 years), middle adulthood (40–55 years) and late adulthood (56-70 years). Most of the radiographs represented young adult patients (40.7%). Adolescent patients (10 – 19 years) were least presented (5.9%). The mean of the population was (41.6 ± 15.1 years (range: 12 to 68 years). The mean ages of the male and female patients were 42.3 ±13.8, and 40.9 ± 16.4 respectively.

Radiographic Measurements

According to Moh et al [2], full lumbar lordosis development is attained at spinal maturity which occurs within adolescent age. In this study, lumbosacral radiographs in the recumbent posture/positioning using standard radiographic imaging technique for patient positioning and exposure are obtained at the study sites. However, some cases like scoliosis series are always obtained in the erect position. Hence, lateral lumbar radiographs of Ghanaian patients (12 years or older) obtained in the recumbent position with good image quality and no positioning error such as spine rotation, and with no associated vertebral pathologies were included in the study. Concerns have been raised about patient position on the account of lumbar lordosis [8]. For this reason, lumbar radiographs obtained in the upright position with metal artifacts or obvious pathologies such as spondylosis, spondylolisthesis, vertebral fractures and spinal tumours, as well as those with scoliosis or kyphosis reported a high Cobb angles for lumbar lordosis, and high interobserver differences existing mainly for measurements involving patients with kyphosis were excluded. Lumbar radiographs of non-Ghanaians were also excluded.

Using the Cobb method, (L1–L5) and (L1–S1) LLAs to the nearest degree were measured from lateral lumbar radiographs. Lines were drawn tangential to the superior endplate of L1, the inferior endplate of L5 and superior endplate of S1 on the radiographic films by means of goniometers and other line drawing instruments. Perpendicular lines were then drawn to each of these endplate lines, and the resulting acute angle formed by the intersection of the perpendiculars from L1 and L5, and the acute angle formed from the perpendiculars of L1 and S1 were recorded as the L1-L5 and L1-S1 LLAs respectively (Fig. 1). No perpendicular lines were required in radiographs with sufficient space around the lumber vertebrae where endplates lines met directly.

Results

Lumbar Lordotic Angles

The distribution of the L1-L5 and L1-S1 lordotic angles are shown in Fig. 2 (a/b), while the influence of patient demographics on the LLAs are summarized in Table 2. The data was bimodal occuring at 54^0 and the other at 58^0. The mean lordotic angles for the L1-L5 and L1-S1 angles were $27.18^o \pm 13.05^o$ and $43.56^o \pm 14.58^o$ respectively. The L1-S1 angle was consistently greater than the L1-L5 angle for each individual. The Cobb-measured lordotic angles ranged from 3^o to 66^o for L1-L5, and 15^o to 77^o for L1-S1, indicating large variability of LLAs among the Ghanaian patients. The highest mean (SD) LLAs for the L1-L5 and L1-S1 were $32.57^o \pm 7.21^o$ and were 49.29^o (10.69^o) respectively, and found in the adolescent patients. Statistically, the average LLA decreased with age, and hence, the lowest mean (SD) L1-L5 [(22.35º (11.97º)] and L1-S1 [39.65 ± 12.97)] angles were recorded among the late adulthood patients.

It has been reported that the LLA measured by the Cobb method does not differ significantly between males ($28.39\circ \pm 0.47\circ$) and females ($28.59\circ \pm 0.43\circ$) ($R = 0.01$, $p > 0.05$) [9]. In this study, the LLAs for the L1-L5 and L1-S1 measurements were 24.32º (SD = 13.98º) and 39.81º (SD = 15.01º) respectively for the male patients. The Cobb-measured LLAs also decreased with age. Hence, the average LLA measurements were higher in the younger male group (L1-L5 = 27.74º; L1-S1 = 43.96º) than the older male group (L1-L5 = 22.00º; L1-S1 = 37.00º). Similalrly, the LLAs for the L1-L5 and L1-S1 measurements for the female patients were 29.85º (SD = 11.59º) and 47.07º (SD = 13.35º) respectively. In line with the decreasing variation of LLA with age, the younger female patients presented with higher average LLAs (L1-L5 = 32.84º; L1-S1 = 49.06º) than the older group (L1-L5 = 26.55º; L1-S1 = 44.86º).

Correlation And Regression Analyses

Pearson and Spearman's statistical analyses were done to determine the rank correlation coefficients between the parameters and measured variables (Fig. 3). In particular, the Pearson correlation coefficient (R = 0.861) indicated strong positive correlations between L1-L5 and L1-S1 LLAs.

This means that patients with high L1-L5 values had high L1-S1 values and vice versa. Using the lines of best fit in Fig. 3, the relationships can be expressed as

L1-L5 $= -6.4 + 0.77L1 - S1$ (1)

The Spearman's coefficient of determination R^2 = 0.742 represented 74.2% accuracy in predicting either LLAs.

Correlation Between Age And L1-l5, L1-s1 Lumbar Lordotic Angles

The linear regression model established a weak correlations between L1-L5, L1-S1 LLAs and age as indicated in the correlation plots (Figs. 4 and 5).

The negative Pearson and Spearman's correlation coefficients of R=-0.257 and R=-0.205 respectively indicate decreasing L1-L5 and L1-S1 LLAs with age as

L1-L5 = 36.37 -0.22y (3)

L1-S1 = 51.77 -0.22y (4)

where y is patient age.

Discussions

Patient Characteristics

A higher female (51.7%) to male (48.3%) gender ratio was found among the study population which mostly consisted of young and middle-aged adults (67.8%). Consistent with this study, Wang et al [10] reported a study population comprising 68.8% females and 31.2% males (age range: 11- 24 years; mean: 16 years) in a study to measure the scoliosis Cobb angle by end vertebra tilt method. In a Hungrarian study comparing angle values of patients with adolescent idiopathic scoliosis (AIS) determined by the ZEBRIS spine examination method with the angle values defined by the standard Cobb method on biplanar X-ray images, Takács et al [6] also reported a higher female (89.5%) to male (10.5%) gender ratio among the 19 children.

Lumbar Lordotic Angles

On a lateral lumbar radiograph, the Cobb angle is the angle between the perpendiculars from the superior endplate of the first lumbar vertebra (L1) and the superior endplate of the first sacral vertebra (S1). It is associated with the spinous process angle of the coronal plane and rotation of the apical vertebra, and hence measured on the coronal or sagittal plane of imaging. The average L1-L5 and L1-S1 LLAs of 27.18^o (SD=13.05^o) and 43.56^o (SD=14.58^o) are similar to other findings reported in the literature. In particular, Benditz et al [11] reported that the L1-S1 angle for lumbar lordosis on radiographs obtained in erect position was 44.99° (range: 29° to 59°), and 47.91° (range: 36° to 78°) on supine MRI images. Using the ZEBRIS spinal examination method, Takács et al [6] obtained a sagittal LLA of 43.0^o (SD= 9.0^0).

It has been suggested that degenerative changes as well as disc herniation start at the lower lumbar segments with aging [9]. Furthermore, it is obvious that with aging, the loss of trunk muscles balance, along with an increase in LLA (decrease in lordosis), would lead to an increase in intervertebral disc stresses with an eventual change in pressure points along the lumbar spine. Furthermore, this study found that the LLAs, particularly to the L1-S1 angle measured among the adolescent group consisting of 7 individuals (mean age: 16.29±2.43 years) was 49.29^o (SD=10.69^o) and comparable to other findings reported in the literature. In particular, in a study conducted to assess the effect of corrective exercises on lumbar lordosis using the spinal mouse method on 40 male students (mean age: 17.24 ± 2.84 years), Yazici & Mohammadi [1] measured LLAs of 48.23^o (SD=1.74^o) (pre-test) and 43.56^o (SD= 0.97^o) (post-test) in the experimental group and 48.51^o (SD=2.18^o) (pre-test) and 49.63^o (SD=1.85^o) (post-test) in the control group. Ko et al [12] also reported pre-intervention and post-intervention LLAs of 40.0^o (SD=2.4^o) and 40.1^o (SD=2.4^o) among a control group in a study to assess the effect of lumbar stabilization exercise and sling exercise on LLA and other parameters on patients with chronic back pain.

The findings of this study are also in agreement with the results of other studies which measuring LLAs using the Cobb method. In particular, this study found the measured L1-S1 lordotic angle for young adults (20 to 39 years) as 46.58^o (SD=14.54^o), while Takács et al [6] and Castillo et al [13] measured similar sagittal lumbar Cobb angles of 47.3° (SD=16.8^0) in children (8-16 years), and of 49.4° (SD=9.5°) among a cohort of young adults (age range: 18 to 35 years). Skaf et al [9] also found that LLA was significantly correlated with age (R= 0.341, p < 0.0001) and showed a tendency to decrease from the third decade onwards, to become relatively constant after the sixth decade. Lee [14] also reported similar findings.

It has been previously hypothesized that an imbalance of the trunk muscle can increase the LLC of the lumbar spine due to weakness of abdominal muscles, along with aging [15]. Per this study's finding, the observed decrease in the Cobb-measured LLAs with age parallels an increase in lumbar lordosis. Moreover, with aging, the loss of trunk muscles balance with associated decrease in lordosis, and consequent increases in LLA results in increased intervertebral disc stresses with subsequent changes in pressure points along the lumbar spine, inducing upward motion. In general, symmetrical facets distribute a given load evenly and bilaterally. In asymmetrical facet joints, the loading force is unevenly distributed and shifted to the side of the facet joint. Subsequently, the induced eccentric stress affects the disc, resulting in disc degeneration or herniation moving cranially with age, according to Karacan [16]. Contrary to the findings of this study, higher LLAs have been reported in other studies. Sparrey et al [7] found an angle 51° (SD=11°) as lordotic angles of modern humans compared to 60.9° (SD=12.0°) (range: 31° to 88°) reported in a much older study after analyzing lumbar lordosis angles of 100 asymptomatic adult volunteers [17]. The range of LLA is however, agreeable with the findings of this study.

Lumbar Lordotic Angles and Gender Dimorphism

This study established that LLAs and the lumbar spine are gender dimorphic with increased lumbar lordosis in adult females than males. In line with this finding, Bailey et al [18] reported higher LLAs in females and stated that the lumbar spine is sexually dimorphic with increased lumbar lordosis in adult females than males. A probable reason for this could be explained by the fact that pregnancy is associated with increased lumbar lordosis in women. From the viewpoint of biomechanics, variations in the load distribution in the lumbar spine could also account for this. Matsumoto et al [19] and Sparrey et al [7] reiterated similar observations and same reasons for the gender dimorphism associated with LLAs. According to Porto & Okazaki [4], there is no evidence that effectively proves the association of LLA with gender and age.

However, other studies found no evidence of gender-based differences in the LLAs. In a review, De Carvalho et al [20] also demonstrated that even though gender differences were assessed, existing tests showed controversy in the literature regarding differences in the association or relationship between LLAs and gender. In particular, whereas some studies have shown no difference in lumbar lordosis, others have found larger angles in females and few found larger angles in males [18].

Conclusion

Using the Cobb technique, the L1-L5 and L1-S1 LLAs for Ghanain patients who presented for lumbar examinations have been measured on the lateral lumbosacral radiographs in the recumbent posture/positioning using standard radiographic imaging technique for patient positioning and exposure. The L1-S1 LLAs are averagely greater than the L1-L5 angles. Pearson and Spearman's rank correlation coefficients indicated strong positive correlations between L1-L5 and L1-S1 LLAs, and weak negative correlations with age. This study demonstrated an association between age and lumbar lordosis. Specifically, this current study found that lumbar lordosis and lordotic curvature decreased with age. The LLA is gender dimorphic and higher among females.

Declarations

Consent for publication

All the authors have consented for the publication of this research study.

Competing interests

The authors declare no competing interest

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The research study was self-funded.

Authors' contributions

SAS, DSS and EMA designed the research study

SAS, DSS, EMA, JNO, VH and FA supervised the study

SAS, EMA, DSS wrote the main manuscript

EMA, SAS and DSS prepared the figures and Tables

JNO, VH and HG reviewed the data and measurements

All authors reviewed the manuscript

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Tables

Table 1
Patient characteristics of patients

Gender and Study sites				
Gender	TH	PC	PIC	Total [*N*, (%)]
Male	37	15	5	57 (48.3)
Female	44	13	4	61 (51.7)
Total	81	28	9	118 (100.0)
Age (yrs) and Gender				
Range	Male	Female	Total *N* (%)	Average
10–19	2	5	7 (5.9)	16.3 ± 2.4
20–39	21	27	48 (40.7)	29.5 ± 5.6
40–55	22	10	32 (27.1)	46.2 ± 5.1
56–70	12	19	31 (26.3)	61.3 ± 3.4
Total	57 (48.3)	61 (51.7)	118 (100.0)	
Mean	43.0 ± 5.0	41.6 ± 4.8	42.3 ± 3.5	
Key: TH = Teaching hospital, PC = Polyclinic, PIC = Private imaging centre				

Table 2
Lumbar Lordotic Angles and Demographics

Lumbar spine	**Mean ± SD (deg)**	**Mode**	**Median**	**Max. value**	**Min. value**	**Range**
L1–L5	27.18 ± 13.045	24	27.00	66	3	63
L1-S1	43.56 ± 14.577	54*	45.00	77	15	62
Age (years)		L1-S1 angle (º)	L1-L5 angle (º)	Patients *N* (%)		
Range	Mean ± SD	Mean ± SD	Mean ± SD	Male	Female	Total
10–19	16.3 ± 2.4	49.29 ± 10.69	32.57 ± 7.21	2 (1.7)	5 (4.3)	7 (5.9)
20–39	29.5 ± 5.6	46.58 ± 14.54	30.44 ± 12.77	21 (17.8)	27 (22.9)	48(40.7)
40–55	46.2 ± 5.1	41.56 ± 15.99	25.78 ± 14.07	22 (18.6)	10 (8.5)	32(27.1)
56–70	61.3 ± 3.4	39.65 ± 12.97	22.35 ± 11.97	12 (10.2)	19(16.1)	31(26.3)
All	41.6 ± 15.1	43.56 ± 14.58	27.18 ± 13.05	57 (48.3)	61(51.7)	118(100.0)
*Data: bimodal						

Figures

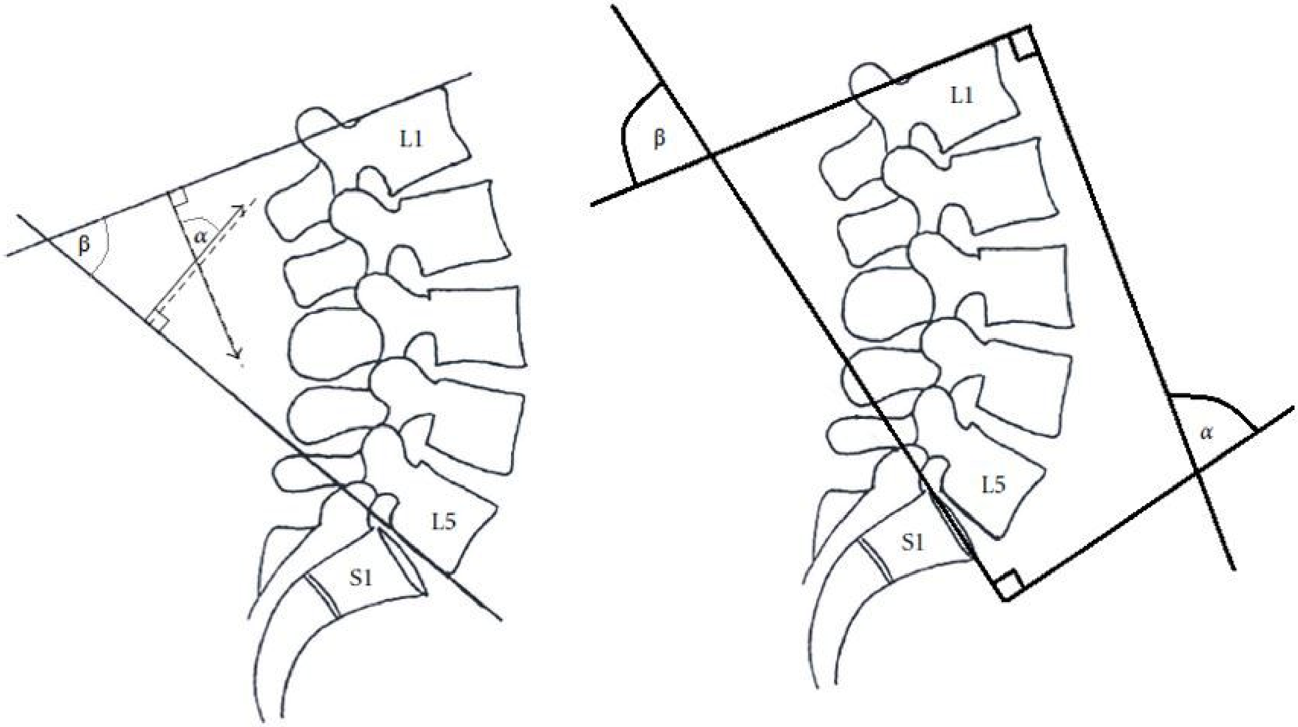

Figure 1

a and b: Measurement of the L1-L5 LLA and L1-S1 LLA

(**α**: using the perpendiculars; **β**: endplate lines are able to meet directly; **α** and **β** are equal).

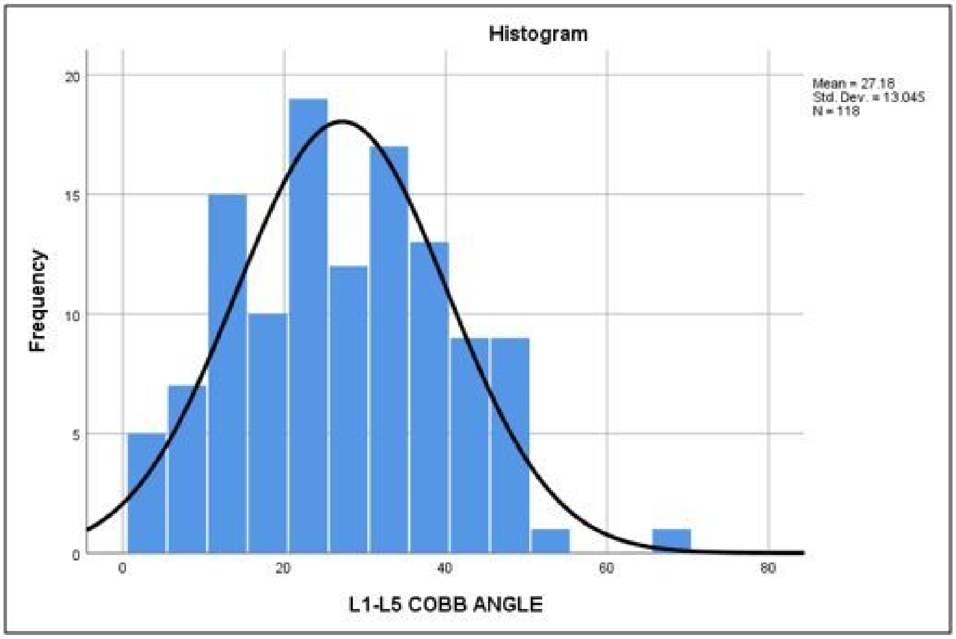

Figure 2a:

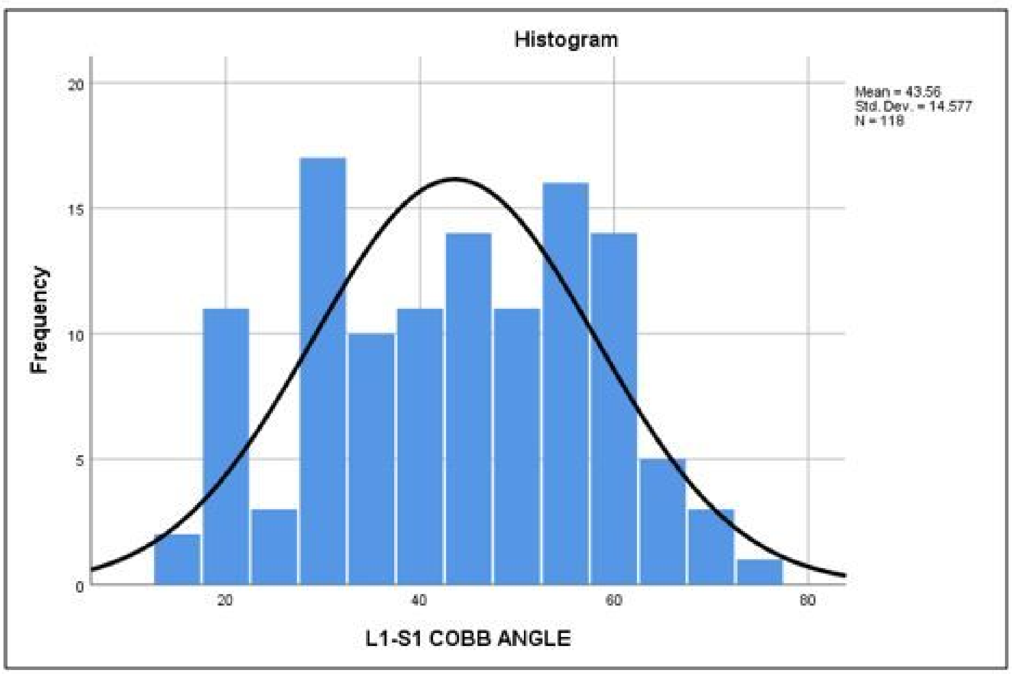

Figure 2b:

Figure 2

a: Distribution of lordotic angles for L1-L5

b: Distribution of lordotic angles for L1-S1

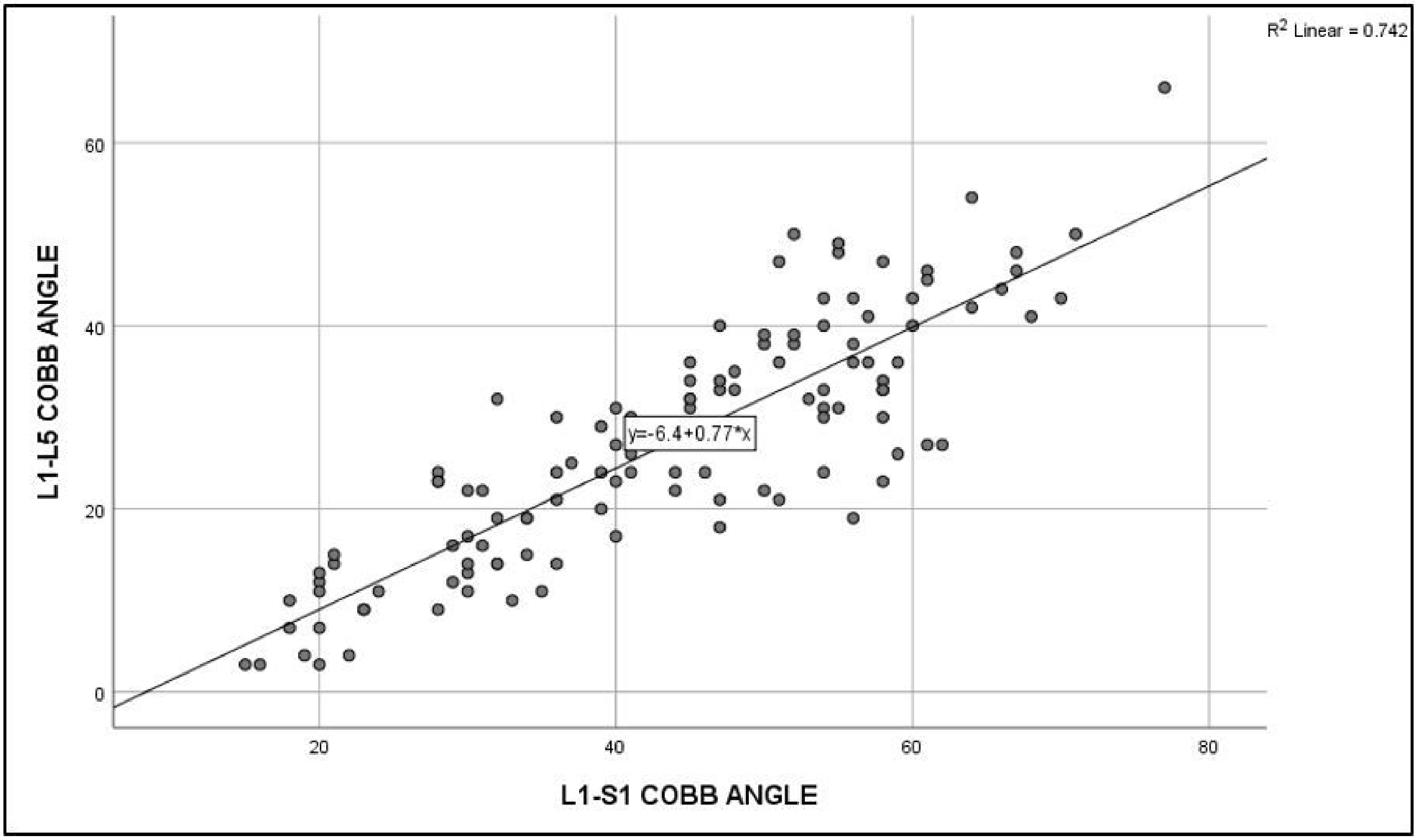

Figure 3

Correlation graph of L1-L5 LLA against L1-S1 LLA

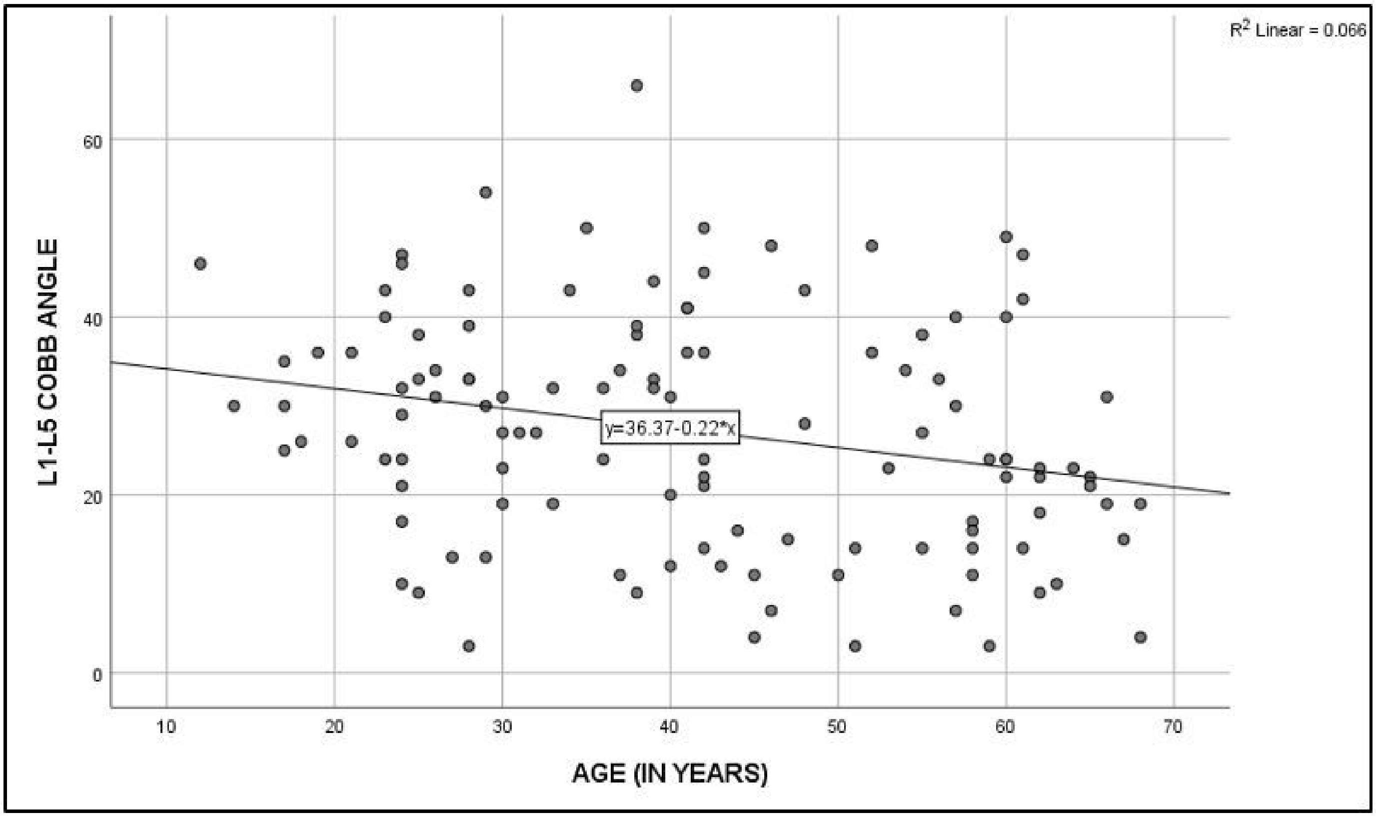

Figure 4

Correlation between L1-L5 LLA and age

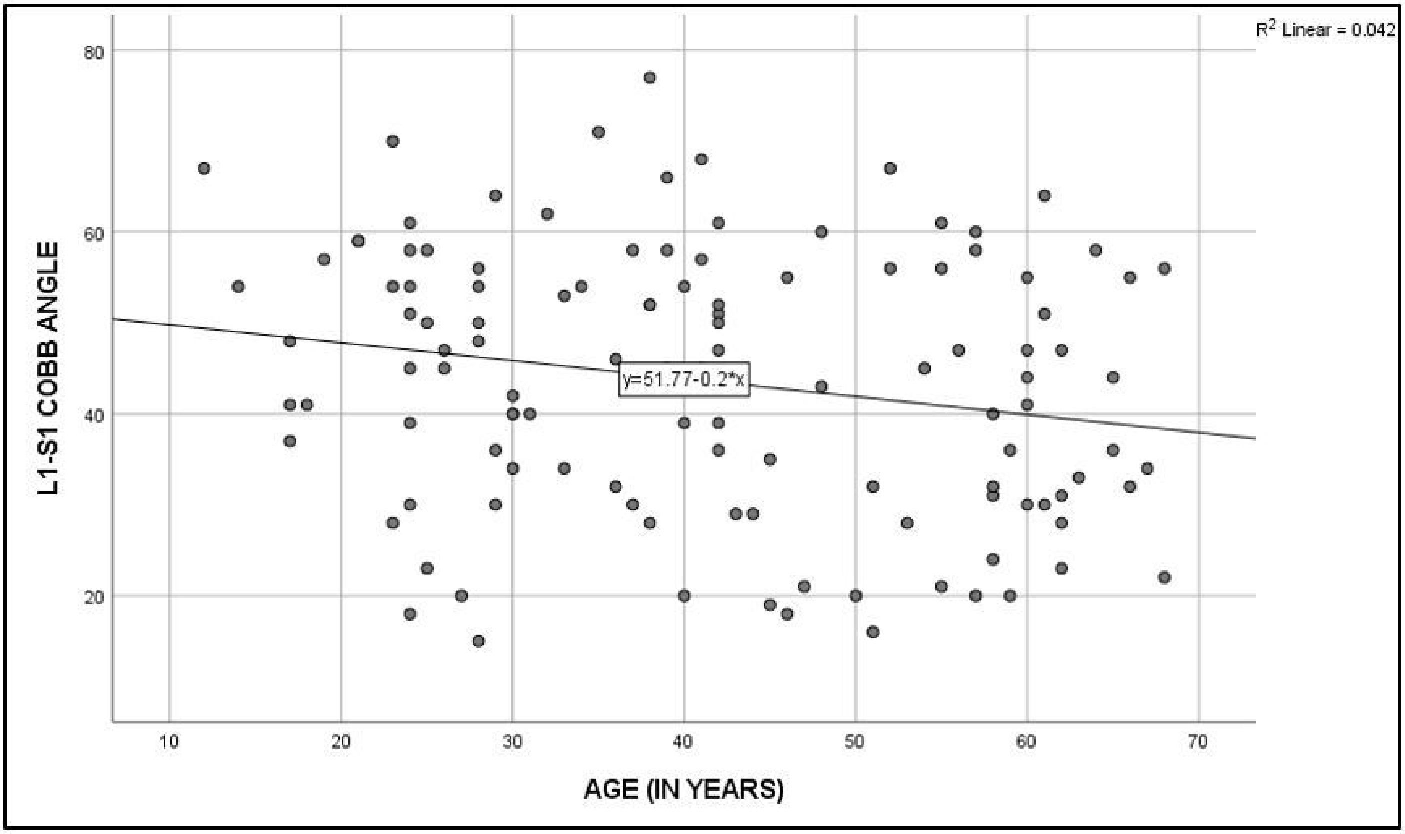

Figure 5

Correlation graph of L1-S1 LLA against age