Determination of the Lumbar Lordotic and Lumbosacral Angles in Normal Adults Ghanaian Population Using Radiologic Imaging Technique

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Abstract

Changes in posture is among the risk factors of low back pain. The shape of the lumbar spine is influenced in a way by a strain on tendons and muscles because of abnormal posture. Little is known about what the nominal value of key radiologic angles for the Ghanaian populace is and accordingly, what comprises hypo-/ hyper-lordosis. The Lumbar Lordotic Angle (LSA) and Lumbosacral Angle (LSA) are potential angles, for the examination of low back issues, in addition to treatment and diagnosis. The study was intended to measure LLA and LSA of this populace using the local data. A retrospective methodology was adopted to gather typical laterally prostrate lumbosacral radiographs of 140 subjects (15 years or more) in a recumbent position.

Results:

The normal LLA values varied between 20.9^0 to 68.0^0 with the mean (standard deviation) of 35.9 (9.82)° and there exist a significant difference with sex but insignificant variations among the age categories comparable to a number of the literature values. The normal LSA values varied between 15.0^0 and 51.0^0 with the mean (standard deviation) of 34.3 (7.45) ° and there was no significant variation with sex and among the age categories.

Conclusion:

Furthermore, it has been established that the measured values at which to consider hypolordosis (below LLA=17.9°; LSA=12.0^0), and hyper-lordosis (above LLA=72.0°; LSA=55.0^0) in the Ghana population. This study have also established that in all the various age groups between 15 and 80 years, there exist no significant difference in the mean LLA and LSA among the groups, and this affirms that the development of lumbar lordosis reaches a plateau when spine is fully developed. Furthermore, female LSA and LLA shows higher measured values compared to their male counterpart in the Ghanaian population which confirmed other study values in literature. Finally, a reference chart of LSA and LLA has also been developed for clinical application in Ghana.

Key words: Lumbar Lordosis, Lumbosacral, radiographs, retrospective, lateral, diagnosis

Background

Estimations of the angles of curvature of human body are applicable of describing a low back pain, which are significant medical problems because of the diagnosis and therapy challenges. Ongoing research recommends that notwithstanding the morphology of the bend of lumbar spine which is a helpful measure for the conclusion of low back (waist) torment, there might be a hereditary component. Numerous examinations have assessed the connection between varieties in the angle of the lumbar spine and back pain (1). In the light of these recommendations, there has been various methodologies and strategies to gauge and measure Lumbar lordosis that prompts lower back pain. These methodologies are comprehensively sorted into conventional radiographic and non-radiographic techniques. Examples of Non radiographic strategies include the following, adaptable rulers, spinal mouse, inclinometer spinal pantograph, and magnetic resonance imaging etc (2). The spinal mouse and adaptable ruler approaches are tedious and can hence not be effortlessly utilized where there is the requirement for snappy feedback response. Then again, the disadvantages of the radiographic strategy incorporate irradiation, generally significant expense of assessment, restricted equipment space and time to acquire and peruse the image. Despite these downsides of the radiographic method, it remains the highest quality level which allows precise measurement of the Lordotic angle in a lateral spine radiograph (3). The radiographic technique is one such modality and a prostrate lateral lumbosacral spine radiograph precisely measures Lumbar lordosis that agitates lower back pain. Among the clinically significant radiographic angles for the assessment of Lumbar lordosis, research uncovers that the Lumbar

Lordotic Angle (L.L.A) and Lumbosacral Angle (L.S.A) are critical in the physical life of the individual's life (4, 5, 6, 7). Lumbar Lordotic Angle (L.L.A) is for the most part and generally determined by the Cobbs Method or procedure where lines are drawn along the superior end plates of the lumbar vertebrae to reach out past the vertebral body. Perpendiculars are then added on the side of convergence of the two lines, and the point of the convergence of these perpendiculars is estimated, forming Cobb's angle, which subsequently has given a worldwide assessment of lumbar lordosis (8, 9). Lumbosacral Angle (L.S.A) is measured using the Ferguson's technique.

Lamentably, there is next to zero data about what the typical estimations of these radiologic angles for the Ghanaian populace is. This study is consequently pointed toward quantifying the normal values of the Lumbar Lordotic Angle (L.L.A) and Lumbosacral Angle (L.S.A) of the Ghanaian populace using five referral health facilities Government Hospital as contextual analysis.

Aim

The aim of this study is to quantify the Lumbar Lordotic Angle (LLA) and Lumbosacral Angle (LSA) and to classify the quantified values as constitutes hypo/hyper lordosis, for Ghanaian population.

Scope

This is a retrospective study to measure both Lumbar Lordotic and Lumbosacral angles in intact lateral supine radiographs of 140 Adults (above 15 years) collected across the country. This study was also facilitated by an extensive literature review related to his study, data collection and analysis using readily available software, testing of hypothesis, evaluating relationships and finally interpretation of the results. Conclusion was drawn and deductions were made from the accumulated results which was an agreement or rejection of the hypothesis specifically null hypothesis.

Literature on the Methods of Measurement

Numerous techniques are utilized to assess the curvature of the lumbar spine. Notwithstanding, there are two normal techniques for assessment; this includes; physical clinical examination and diagnostic image assessment (10). Clinical examinations assess the extent of lordosis directly on the person's body. Diagnostic image assessment utilizes tomography, radiographs, and magnetic resonance imaging. Every strategy for assessment has its advantages and detriments, yet the serious issue is that it is hard to look at the estimations when performed by various approaches. Clinical techniques for assessing lordotic angles incorporate different posture examination systems and surface geography systems (11). A large portion of these strategies utilize the spinous processes of the lumbar vertebrae to assess the extent of lordosis. The fundamental bit of these estimations is the utilization of non-radiological techniques, this permit incessant assessment of the spinal bends or the lordosis angle. Even though clinical strategies have a good reproducibility, radiologic techniques are better with an interobserver accuracy of 87% (12, 13 14 15).

A couple of articles have proposed the utilization of laser and electronic technologies to estimate the lordotic angle. Using an adaptable plastic ruler and an AutoCAD for lordotic angle estimations, Letafatkar et al. demonstrated that these techniques are reliable technique, and suggested the use of these techniques as alternative to the radiography method in assessing lumbar lordosis. Celan et al (16). estimated the lordotic and kyphotic angles utilizing a laser triangulation strategy with accurate precision. Additionally, in spite of the fact that there are advanced 3D posture examination frameworks for displaying and measuring LLA, for example, Optotrak, Vicon Motion Systems, Motion Analysis and surface geography systems. Unfortunately, these systems are not open for most clinicians even though despite its numerous advantages in assess the lordotic angle in various stances and settings 916). Hence it is conclusive to suggest that using clinical strategies using radiologic method for assessing lordosis angles is still a better option to the many proposed techniques due to the unreliable results from most of these techniques.

Radiologic Measurement of Lumbar Lordosis (LL)

Different efforts have been made to quantify the Lumbar Lordosis measuring technique; nonetheless, as researchers have significantly shown that radiography is still a better technique, with a prostrate lateral lumbosacral spine radiograph to precisely measures LLA (17, 18, 19). Clinically there are a number of radiographic angular measuring technique that are available to be use to measure Lumbar Lordosis include lumbosacral angle (LSA), Lumbar Lordotic Angle (LLA)/Cobb point, Sacrohorizontal point and Sacral Inclination angle (SIA). However, the widely used and most accepted method and technique in measuring radiographic Lumbar Lordosis is the Cobb method and the Ferguson's angle technique (18, 19). These two accepted methods are used to estimate scoliosis using the LSA and LL angle among others, hence has been adopted in this study.

Materials

Materials used include the digital X-ray equipment and the MeVisLab DICOM application software for image analysis. The X-ray was used to acquire the images of the lumbar spine while the MeVisLab DICOM application software was used to view and measure the various angles.

X-ray Machine

Digital image data was retrieved from the PACS which were acquired by the x-ray machine with the following detailed specifications and features shown in figure 1 and Table 1.

Figure 1: X-Ray Machine (YSX200G)

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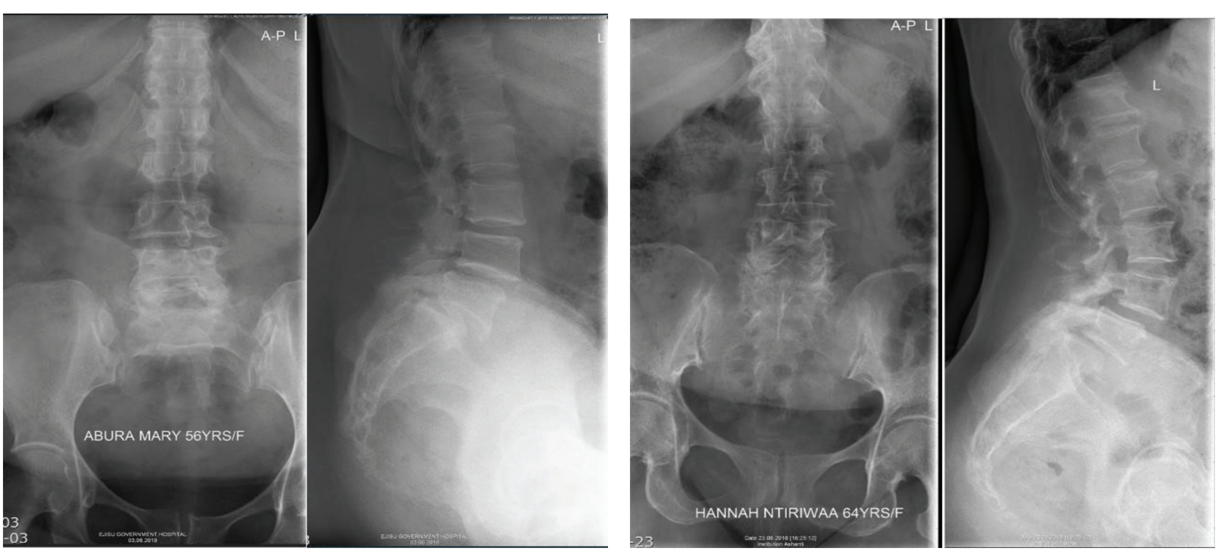
Table 1: Specification of X-ray Equipment

CONTENTS	**YSX200G**
Intermittent mode	100kV, 200mA, 20kW
Tube current	16mA~200mA
Output voltage	40-125KV step by 1kV
Exposure time	0.0025s~6.4s adjustable
Anode rotating speed	2800r/min
Anode heat capacity	140KHU
Focus	Small focus:1.0mm & Big focus:2.0mm
Focus distance	100cm

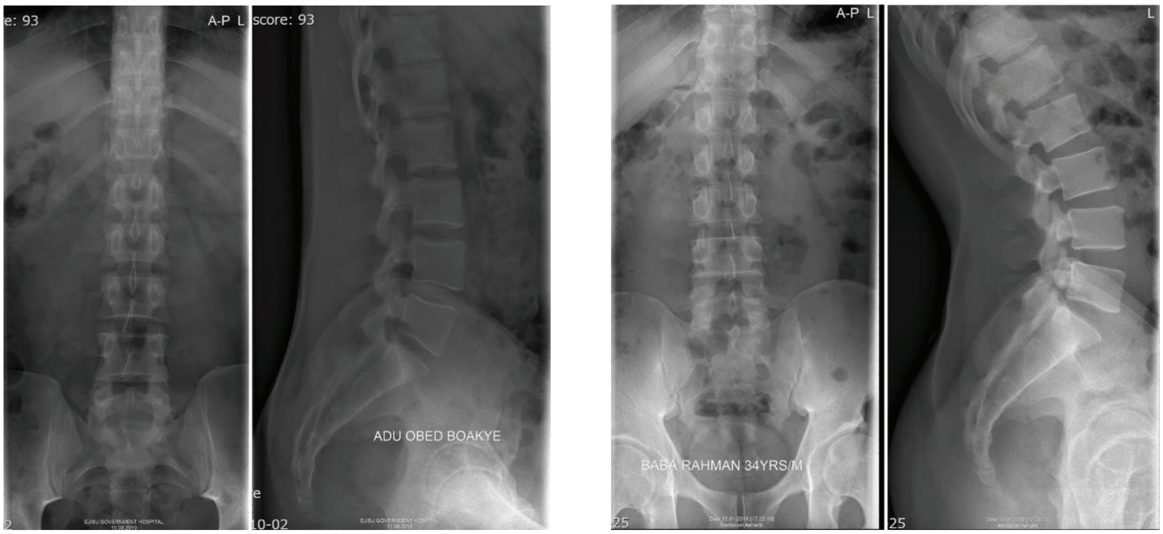
Normal and Abnormal Images

Normal radiographs as shown in Figure 2A, of the lumbar spine were used for the study. Radiographs that were judged by experience radiologist to be abnormal as shown in Figure 2B were excluded in the study. Below is the representation of normal and abnormal curvature of lumbar spine radiograph in a recumbent position for Female (Figure 2A and 2B) and Male (Figure 3A and 3B).



A **B**

Fig 2: Female normal curvature of spine (A) and abnormal curvature (B) of the lumbar spine



A B

Fig 3: Male normal curvature of spine (A) and abnormal curvature (B) of the lumbar spine

MeVisLab DICOM Application Software

MeVisLab is an application framework for medical image processing and scientific visualization. It includes advanced algorithms for image registration, segmentation and quantitative morphological and functional image analysis. There is also an integrated development environment (IDE) for graphical programming. MeVisLab is an integrated platform for medical image processing and visualization. It features a high quality volume renderer known as Giga voxel renderer that is based on OpenGL. The software supports rendering of large volume datasets based on an Octree algorithm, which takes the region of interest (ROI) into consideration. The software incorporates active contour model (Snake technique), which is a framework in computer vision for delineating outline of objects in a 2D image space. This advance application software was used in viewing and measuring LSA and LLA with 99.9% accuracy and precision.

Methodology

A retrospective study design approach was used for this study where the Lumbar Lordotic Angle (L.L.A) and Lumbosacral Angle (L.S.A) of healthy lumbar spine radiographs were measured. This was done, using radiograph which were taken in the recumbent position among 140 sampled patients' images with age and gender variation of adult patients.

The largely accepted Cobb's method, was used in this study which was done as follows:

A tangent line was drawn along the superior end of L1 and another one at the superior end of S1 vertebra.

Perpendiculars lines to each of the tangential lines were also drawn to form Lumbar Lordotic Angle (L.L.A) as shown in Figure 4A.

The Lumbosacral Angle (LSA) was obtained by drawing two lines, the first line across the upper border of the sacrum and the lower border of the L5 vertebra using the Ferguson's technique as shown in Figure 4B.

Figure 4: A) LLA Measurements B) LSA Measurement

Selection Criterion

The selection criterion includes normal radiographs of adults age 15 and above that include the following:

It must be declared as accepted radiography (2A and 3C) on a scale of 4 out of 5 by radiologist.

All the five lumbar sacral vertebras must be present in the radiograph

The age and gender variation must be clearly visible on the radiograph

There must be no expansion in vertebral range from L1 to L5.

Patients under 15 years old, or whose age as well as sex were not recorded were excluded

Low quality radiographs and radiographs indicating uncertainty or inherent anomaly were exempted.

Data Collection

Measurements of Lumbar Lordotic Angle (LLA) and Lumbosacral angle (LSA) were recorded from radiographs of normal patients. However, 25% of the data included radiographs of abnormal in nature who were diagnose of suffering from low back pain. This was to enable the difference between normal LLA and LSA to be established. The Lumbar Lordotic Angle was measured using Cobbs Method while the Lumbosacral Angle was measured using the Ferguson's technique.

Data Analysis

Data was analyzed using Minitab statistical tool. The analyzed data was represented in tables, charts and graphs. Both descriptive and inferential statistical analysis was performed on the data to quantify the normal value of the Lumbar Lordotic Angle (L.L.A) and Lumbosacral Angle (L.S.A) of the Ghanaian population and distinguished the normal measured values from the abnormal values. Statistical models tool were also used to establish how LSA, LLA and age variation were interrelated with reference to gender.

Ethical Consideration

Approval was obtained from the Ethical and Protocol Review Committee of the College of Basic and Applied Science, University of Ghana and the participating facility and the Department for the radiographs to be use for this study.

Declarations:Ethics approval

Approval was given for the research by the ethical and Protocol Review Committee of the College of Basic and Applied Science, University of Ghana, and the Participating Health Facilities. Additionally, the protocol and the application of same for this study was granted ethical clearance by the Committee. All participants were assured of confidentiality and anonymity throughout the study. The approval of the study was done in accordance with relevant guidelines and regulations of the Ethical and Protocol Review Committee of the College of Basic and Applied Science.

Consent to participate.

All the participants were adults of age 18 years or more. Each participant gave informed consent at study entry and offered the choice to exit from the study at any point during data collection without providing a reason for doing so.

Consent for publication

Not Applicable

Availability of data and materials

The data raw and comprehensive research materials to be use for the publication are all available upon request at any time.

Competing interests

Not Applicable

Funding

Not applicable

Authors' contributions

All the Authors were involved in Data collection and analysis during the study.

The following specific activities were done by the Authors.

Concept Note: Issahaku Shirazu and Eric Sackey

Pre-data collection activities including application for ethical clearance: Issahaku Shirazu, Elvis K Tiburu and Eric Sackey

Data collection and analysis: All Authors (Issahaku Shirazu, Eric Sackey, Elvis K. Tiburu, Ken Dapaa, Theophilus A. Sackey)

Drafting of Text: Issahaku Shirazu, Eric Sackey and Elvis K. Tiburu

Review of Text: Issahaku Shirazu, Eric Sackey, Elvis K. Tiburu, Theophilus A. Sackey

Statistical analysis: Issahaku Shirazu, and Isaac Dapaah

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Results and Discussion

Demographics

The figure 5 show a representation of the gender distribution of 140 radiographs that was analysed. Out of the sample population of 140, 71 patients were females representing 50.7% and 69 were males which represents 49.3 % of the total studied radiographs.

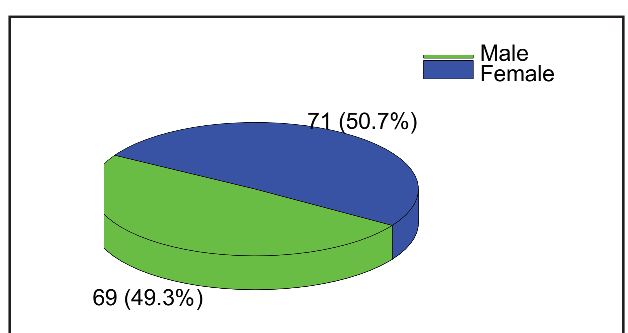

Figure 5: Gender Distributions from Radiographs

This study is a retrospective study where Lumbar Lordotic Angle (L.L.A) and Lumbosacral Angle (L.S.A) measured using the radiograph of the lumbar spine. Descriptive statistic analysis was use to compute the mean, range and standard deviation of the various parameters, in terms of sex, age, and the radiologic angles.

One Sample T-Test was conducted to ascertain the significant difference between the measured mean and other published data. The null hypothesis of this test was that there is no difference between the mean measured values and the published data. For a computed P-value greater than α- level (**0.05**) at **95%** confident interval, it implies that the null hypothesis was accepted that there is no significant difference in the mean values. For a computed P-value lesser than or equal to α- level (**0.05**) at **95%** confident interval, it also implies that the null hypothesis is rejected and the alternate hypothesis is accepted that, there is a significant difference between the mean values of interests.

Independent Sample T-Test was used to establish whether or not there is any significant difference in the mean value of a common variable among the male and female population of this study. The null hypothesis of this test is that there is no difference between the mean values of the two groups. For a computed P-value greater than α-level (**0.05**) at **95%** confident interval, it implies that we accept the null hypothesis that there is no significant difference in the mean values. For a computed P-value lesser than or equal to α-level (**0.05**) at **95%** confident interval, it also implies that we reject the null hypothesis and accept the alternate hypothesis that, there is a significant difference between the mean values.

Table 2: Descriptive Statistics

Variable	Mean	Minimum	Maximum	Std. Deviation
Age (years)	41.19	80	18	13.92
Lumbar Lordotic Angle (degrees)	35.9	20.9	68.0	9.82
Lumbosacral Angle (degrees)	34.3	15.0	51.0	7.45

Table 2 shows a summary of the descriptive statistics of the 140 radiographs. This were presented as the mean, the minimum, maximum values and the standard deviation. The average age was **(Mean=41)** with a standard deviation of **(SD=14).** The high SD means a broad range of the sample population with a minimum and maximum ages between 18 years and 80 years respectively and a mean age of 41±14 (27-55) years. Considering the measured values of the Lumbar Lordotic Angle (LLA), the computed average value was **(Mean= 35.9^0)** with a standard deviation of **(SD= 9.82).** The measured minimum and maximum angles were 20.9^0 and 93.0^0 respectively. Furthermore, the measured values of the Lumbosacral Angle, the computed average value was **(Mean= 34.3^0)** with a standard deviation of **(SD= 7.45).** The associated minimum and maximum angles were 15.0^0 and 68.0^0 respectively. This implied that the mean values of the LLA and LSA was **35.9^0 ± 9.82 (26.08-45.72)** and **34.3^0 ± 7.45 (26.85 – 41.75)** respectively.

Table 3: **Analysis of gender variation**

Radiologic Angle	Gender	sample	Mean	Std. Deviation
Lumbar Lordotic Angle	Female	71	37.5^0	11.32
	Male	69	34.3^0	7.73
Lumbosacral Angle	Female	71	35.1^0	8.31
	Male	69	33.4^0	6.40

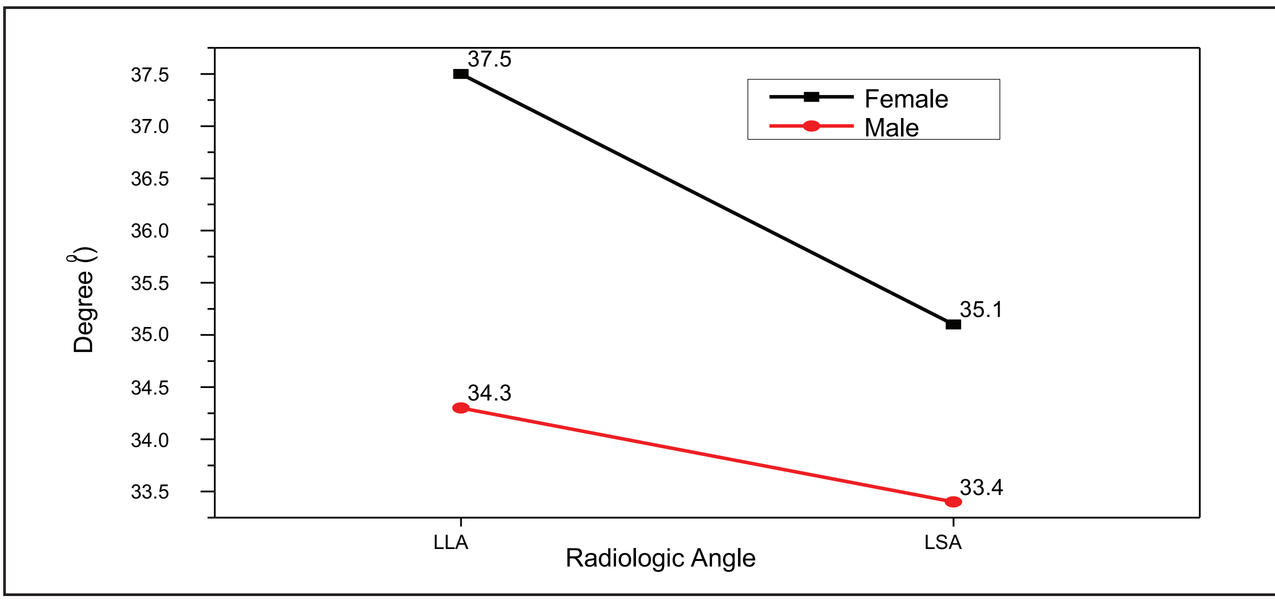

Figure 6: mean values of radiologic angles for Females and Males

The table 3 shows a summary of the group statistics of the radiologic angles with reference to the gender distribution. The general observation from figure 6 shows the average, LLA value **(37.5^0)** for females is comparatively higher than that of the males **(34.3^0).** Similarly, LSA values shows that females **(35.1^0)** is higher than the corresponding average value for males **(33.4^0).** These observations are similar to reported literature from other studies. In the Caucasians study, Bryan reported LSA changes in the range of 15° and 25° and that males have lower values than females. Okpala in his 2016 study using 279 subjects reported LSA values of 45.5^0 and 43.4^0 for females and males respectively. This trend was repeated in his study in 2018 using 200 subjects, where he reported LSA values of 45.2^0 and 43.1^0 for females and males respectively. In this study, the measured LLA values were 52.4^0 and 47.4^0 for females and males respectively. Following these observations in the difference in radiologic angles between females and males, an Independent Sample T-Test was conducted to validate whether the observed difference is statistically significant. The results of the analysis are shown in Table 4.

Table 4: T-Test for similarity of average values

Radiological Angle	t Value	Difference in mean values	Std. Error Difference	P-Value
Lumbar Lordotic Angle	1.95	3.21	1.64	**0.05**
Lumbosacral Angle	1.32	1.66	1.26	0.19

The outcome of the analysis as shown in Table 4 shows that there is a statistically significant difference between the female and male LLA measurements. This implies that the average LLA value measured for females in this study is significantly higher than that of males. This is based on the P-value which was equal to significance level of 0.05. This measured value is similar to the study conducted by Okpala which compared four radiologic angle. He mentioned that the gender difference was significant for the Cobb Angle which in this study is the Lumbar Lordotic Angle (LLA). This is contrary to the observation made for LLA measurements, where there is statistically insignificant difference between the female and male LSA measurements. As shown in the P-value which is greater than the significance level of 0.05.

Table 5: Comparative analysis of the current study with similar studies

Author, Year	Study Type (Posture)	Reported LSA	P-Value
Splithoff, 1953	Prospective	42.0^0	0.000
Hellems &Keats, 1971	Retrospective	41.1^0	0.000
Troyanovich et al. 1997	Retrospective	39.0^0	0.000
Maduforo et al., 2012	Retrospective	36.0^0	0.007
Okpala, 2014	Retrospective	44.5^0	0.000
Lin RM,1992	Prospective	33.2^0	0.001
Ella Been et al., 2007	Prospective	51.0^0	0.000
Okpala, 2016	Retrospective	35.6^0	0.711
Okpala, 2018	Retrospective	49.9^0	0.000

The normal value reported by a number of authors in Table 5 show great variation. Lin Rm recorded mean of LLA to be 33.2^0 ±12. 1^0 in a prospective study of 149 subjects. Ella Been *et al.* who also adopted a prospective approach in the assessment of lateral radiographs of the lumbar spine of 379 subjects, the reported mean LLA was 51.0^0 ±11.0. According to Okpala who conducted a retrospective measurement of lumbar lordosis in normal supine lateral lumbosacral spine radiographs of 27 children aged 0.04-14.00 years, he reported an average LLA of 35.6^0. In 2018, another retrospective study conducted by Okpala using 200 normal adult subjects, (100 males, 100 females) in recumbent position revealed that the mean (SD) LLA recorded as 49.9^0. In this current study, irrespective of gender, the measured mean LLA was 35.9^0 ±9.82. A One Sample T-test was further conducted to observe whether the measured value of LLA was distinct from similar studies as shown in Table 4, it was observed that there was a statistically significant difference between the measured mean LLA and most of the reported values in the other studies (thus, P-value < 0.05) with the exception of the outcome reported by Okpala in 2016 which showed no significant difference.

Multiple Comparison between groups (Age categories) of sample

Table 6 and Figure 7 gives a tabular and graphical distribution of the mean value of LLA with regards to the various categories. A total number of 70 subjects between 21-40 years, had the highest mean LLA of approximately 36.7^0 ±11. This was followed by 51 subjects between 41-60 years with mean LLA of approximately 35.7^0 ±9.12. Then 4 subjects who are less than 20 years had mean LLA of 34.5^0 ±8.35. Finally, 15 subjects who were older than 60 years had the least mean LLA of approximately 33.3^0 ±5.86.

Table **6**: **Lumbar Lordotic Angle**

Age	Mean	N	Std. Deviation
<20	34.5000	4	8.34666
21-40	36.6614	70	10.99757
41-60	35.7392	51	9.17946
> 60	33.3467	15	5.86404
Total	**35.9086**	**140**	**9.81717**

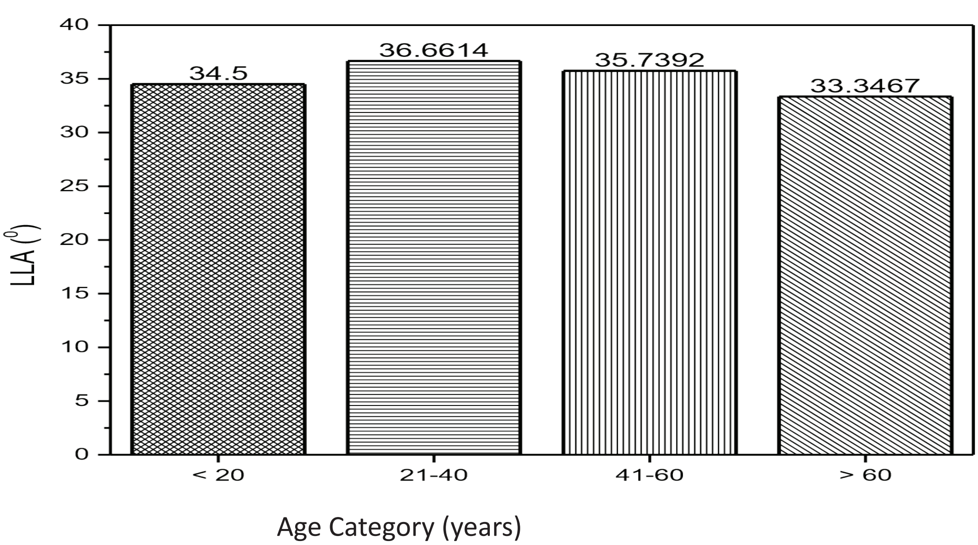

Figure 7: Lumbar Lordotic angle across various age categories

Table **7**: **Lumbosacral Angle**

Age category of patient	Mean	N	Std. Deviation
Below 20	37.0000	4	5.88784
21-40	34.4000	70	8.13716
41-60	34.1353	51	7.14663
Above 60	33.4067	15	5.67683
Total	34.2714	140	7.45283

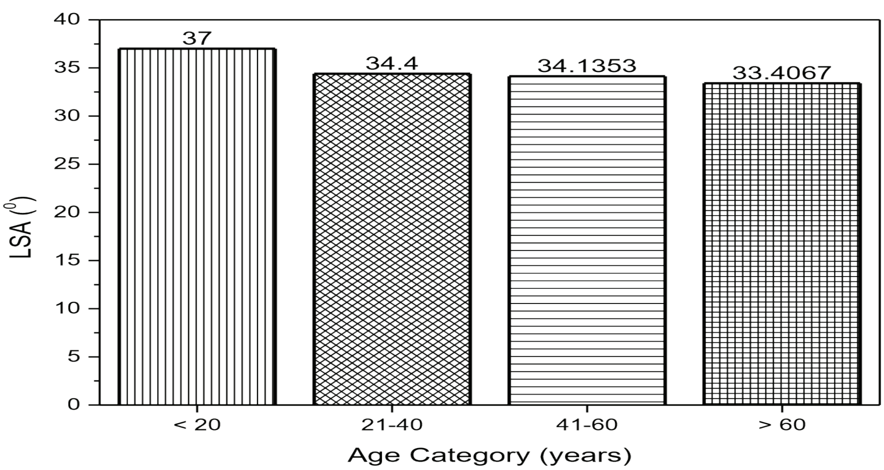

Figure 8: Lumbosacral angle across various age categories

Table 7 and Figure 8 represent a tabular and graphical distribution of the mean value of LSA with regards to the various age categories. A total number of 4 patients who are less than 20 years, had the highest mean LSA of 37.0^0 ±5.89. This was followed by 70 patients between 21-40 years with mean LSA of 34.4^0±8.14. Additionally, between 41-60 years had mean LSA of 34.1^0 ±7.15. Finally, 15 subjects who were older than 60 years had the least mean LSA of approximately 33.4^0 ±5.68.

Conclusion

The study concluded that, the normal range of LLA value is $20.9\text{-}68.0^0$ and LSA is 15-51° irrespective of gender or age variation. This mean value, obtained in a retrospective study was distinct as compared to a number of the literature values that were either obtained using retrospective or prospective approach. Furthermore, it has been established that the measured values at which to consider hypolordosis (below LLA=17.9°; LSA=12.0^0), and hyper-lordosis (above LLA=72.0°; LSA=55.0^0) in the Ghana population. This study have also established that in all the various age groups between 15 and 80 years, there exist no significant difference in the mean LLA and LSA among the groups, and this affirms that the development of lumbar lordosis reaches a plateau when spine is fully developed. Furthermore, female LSA and LLA shows higher measured values compared to their male counterpart in the Ghanaian population which confirmed other study values in literature. Finally, a reference chart of LSA and LLA has also been developed for clinical application in Ghana.

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