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Radiological measurements of lumbar vertebral body dimensions among adult population in Eastern Ethiopia: A cross-sectional study

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Abstract

Background: Lumbar vertebrae (LV) dimensions offer essential information with immense diagnostic benefits for clinicians. Lower back pain (LBP) is one of the most prevalent musculoskeletal disorders. From a surgical perspective, this is an important area for many medical conditions. However, surgical access to lumbar vertebrae (LV) and their surroundings is technically challenging. There is a scarcity of studies that have determined normal LV values in Ethiopia. Therefore, this study aimed to determine normal morphometric values of the LV in Ethiopia.

Methods and materials: A cross-sectional study was conducted to perform morphometric analysis of the LV in 300 adults from May 2017 to August 2018. Various lumbar structures, such as the anteroposterior and lateral views, were measured on X-ray films using a digital Vernier caliper. Data were analyzed using SPSS version 20, and the mean and standard deviation were calculated for each parameter.

Results: Three hundred Ethiopian adults participated in this study, 149 (49.7%) of whom were female. The mean age was (36.42 ± 12.78) years. The mean anterior heights of the LV from L1 to L5 were: (22.8± 2.4, 24.3 ± 2.5, 23.9 ± 2.3, 23.26 ± 2.18, 25.08 ± 2.137 mm) respectively with a gradual increase from L1 to L2, then L4 to L5. Whereas, the mean posterior heights from L1 to L5 were: (24.23 ± 2.32, 24.14 ± 2.22, 25.08 ± 2.49, 23.26 ± 2.18, 22.25 ± 1.90 mm), respectively.

Conclusion: The findings showed notable variations between males and females in terms of the measured parameters. The measurements obtained will serve as a baseline for adults in Ethiopia, and guide clinicians during evaluation and treatment of patients.

Keywords: Morphometric value; Body of lumbar vertebrae; Back pain

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1. Introduction

Morphometric values of the lumbar vertebrae (LV) are vital for diagnosing and treating different lower spinal or lumbar deformities [1]. Moreover, extensive knowledge of the lumbar vertebrae is necessary to analyze the size and proportions of the lumbar vertebrae, which helps healthcare professionals to accurately diagnose and treat lower back pain (LBP) [1, 2] . Measurements of LV also help to prevent postoperative and regional anesthesia-related complications [3, 4]. Normal anatomical parameters of the bone structures of the spine can be determined using X-rays. Owing to their high information content, radiographic surveys using X-rays of direct and lateral projections remain important diagnostic methods for determining vertebral dimensions because they are widely available, relatively inexpensive, and have a high spatial resolution [5, 6] .

Existing evidence on the dimensions of the lumbar vertebrae (LV) is currently incomplete and limited in terms of accuracy, study duration, study area and population, and measurement parameters. However, information on the precise or exact dimensions of the LV is essential for spinal implant design, lumbar decompression surgery, and workspace definition for robot-assisted surgery [7] Kunkel et al. established predictive equations for thoracic and LV morphometry [8] . Some spine studies have indicated a decrease in vertebral height with advancing age and menopause [9] .

Low back pain (LBP) is a common health problem and a major cause of disability that affects work performance and wellbeing. The socioeconomic impact of LBP is considerable in terms of work loss [1, 10]. LBP is the leading cause of work absence, activity limitation, and an enormous economic burden worldwide [10, 11]. Several studies in Europe have evaluated LBP. The overall prevalence of LBP was 44.6%, ranging from 33.4% to 67.7%, after accounting for sex, age, and socioeconomic status [12, 13]. In the United Kingdom (UK), LBP has been identified as a common cause of disability in adults, with more than 100 million work days lost annually [14]. The prevalence of LBP among Africans is a concern and is increasing, with a pooled prevalence of 47% [15, 16] Ethiopia was estimated at 54% [17].

A global review showed that the prevalence of LBP in the general adult population has increased over the last few decades, and the number of individuals with low back pain is likely to increase substantially [11] . Until recently, LBP was largely thought of as a problem confined to Western countries, but research conducted in the last decade clearly showed that LBP is also a major problem in developing countries.

Different studies have been conducted abroad by different researchers to determine the normal morphometric values of lumbar vertebrae; however, to our knowledge, no such study has been conducted in Ethiopia. Moreover, the LV morphometric values may vary according to race and sex.

Therefore, establishing normal morphological LV values is crucial in Ethiopia. Hence, the present study aimed to determine normal morphometric values of the lumbar vertebrae.

The findings of this study can be used as baseline data in future studies. Moreover, this information can provide useful information for the diagnosis, treatment, and prognosis while dealing with patients of LBP in the Ethiopian population. This information may be of forensic importance for Ethiopian adults. Research Question: (1). What are the normal morphometric values of lumbar vertebral dimensions in Ethiopians? (2). Do body dimensions of the lumbar vertebrae show significant differences according to sex and age?

2. Methods and materials

2.1 Study design and period

A cross-sectional study was conducted among randomly selected adults in Dire Dawa City between May 2017 and August 2018, using radiological data from the Sabian General Hospital in Dire Dawa. The study was in line with the STROCSS criteria updated in 2021 and registered with the unique (ID): researchregistry9217 [18].

2.3 Study setting

Dire Dawa is the second federal city, located 515 km east of the capital city of Addis Ababa, Ethiopia. According to the official websites of the Dire Dawa Administration (DDA) for 2022, a total of 521,000 administrations are subdivided into nine urban and 38 rural kebeles. The total area of the administration is 128,802 hectares, and the administration shares common boundaries with the Ethiopian Somali Regional States in the West, North, and East and with the Oromia Regional State in the South. Its altitude ranges from 960 m above sea level in the northeast to 2450 meters in the southwest.

2.4 Inclusion and exclusion criteria:

The inclusion criteria were as follows: no prior spinal surgery, no history of lower back pain, and no current pregnancy. The exclusion criteria were as follows: diagnosis of lumbosacral spinal pathology; clinical spinal abnormalities diagnosed via physical examination and/or radiography; and diagnosis of osteoporosis.

2.5 Sample size estimation

To estimate the sample size for this study, as there was no previous related research, a pilot study was carried out on 40 randomly chosen normal cases to determine the sample size for this investigation. Twenty patients who underwent radiological examination did not report back discomfort. Based on the results of pilot study, a 50% prevalence was regarded as the anticipated proportion. The sample size for the main study was calculated using Epi Info 7 programme. The

formula for determining sample size was n=3.84pq/d2 with an expected proportion of 50% and a permitted marginal error of 5% at a 95% confidence interval. By substituting these values (p=0.5, q=0.5, and d=0.05) into the formula, a sample size of 384 participants was obtained. The sample size was adjusted to include 300 adults. The initial idea was to include the pediatric age group starting from 10 years with an interval of 10 years for both males and females; however, we failed to include the pediatric age group.

2.5.1 Radiographic measurements

Data were collected using a carefully designed questionnaire. Three plain radiographic images of the lumbosacral spine were obtained for each participant.

a) An antero-posterior view of lumbo-vertebral region with upper end of femur

b) Lateral view of the lumbosacral region in the lateral recumbent position with hips and knees flexed at 45°. This position was considered preferable in studies on lumbar lordosis because the angle at which the knees and hips were flexed provided balanced relaxation of the thigh and knee, thus producing a more or less normal lumbar curve [19].

All radiographs' images were obtained such that the X–ray beam was centered on L3, with an anode film distance of 100 cm. The magnification obtained using this technique is negligible. Measurements were made directly on the X-ray films using digital vernier calipers and recorded to the nearest tenth of a millimeter [20,21] .

We used digital X-ray. The standard X-ray films were developed by radiology technicians and radiologists. Two radiographs' images were obtained for each participant: anteroposterior and lateral views of the lumbosacral spine. Therefore, 600 X-ray films were collected for morphometric analysis of anteroposterior and lateral films (**Error! Reference source not found.** and Figure).

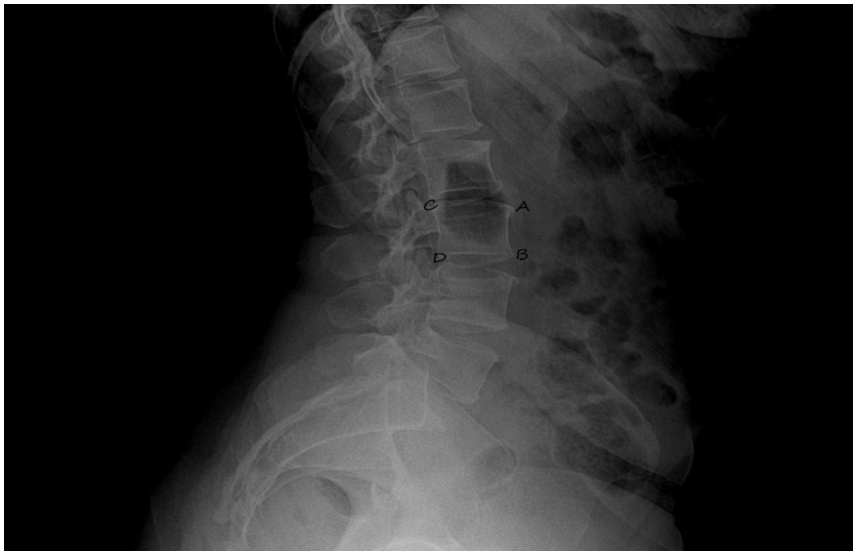

Figure 1: A 34-year female lateral imaging

The anterior height (AB) of the lumbar vertebral body was measured from distance A to B (**Error! Reference source not found.**).

The posterior height (CD) of the lumbar vertebral body was measured at distances C to D (**Error! Reference source not found.**).

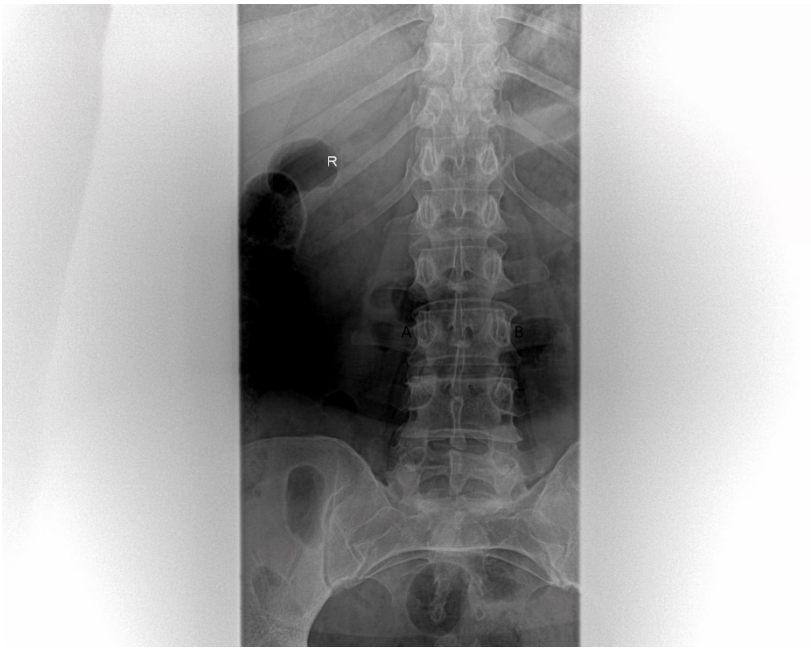

Figure 2: A 34-year female antero-posterior imaging

AB: Transverse distance of the lumbar body was measured from the outer edge of the right pedicle to the outer edge of the left pedicle (Figure).

2.6 Data collection process

Two experienced medical staff members (radiographers) who spoke the local language were recruited to interview and screen study participants. They screened individuals attending the outpatient department using a questionnaire that focused on the inclusion and exclusion criteria of the study. Two-day training sessions were given to assistants on the objectives of the study, data collection procedures, imaging, interviewing, consent procedure, and issues related to the confidentiality of the results.

2.7 Data quality control

A range of mechanisms were employed to ensure data quality. Two-days training was provided for the data collectors on the objective of the study and pre-analytical, analytical, and post-analytical procedures. A critical focus was given by a radiologist while reading the X-ray images. Any errors found during the pre-analytical, analytical, and post-analytical processes were immediately corrected. The principal investigators checked all the procedures during the data collection period.

2.8 Data analysis

The data collected from the questionnaire and the results of the radiological investigations were analyzed using SPSS version 20.0. Descriptive statistics: mean and standard deviation for continuous variables and frequency for categorical variables were used to compare the lumbar vertebral bodies at different spinal levels based on age and sex to determine differences in dimensions. Statistical significance level of $P < 0.05$ was used at 95% confidence interval.

3. Results

This study included 300 adults from study area. Of these, 149 (49.7%) were females. The age range was 20-67 year, with a mean ± standard deviation (SD) of 36.42 ± 12.78 year. The mean anterior height of the bodies of the lumbar vertebrae increased from L1 to L2, remained similar, and then increased from L4 to L5 (Table 1). The mean posterior height was similar between L1 and L2 and increased from L3 to L4, and then decreased from L2 to L5 (Table 2).

Table 1 Anterior height of body of lumbar vertebrae (mm)

	Anterior height		
Variables	Min.	Max.	Mean ± SD
L1	17	28	22.89 ± 2.491
L2	17	30	24.33 ± 2.567
L3	19	31	23.92 ± 2.301
L4	17	30	23.26 ± 2.186
L5	14	30	25.08 ± 2.137

Table 2 Posterior height of body of lumbar vertebrae (mm)

Varia	Posterior height		
	Minimum	Maximum	Mean ± SD
	18	33	24.23 ± 2.326
	18	32	24.14 ± 2.229
	20	31	25.08 ± 2.493
	17	30	23.26 ± 2.186
	16	27	22.25 ± 1.904

The mean transverse diameter of bodies of the lumbar vertebrae showed gradual increase from L1 to L5 (Table 3).

Table 3 Transverse distance of body of lumbar vertebrae (mm)

Variables	Transverse distance		
	Minimum	Maximum	Mean ± SD
L1	31	44	38.41 ± 3.401
L2	32	46	40.43 ± 3.116
L3	33	48	42.95 ± 3.382
L4	35	51	45.60 ± 3.456
L5	37	58	50.40 ± 4.182

The mean anterior height of the body of the lumbar vertebrae showed a gradual increase in females from L1 to L2 and remained constant from L2 to L4, with the highest recorded in L5. Males were more or less constant and showed an increase from L4 to L5, with a statistically significant difference between female and male anterior height of the lumbar vertebrae of L1, L2 and L3, but not at L4 and L5 (Table 4).

Table 4: Independent sample test for mean difference of anterior height of body of lumbar vertebrae by sex.

VARIABLES AH	**SEX**	**MEAN**	**STD. DEVIATION**	**INDEPENDENT SAMPLE TEST**	**P VALUE**	**95% CI**	
						Lower	Upp
L1	F	22.30	2.025	43.179	<0.0001	-1.739	-0.638
	M	23.48	2.759				
L2	F	23.72	2.512	.756	<0.0001	-1.777	-0.641
	M	24.93	2.485				
L3	F	23.50	2.495	7.930	0.002	-1.349	-0.319
	M	24.34	2.016				
L4	F	23.48	2.358	7.445	0.083	-.058	0.932
	M	23.05	1.984				
L5	F	24.81	2.384	9.141	0.025	-1.034	-0.070
	M	**25.36**	**1.827**				

Note: AH- Anterior height, CI- Confidence Interval

The mean posterior height of the body of the lumbar vertebrae of females showed remained similar from L1 to L2, and the highest recorded in L3 then gradually decreased. While males showed a slight increase from L1 to L3 and then decreased from L3 to L5. Statistically significant differences were observed between the posterior heights of lumbar vertebrae L1, L2 and L3, but not at L4 and L5 (Table 5).

Table 5**:** Independent sample test for mean difference of posterior height of body of lumbar vertebrae by sex

Variables	sex	Mean	Std. Deviatio	Independent sampl test	P-value	95% CI	
						Upper	Lower
	F	23.72	1.965	4.586	<0.0001	-1.527	-0.493
	M	24.74	2.542				
	F	23.42	2.408	9.535	<0.000	-1.907	-0.943
	M	24.85	1.780				
	F	24.58	2.654	14.415	<0.000	-1.555	-0.443
	M	25.58	2.222				
	F	23.28	2.371	50.201	0.002	0.257	1.181
	M	22.56	1.635				
	F	22.04	2.121	3.264	0.058	-0.848	0.014
	M	22.46	1.644				

Note: PH- Posterior height, CI**-** Confidence Interval

The mean transverse diameter of the lumbar vertebrae gradually increases from L1 to L5. This gradual increase was observed in both females and males, with a statistically significant difference between the transverse diameters of the lumbar vertebrae L1 to L5 in females and males (Table 6).

Table 6 **:** Independent sample test for mean difference of transverse diameter of body of lumbar vertebrae (mm) by sex.

VARIABLES T	**SEX**	**MEAN**	**STANDARD DEVIATION**	**INDEPENDENT SAMPLE TEST**	**P-VALUE**	**95% CI**	
						Lower	Upper
L1	F	36.49	2.489	8.501	<0.0001	-4.455	-3.174
	M	40.30	3.109				
L2	F	39.03	2.920	2.649	<0.0001	-3.422	-2.154
	M	41.81	2.657				
L3	F	41.62	3.496	6.817	<0.0001	-3.349	-1.932
	M	44.26	2.692				
L4	F	44.40	3.841	27.802	<0.0001	-3.124	-1.647
	M	46.78	2.532				
L5	F	49.44	4.429	3.746	<0.0001	-2.835	-0.981
	M	51.35	3.699				

Note: TD- Transverse distance, CI**-** Confidence Interval

The mean anterior height of the lumbar vertebrae (L1) of the different age groups increased from 20 to 49 years and then decreased after 50 years. In contrast, the mean anterior height of the lumbar bodies L2, L3, L4, and L5 increased from 20 to 39 years and then decreased after 40 years (

Table 7).

Table 7: The mean Anterior, posterior and transverse diameter of LV (mm) according to age group.

Body of lumbar vertebrae in (mm)				
L1	L2	L3	L4	L5

Age gro	N		AH	PH	TD	AH	PH	TD	AH	PH	TD	AH	PH	TD	AH	PH	TD
20-29	111	Mean	22.8	24.2	38.8	24.2	24.3	40.5	24.3	25.3	42.5	23.2	23.1	45.2	25.1	21.8	49.6
		SD	2.52	2.66	3.35	2.35	2.01	2.96	1.89	2.20	2.91	2.00	2.13	2.87	1.83	1.81	2.72
30-39	69	Mean	23.4	24.3	36.1	24.4	24.4	38.4	24.7	24.9	41.1	23.8	23.5	43.7	25.8	22.1	48.2
		SD	2.37	2.78	2.81	2.19	2.53	2.76	2.48	3.00	2.43	2.45	2.13	2.63	2.01	2.26	3.74
40-49	61	Mean	23.4	24.1	39.5	25.0	24.1	41.7	23.4	25.1	45.4	23.0	23.2	48.5	25.3	23.0	52.5
		SD	2.19	.907	3.41	2.62	2.07	2.03	2.77	2.52	2.69	2.25	1.93	2.05	1.47	1.14	3.64
>=50	59	Mean	21.8	24.1	39.0	23.4	23.2	41.1	22.7	24.6	43.1	22.8	21.4	45.3	23.8	22.3	52.0
		SD	2.52	2.09	2.90	3.05	2.22	3.64	1.63	2.29	4.23	2.00	1.12	4.44	2.80	2.03	5.64
Total	300	Mean	22.8	24.2	38.4	24.3	24.1	40.4	23.9	25.0	42.9	23.2	22.9	45.6	25.0	22.2	50.4
		SD	2.49	2.32	3.40	2.5	2.22	3.11	2.30	2.49	3.38	2.18	2.06	3.45	2.13	1.90	4.18

Note: N-Number of participants; AH, anterior height; PH, posterior height; TD- Transverse diameter.

4. Discussion

The finding of the present study revealed that the mean anterior heights of the bodies of the lumbar vertebrae from L1 to L5 were: (22.89 ± 2.49, 24.33 ± 2.56, 23.92 ± 2.30, 23.26 ± 2.18, 25.08 ± 2.137 mm), respectively. There was a gradual increase from L1 to L2 and then from L4 to L5. Whereas the mean posterior heights from L1 to L5 were: (24.23 ± 2.32, 24.14 ± 2.22, 25.08 ± 2.49, 23.26 ± 2.18, 22.25 ± 1.90 mm), respectively. A study conducted to analyze the size of lumbar vertebrae in Turkey by MRI imaging reported a larger transverse diameter of the bodies of lumbar vertebrae from L1 to L5 and recorded smaller values than the present finding for the anterior height of the bodies of the lumbar vertebrae [22]. In contrast to the current findings, our results showed a gradual cephalocaudal increase. This study also compared the results of the study conducted by Ablyazov [23] on Uzbekistani, which recorded results nearly equal to those of the present study for anterior and posterior vertebral body heights. In contrast to the current findings [23], our results show a gradual cephalocaudal increase.

In a comprehensive investigation of 240 adult human skeletons from the Cleveland Museum of Natural History, T1–L5 vertebral body dimensions were obtained; however, no age-related data were available [24]. Mavrych et al. established a comprehensive database of vertebral body dimensions generated from direct measurements of 1060 lumbar vertebrae (LV) [24]. These results are invaluable for establishing an anthropometric model of the human lumbar spine and for providing useful data for spinal surgery and spinal implant design. This finding has important implications for workspace specifications of robot-assisted surgical systems. Low back pain is the leading cause of activity limitation and enormous economic burden on individuals and families worldwide [25]. The frequency of low back pain increases with age, and its frequency in the adult population has been reported to vary between 60 and 90 % [26]. Hence, knowing the exact dimensions

of the lumbar vertebral bodies (LBV) is necessary for spinal surgery and for diagnosing LBP. The anatomical structure of vertebrae varies depending on the level of the spinal segment [23, 27].

The vertebral column is designed to absorb impact, reduce longitudinal stiffness, and intensify muscle function, which also contributes to abnormal changes in the curve [27]. Many studies have been conducted in many countries to determine the normal morphometric values of different anatomical parts of the lumbosacral spine. They revealed that the morphometric parameters of various anatomical structures differed according to the race [28]. The present study can help to evaluate the body of the lumbar vertebrae in healthy adults and provide guidance to surgeons and other health professionals.

5. Conclusion

This study revealed variations in body parameters of the lumbar vertebrae with respect to age and sexes. In addition, there are some variations in the Ethiopian population compared with other countries. This suggests that there are notable variations between sexes in terms of the measured parameters. The measurements obtained in this study will serve as a baseline for healthy adults in Ethiopia, and may provide guidance to clinicians for the evaluation and treatment of abnormalities related to the lumbar vertebrae. Further studies should be conducted in the general population as this study was confined to healthy adult subjects.

List of abbreviations:

AH, anterior height; PH, posterior height; TD, transverse diameter; LV, lumbar vertebra; LBP, low back pain; VBD, vertebral body diameter; VBH, vertebral body height.

Ethics approval

Ethical clearance was obtained from the Institutional Review Board of DDU (IRB) with Ref No. DDU/CMHS/330/10 on February 14,2018.

Informed consent

Verbal and written informed consent was obtained from the study participants.

Availability of data and materials

The data and materials used to analyze the study are available from the author (Y.T.) upon reasonable request. E-mail: yaredtkl@gmail.com

Competing interests

The authors declare no conflicts of interest.

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Research registration and unique identifying number (UIN)

The study registered and received unique registration (ID): researchregistry9217

Authors' contributions

This study was carried out in collaboration with all authors, and its contribution to the paper was confirmed as follows. The authors (Y. T. and S. H) conceived the idea of the title, developed the proposal, analyzed the data, and interpreted the results, and finalized the research. Author (A. F. I.) assisted in data analysis, prepared the manuscript, and sent for publication. Author (H.M.) has approved the idea of this title and assisted in writing, rewriting the manuscript. The authors (N. F. and S. Y.) participated in supervised data collection and assisted with the interpretation of the results.

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