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Morphometric assessment of adult human lumbar vertebrae

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ABSTRACT

The lumbar area of human spine is the commonest site of low backache. Knowledge of lumbar morphometry is crucial not only to understand the biomechanics of lumbar spine but also for abundant interventions intended at its stabilization and correction of deformities.

Aims and Objective: Aims and objective was to prepare morphometric data on dimensions of lumbar vertebral body which can be used in clinical practice. An observational study was implemented where 47 dry macerated adult human lumbar vertebral sets were directly examined and their morphometric analysis in preference to vertebral body was done. Data was processed and analyzed by SPSS Ver.20. 'ANOVA' and 'Z test' were administered to evaluate statistical differences.

Results: From L1 to L5, there was a gradual increase in antero-posterior (AP) diameter of superior surface. However, AP diameter of inferior surface increased up to L4 but it reduced at L5. Transverse measurements also shows gradual increase above downwards from L1 to L5. There were fluctuations in heights of vertebral bodies. There is gradual elevation of superior surface area (SA) from L1 to L5. However, inferior surface area (IA) increases up to L4 and decreases at L5.

Discussion and Conclusion: The study showed highly significant differences for all vertebral dimensions except 'posterior height' of lumbar vertebral bodies. The generated results need to be expanded in view of larger sample size and also in known sets of male and female lumbar vertebrae in diverse population.

1. Introduction

The vertebrae undergo continuous remodeling throughout life, primarily in response to the changing needs of the body.[1] Evolution of human erect posture and bipedal gait coupled with lifestyle changes is often reflected as stress on the vertebral column.[2] The lumbar region of vertebral column being the most common site of expression of this stress in the form of low backache.[2]

The five lumbar vertebrae are distinguished by their large size, wider body in transverse plane, strong and short paired pedicles, shallow superior vertebral notches, spinal canal etc. The dimensions of these vertebral segments provide key relevance in clinical diagnosis of lower backache as well as other pathological lumbar diseases.

Lumbar morphometry is intended at its stabilization and correction of deformities.[3] Accurate anatomical description of the shape and orientation of lumbar vertebrae are necessary for the development and use of implantable devices and spinal instrumentation in spinal disorders including fractures.[4] It is also imperative to assess the differences in morphometry of vertebrae in men and women and to understand changes among them, as incorrect placement of instruments and devices may have serious complications.[4]

The research noted that vertebral bodies and intervertebral disc sustain all the vertebral compression force, the magnitude of which increases from the axis vertebra to the lumbo-sacral joint.[5] Thus each vertebra bears the weight of all the part of the body above it and since the lower ones have to bear much more weight than the upper ones, the former are much larger.[5]

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Several studies have been carried out to analyze morphometry of posterior element of lumbar vertebra.[4,6] However, the morphometric data on vertebral body is relatively scarce. The present study, the objective was intended to formulate morphometric database of lumbar vertebral bodies.

2. Materials and Methods

This was an observational study on 47 dry macerated adult human lumbar vertebral sets. All sets were taken from Department of Anatomy Bharati Vidyapeetham Medical college and Kashibai Nawale Medical college in Pune, Maharashtra. An Institutional Ethics Committee approval as well as prior permission of the concerned authorities were obtained. It was ensured that all selected vertebrae were apparently normal, fully ossified without any congenital or degenerative.

Each vertebra was marked for both segments (body and arch) followed by measurements. Linear measurements were done by 'Digital Vernier Caliper' with precision 0.01mm and 'Digital Planimeter' (figure1). Various parameters of body measured were 1) Anteroposterior length and transverse width 2) Anterior and Posterior height and 3) Superior and Inferior surface area. Standardized measurement procedure was established. Maximum Anteroposterior (AP) lengths on superior (SAP) and inferior (IAP) surfaces and m aximum transverse width on superior (ST) and inferior (IT) surfaces of vertebral bodies were measured. Height of the body was measured between the midpoint of the superior and inferior borders on anterior (AH) and posterior (PH) surfaces. Surface area of superior (SA) and inferior (IA) surfaces was measured by Digital Planimeter after tracing on paper with the help of lead pencil.

Entire data was processed and analyzed on SPSS ver. 20 (SPSS Inc., Chicago, IL,

3. Observations and Results

In present study, an individual vertebral body from 47 sets of lumbar vertebrae was studied. It was observed that, from L1 to L5, there was a gradual increase in anteroposterior (AP) diameter of superior surface. However, AP diameter of inferior surface increased up to L4 but remains stable at L5 (Table 1, Figure 2)

Progressive elevation was noted in transverse diameter (TD) of both the surfaces except on the inferior aspect of L5 which showed decline in TD than L4 (Table 1, Figure 2). Surface area (SA) of superior surface was more from L1 to L5. However, dissimilar findings were revealed for inferior surface with maximum surface area at L4 and later it declined at L5 (Table 1).

Table 1 andFigure 2 depicts fluctuations in the heights of vertebral bodies. Anterior height (AH) was uniformly raised from L1 to L5. In contrary to it, posterior height (PH) was high till L2 and subsequently it dropped to L5. AH was less than PH in L1 and L2 but for lower vertebrae, AH was more than PH.

Table 2 delineates statistical significance of multiple parameters of lumbar vertebral bodies. Highly significant difference ($p < 0.01$) was observed for all parameters except PH ($p > 0.01$).

4. Discussion

In current study, morphometric database of dried human lumbar vertebral bodies in Indian population was created. This preliminary information may be useful for the calculation of the anthropometric indices which meet the changing clinical and surgical demands.[7] Numerous studies have been conducted so far to evaluate morphometry of lumbar vertebrae in diverse population. However, the data from Indian population is relatively sparse.

Besides 'Digital Vernier Caliper' the present study also utilized instruments like 'Digital Planimeter' and lead pencil for Tracing on paper for measuring the dimens ions of vertebrae. Paul D et al. used parameters of morphometric studies to prepare spine model with computer program.[8] 'Sliding Vernier Caliper' was used by study of Chawla K et al.[9] However, it was restricted to lumbar pedicle only.

In this study, mean SAP diameter of vertebral body was minimum at L1 and maximum at L5. This finding corroborated with the study finding of Jadhav A et al.[10] and Sexena S et al.[11] In current study, gradual rise was noted from L1 to L5 in mean TD of both the surfaces except on the inferior surface of L5 which showed reduction in TD than L4. However, Saxena S et al.[11] and Jadhav et al.[10] reported contrast finding with least and highest mean TD at L1 and L5 respectively.

In present study, inferior surface area of L5 was found to be less than L4 but inferior area of L4 was more than L3. This can be explained by the fact that the weight was transmitted through 'Transverse processes and 'Iliolumbar Ligament'. However, superior surface area increased from L1 to L5. Comparison of superior surface areas with similar studies could not be done as superior surface area measurements were not found in most of the studies.

It is imperative to mention that most of the morphometric studies on lumbar vertebrae have utilized measurements from various imaging techniques including radiography.[12] Very few studies have implemented direct measurements of lumbar vertebrae. It is argued that direct measurements may provide accurate and reproducible

Parameters of vertebral body were compared where statistically significant difference ($p<0.05$) was revealed for most of the parameters (Table 3).

Table 1: Various dimensions of vertebral body

	L1		L2		L3		L4		L5	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
SAP(mm)	24.9	1.6	26.6	1.8	27.8	1.7	28.4	1.4	29.7	2.3
ST(mm)	36.1	3.0	38.1	4.0	40.2	3.7	42.8	3.8	44.2	4.7
IAP(mm)	26.3	1.7	27.1	2.1	28.3	1.5	29.5	1.5	29.8	3.3
IT(mm)	39.9	2.7	42.3	2.7	44.7	3.0	46.2	3.6	44.8	4.4
AH(mm)	22.6	1.7	23.4	1.7	24.0	2.0	23.9	2.3	24.6	3.7
PH(mm)	24.3	1.9	33.8	41.4	24.7	1.8	23.2	1.8	21.0	2.4
SA(mm^2)	93.5	16.5	102.7	14.5	117.0	14.6	125.3	15.5	129.6	20.4
IA(mm^2)	104.4	16.6	115.3	15.6	122.3	13.8	124.1	16.9	118.0	18.3

SAP-Superior surface anteroposterior, IAP- Inferior surface anteroposterior. ST - Superior surface transverse, IT - Inferior surface transverse. AH – Anterior height, PH – Posterior height, SA –Superior area, IA – Inferior area.

Table 2: Various parameters of lumbar vertebral body (L1 to L5)

Parameter	**F-value**	**p-value**	**Significance**
AP diameter of superior surface (SAP)	49.14	0.000	HS
Transverse diameter of superior surface (ST)	34.14	0.000	HS
AP diameter of inferior surface (IAP)	22.98	0.000	HS
Transverse diameter of inferior surface (IT)	26.30	0.000	HS
Anterior height (AH)	4.81	0.000	HS
Posterior height (PH)	3.26	0.012	S
Surface area of superior surface (SA)	40.33	0.000	HS
Surface area of inferior surface (IA)	10.61	0.000	HS

SAP-Superior surface anteroposterior, IAP- Inferior surface anteroposterior. ST - Superior surface transverse, IT - Inferior surface transverse. AH – Anterior height, PH – Posterior height, SA – Superior area, IA – Inferior area. AP – Antero-posterior, HS: Highly significant (p-value < 0.01), S: Significant (p-value < 0.05)

Table 3: Comparison of parameters of lumbar vertebral body (L1 to L5)

	L1		L2		L3		L4		L5	
	p-value	**Signf.**	**p-value**	**Signf.**	**p-value**	**Signf.**	**p-value**	**Signf.**	**p-value**	**Signf.**
SAP x IAP	< 0.001	HS	0.11	NS	0.067	NS	< 0.001	HS	0.462	NS
ST x IT	< 0.001	HS	< 0.001	HS	< 0.001	HS	< 0.001	HS	0.272	NS
AH x PH	< 0.001	HS	< 0.001	HS	0.032	S	0.0617	NS	< 0.001	HS
SA x IA	< 0.001	HS	< 0.001	HS	0.031	S	0.358	NS	0.001	HS

SAP – Anteroposterior diameter of superior surface, ST - Transverse diameter of superior surface, IAP - AP diameter of inferior surface, IT - Transverse diameter of inferior surface, AH - Anterior height, PH - Posterior height, SA - Surface area of superior surface, IA - Surface area of inferior surface, Signf. – Significant, HS: Highly significant (p-value < 0.01), S: Significant (p-value < 0.05), NS: Not significant (p – value > 0.05)

Fig. 1: Digital planimeter

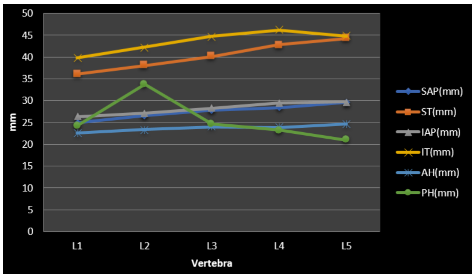

Fig. 2: Diameters of lumbar vertebral body

SAP-Superior surface anteroposterior, IAP- Inferior surface anteroposterior. ST - Superior surface transverse, IT - Inferior surface transverse. AH – Anterior hieght, PH – Posterior hieght.

5. Conclusion

The morphometric data of lumbar vertebrae at L4-L5 junction was suggestive of the weight transmission from anterior column to pelvic bone. In this study, mean SAP diameter and superior area (SA) was minimum at L1 and maximum at L5 but fluctuations were detected in mean IAP diameter and inferior area (IA) which was reduced at L5. The study revealed highly significant differences for all vertebral dimensions except 'posterior height'. These values may be used to design vertebral body implants in 'Vertebroplasty'.

6. Source of Funding

None.

7. Conflict of Interest

None.

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