The morphometric study of the body of dry human subaxial cervical vertebrae

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Received: 18th September, 2018 **Accepted:** 15th October, 2018

Abstract
Cervical vertebral column is influenced by mechanical, environmental, genetic, metabolic and hormonal factors and has to react to the forces of everyday lifelike compression, traction, torsion and shearing. The key position and function of vertebral column has always interested workers in the research field. Many clinical problems affect the different components of the vertebral column and especially cervical region. The cervical region of vertebral column being the most common site of expression of stress in the form of cervical pain, formation of osteophytes, osteoporosis, prolapsed intervertebral disc and spondilitis etc. In view of the surgical procedures carried on cervical vertebral column and certain percentages of failures in some of them, many workers have tried to standardize the measurements of the different parts of cervical vertebrae. The morphometric database of the cervical vertebrae can be used for developing implantable devices and spinal instrumentation.

Keywords: Cervical vertebrae, Cervical spine, Morphometry, Sub axial.

Introduction
Evolution of human erect posture and bipedal gait coupled with modern lifestyle is often reflected as stress on the vertebral column. This affects the cervical vertebrae and expressed as a pain in neck, cervical disc prolapse and cervical neuropraxia. Many factors influences the normal structure and function of vertebral column such as mechanical, environmental- occupation and defective posture also affect the ability of the cervical vertebral column to withstand the force of the compression, torsion and traction.[1]

The fetal body appears flexed ventrally. In the adults, thoracic and pelvic are primary curvature and concave ventrally well as cervical and lumbar are secondary curvature and convex ventrally. These develop due to neck holding and bipedal gait adapted by human beings at early age.[1]

Weight of head, neck, trunk and upper limbs is transmitted by vertebral column to the lower limb through hip bones. The vertebral column consisting of the vertebrae and the intervertebral discs in between them is subjected to vertical compression forces under the gravitational pull. The magnitude of this force increases from atlanto-occipital to lumbo-sacral joint. In normal anatomical position the line of weight transmission is seen to pass through odontoid process atlas, the point just anterior to T2, centre of T12, posterior to L5 and anterior to sacrum. Therefore, one would expect the size of vertebral bodies to increase gradually from first cervical to the fifth lumbar vertebra.[1]

The characteristics features of cervical vertebrae are small size of the body and presence of foramen transversarium. The sub axial 3rd to 6th shows similar anatomical features and described as typical cervical vertebrae, has minor differences which usually enable its distinction from others & the seventh is atypical due to its distinct features.

The subaxial cervical vertebrae have a small, relatively broad vertebral body & convex anterior surface. However, the posterior surface is flat or minimally concave. The superior surface of the cervical vertebral body shows raised lip of lateral circumference of upper margin; this are described as uncinate or neurocentral lip or processes.[1]

The standard morphology is necessary in designing appropriate spinal instruments for selection of transpedicular screw size or for replacing loose or damaged parts of a vertebra. The morphometry of vertebral bodies is useful for surgeons who perform anterior cervical reconstructions using plate fixation (Abuzayed et al.).[2,3]

The key position and function of vertebral column has always interested workers in the research field. The vertebral column is a common site of many clinical problems and often requires surgical intervention. The cervical region of vertebral column being the most common site of expression of stress in the form of cervical pain, formation of osteophytes, osteoporosis, prolapsed intervertebral disc and spondylitis etc. In view of the surgical procedures carried on cervical vertebral column and certain percentages of failures in some of them, many workers have tried to standardize the measurements of the different parts of cervical vertebrae. The secondary cervical curvature convex ventrally in the sagittal plane. Increased convexity corresponds with the greater anterior height of vertebral bodies and the greater anterior depth of the intervertebral discs associated with posterior wedging of vertebral bodies.

Petter,[4] Davis,[5] Taylor and Twomey[6] noted that the 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. 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 (Rosch and Burke).[7] This assumption is supported by serial measurements of the vertebral bodies (Brandner)[8] (Taylor and Twomey).[6] Williams and Warwick[9] are of the opinion that the weight of head and trunk is supported by a continuous flexible pillar formed by the vertebral bodies and intervertebral discs.

'Loading exercise' have been performed to see the mechanical response of the spine to the external forces. These experimental models were used in the study of the spine for instrumentation.[10,11] Gross anatomical differences in cervical vertebrae from the 3rd to the 7th cervical vertebrae were mainly seen in shape of the vertebral bodies and uncinate processes. (Romanes,[12] Williams et al.[13]

Materials and Methods

For the present study Fifty-seven dry macerated known sets of adult human cervical vertebral column from Department of Anatomy, two medical colleges from Maharashtra were selected. All vertebrae were apparently normal, fully ossified without any congenital anomalies and degenerative changes. The following measurements were taken with Vernier caliper with 0.1mm accuracy.

Anteroposterior (SAP) length was measured from the most anterior to most posterior point in the midline. And transverse (ST) width was measured as the maximum measurement in a line perpendicular to the midline of superior surface. The Anteroposterior length (IAP) and the transverse width (IT) on the inferior surface of the body also were measured.

Height of the body was measured between the midpoint of the superior and inferior borders on anterior (AH) as well as Posterior (PH) surfaces.

The observations were statistically analyzed by applying tests of significance viz. 'ANOVA' and 'Z-test' and the results are discussed.

Observations

Individual vertebra from the fifty seven sets of cervical vertebrae was studied and the observations were noted as shown in the following tables. The observations were stastically analysed by applying tests of significance viz. 'ANOVA' and 'Z-test' and the results are discussed.

While studying the cervical vertebral bodies it is observed that: - The anteroposterior length of superior surface shows gradual increase from the third to the sixth cervical vertebrae and it decreases at the seventh vertebra. The anteroposterior length of inferior surface shows gradual increase from the third to the fifth cervical vertebrae and it decreases at the sixth and seventh vertebra. (Table 1)

Transverse length of superior and inferior surfaces of all the vertebrae shows gradual increase from the third to the seventh cervical vertebrae except on the inferior surface of the fourth vertebra which shows reduction in transverse length than the third. (Table 2).

The anterior and the posterior height of vertebrae decreases gradually from the third to the fifth vertebra, then increases from the fifth to the seventh vertebrae. It is further observed that, the anterior height is less than posterior height except at C3 and C4. Statistically anterior and posterior height are same (Table 3)

After applying 'ANOVA test' to these observations to find out the significance of different parameters of the third to the seventh vertebra, the p-values for all the parameters are less than 0.001 which is highly significant except for superior anteroposterior where the P-value is less than 0.05 which is significant.

Similarly 'Z-test' is applied to these observations to compare two parameters of the same vertebra. P-values obtained by Z-test for superior anteroposterior and inferior anteroposterior is found to be highly significant in third and fifth vertebrae, significant in fourth vertebra and not significant in sixth and seventh vertebrae.

P- value of superior and inferior transverse length show significant difference from C3 to C5 and the p- values of C7 is not significant.

Table 1: Vertebral body anteroposterior length of superior and inferior surface

Vertebra	SAP	IAP	Z Value	P Value
	Mean ± SD (n=57)	Mean ± SD (n=57)		
C3	14.57 ± 1.50	15.56 ± 1.75	3.25	<0.01
C4	14.91 ± 1.86	15.73 ± 1.89	2.35	<0.05
C5	15.14 ± 1.75	16.31 ± 1.98	3.33	<0.01
C6	15.57 ± 1.67	15.87 ± 1.93	0.87	>0.05
C7	15.21 ± 2.18	14.82 ± 1.48	1.11	>0.05
F Value	2.41	5.10		
P Value	<0.05	<0.001		

Table 2: Vertebral body transverse length of superior and inferior surface

Vertebra	ST	IT	Z Value	P Value
	Mean ± SD (n=57)	Mean ± SD (n=57)		
C3	20.99 ± 2.10	19.13 ± 2.48	4.33	<0.001
C4	21.91 ± 2.67	18.97 ± 2.96	5.58	<0.0001
C5	22.81 ± 2.31	21.46 ± 3.33	2.50	<0.05

C6	24.74 ± 2.47	23 ± 2.91	3.45	<0.001
C7	26.41 ± 2.58	25.87 ± 2.12	1.21	>0.05
F Value	46.19	60.63		
P Value	<0.0001	<0.0001		

Table 3: Vertebral body anterior and posterior height

Vertebra	AH	PH	Z Value	P Value
	Mean ± SD (n=57)	Mean ± SD (n=57)		
C3	12.10 ± 1.35	12.23 ± 1.43	0.53	>0.05
C4	11.79 ± 1.68	11.88 ± 1.31	0.33	>0.05
C5	10.79 ± 1.31	11.77 ± 1.17	4.22	<0.001
C6	11.42 ± 1.18	12.33 ± 1.19	4.07	<0.001
C7	12.91 ± 1.22	13.78 ± 1.30	3.66	<0.001
F Value	19.11	22.46		
P Value	<0.0001	<0.0001		

Table 4: ANOVA test this test is used to find the significance of different parameters values for C3 to C7

	F-value	p-value	Significance
SAP	2.41	<0.05	S
IAP	5.10	<0.001	HS
ST	46.19	<0.0001	HS
IT	60.63	<0.0001	HS
AH	19.11	<0.0001	HS
PH	22.46	<0.0001	HS

HS: Highly significant (p-value < 0.01) S: Significant (p-value < 0.05)

Table 5: Z – test

	C3		C4		C5		C6		C7	
	p-value	Signf.	p-value	Signf.	p-value	Signf.	p-value	Signf.	p-value	Signf.
SAP x IAP	<0.01	HS	<0.05	S	<0.01	HS	>0.05	NS	>0.05	NS
ST x IT	<0.001	HS	<0.0001	HS	<0.05	S	<0.001	HS	>0.05	NS
AH x PH	>0.05	NS	>0.05	NS	<0.001	HS	<0.001	HS	<0.001	HS

HS: Highly significant (p-value < 0.01), S: Significant (p-value < 0.05), NS: Not significant (p – value > 0.5)

Fig. 1: Antero-posterior length of superior surface of vertebral body (SAP)

Fig. 2: Transverse length of superior surface of vertebral body (ST)

Fig. 3: Anterior height of vertebral body (AH)

Discussion

In this study an attempt is made to prepare morphometric database body of the dried skeleton of Human subaxial cervical vertebrae in Indian population.

Similar studies are done on dried cervical vertebral specimen in Indian population (Pal and Routal)[14,15] who used 'tracing on graph paper', 'goniometer' and 'sliding vernier caliper'. However they studied vertebral body surface area, pedicle size and pedicle angle in relation to the pattern of weight transmission and all the vertebrae were included in their studies.

Studies on dried vertebral specimen in Indian population by Singel et al. used 'sliding vernier caliper'.[16] In the present study, measurements of the cervical vertebrae were taken by 'digital vernier caliper'. The findings of the present study are discussed here.

One would expect increase in size of vertebral bodies from first to seventh cervical vertebra due to increase in vertical compression forces in the human erect posture. In this regard, the diameters of all the vertebrae are studied by Anderson.[17] He concluded that the anteroposterior length increases from C3 to L3. Other workers viz. Dennis, Louis[18] and Pal and Routal measured the 'surface area' of bodies and found it to increase from C2 to T5. This surface area was measured from the inferior surface of the cervical vertebral bodies. The transverse length of vertebral bodies measured by Anderson showed increase in value from C2 downwards. In the present study the anteroposterior length of both superior and inferior surfaces were measured and found to increase from C3 to C6, however it is significantly less in C7 (Table 1 and Table 2). The findings of transverse length of the superior surface of cervical vertebrae in the present study showed increase in the value from C3 to C6 and sudden increase in the value in C7 (Table 3).

In his study, Anderson mentioned that the vertical length (height) of the vertebrae in cervical region in front and behind were generally the same. He observed that the 'lumbar curve' was mainly due to the intervertebral cartilages, however agreed to the fact that the anterior and posterior diameters are given differently by different authors.

In the present study the anterior height (AH) and posterior height (PH) in C3 and C4 are not much different. The AH in C5, C6 and C7 is significantly less than PH and both AH and PH in C7 are more than respective measurements from C3 to C6. Pal G.P. and Routal R.V. measured the inferior surface areas of the bodies of the vertebrae and found it to be increasing from C2 to T5. In our study surface area was not measured due to 'lipping' on both upper and lower aspects of the vertebral bodies. However, considering the anteroposterior and transverse length of both superior and inferior surfaces of C3 to C7 vertebrae, it appears that the surface area would show gradual increase from C3 to C7.

Conclusion

1. The present study involved the preparation of morphometric database of body of subaxial cervical vertebrae in Indian population, using various parameters.
2. In C3, C4 and C5 anteroposterior length of superior surface of body appears significantly less than the corresponding inferior surface and in C6, C7 it is significantly same.
3. In C3 to C6, transverse length of superior surface is more than the corresponding inferior surface and in C7 it is significantly same.
4. In C3 and C4 anterior height and posterior height of body is significantly same and C5, C6 and C7 posterior height is significantly more than anterior height. This is contrary to the expectation of the vertebral cervical curvature.
5. Variations in racial data must be taken into consideration during surgical procedures.
6. Quantitative report of the cervical vertebrae morphology was prepared that may be useful for surgeons and orthopedicians who perform plate fixation during anterior cervical spine surgery.

Conflict of Interest: None.

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How to cite this article: Khemnar G, Garud R. The morphometric study of the body of dry human subaxial cervical vertebrae. *Indian J Clin Anat Physiol* 2019;6(1):18-22.