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A MORPHOMETRIC STUDY OF BODY AND VERTEBRAL CANAL OF THORACIC VERTEBRAE & ITS CLINICAL SIGNIFICANCE

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ABSTRACT

Introduction: Accurate anatomical descriptions of the size, shape and orientation of the main structures of the human vertebrae and intervertebral discs are necessary for a variety of approaches and objectives such as the identification of clinical situations that are related to the morphometry of the spine structures, such as the incidence of low-back pain related to the spinal canal size. So the present study was done to measure the various morphometric parameters of thoracic vertebral body and neural canal.

Materials and Methods: Total 100 sets of dry human thoracic vertebra were obtained. These are of unknown age and sex. All Morphometric parameters were measured by digital Vernier caliper of accuracy of 0.01mm. Anterior height of the body (VBAH), Posterior height of the body (VBPH), Antero-posterior Diameter of Vertebral body (VBAPD), Transverse Diameter of Vertebral body (VBTD), Anteroposterior diameter of Vertebral Canal (VCAPD) and Transverse diameter of Vertebral Canal (VCTD). All parameters were entered into excel sheet and analysis was done by SPSS.

Results: Mean VBAH ranged from 13.17±1.35mm (T1) to 17.92±2.25mm (T12), mean VBPH from 15.01±1.27mm (T1) to 20.92±4.58mm (T12), mean VBAPD ranged from 11.62±1.96mm (T1) to 18.12±5.71mm (T12), mean VBTD from 24.28±5.68mm (T1) to 28.59±5.97mm (T12), mean VCAPD ranged from 12.46±1.30mm (T1) to 16.05±2.41mm (T12) and VCTD from 17.15±2.19mm (T1) to 20.11±3.74mm (T12).

Conclusion: The results of the present study may help in designing implants and instrumentations; understanding spine pathologies; and management of spinal disorder.

KEY WORDS: Vertebral Canal, Thoracic Vertebrae, Morphometric Study, Clinical Significance.

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INTRODUCTION

The adult human vertebral column (also called the spine or spinal column) usually consists of 33 vertebral segments- 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal. The linkages between the vertebrae include fibro-cartilaginous interbody joints (intervertebral disc) and paired synovial facet (zygapophysial) joints, together with a complex of ligaments and overlying muscles and fasciae. The functions of the vertebral column are to support the trunk, to protect the spinal cord and nerves, and to provide attachments for muscles. It is also an important site of hematopoiesis throughout life [1]. The vertebrae can be involved in various conditions like fractures, infections, malignancies abnormal curvatures such as kyphosis and scoliosis may result from developmental anomalies or pathological processes involving the vertebrae [2]. The vertebral bodies and the intervertebral discs form an important column in transmission of weight of the body. In the upper thoracic region, due to the anterior curvature, the main part of the compressive force is transmitted through the anterior column formed vertebral body and intervertebral disc, with resulting increased stress [3]. The compressive force in the lower thoracic region is transmitted through two parallel columns, one anterior and one posterior formed by successive articulations of laminae with each other [4].

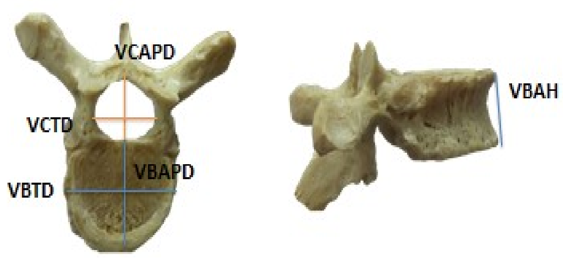
During the last decade there have been considerable developments in new techniques of surgical treatments to stabilize and correct the human spine. Many approaches have been proposed for patient-specific modeling of the human spine to explore the correction of spinal deformities, such as scoliosis, by spinal instrumentation. The current increased interest in biomechanical models of the spine and spinal implants calls for a detailed knowledge of spine morphometry. The malfunction of these structures due to spinal pathologies or accidents represents worldwide a high-cost for medical care [5, 6]. Accurate anatomical descriptions of the size, shape and orientation of the main structures of the human vertebrae and intervertebral discs are necessary for a variety of approaches and objectives such as the identification of clinical situations that are related to the morphometry of the spine structures, such as the incidence of low-back pain related to the spinal canal size [7]; the incidence of disc herniation dependent on the shape of the lumbar vertebrae [8]. The development of anthropological and forensic approaches for the identification of human remains [9-11].

The understanding of both the normal and abnormal morphology of the spine in cases of spine disorders such as scoliosis and kyphosis [12]. The development and use of implantable devices for spinal instrumentation.[13, 14] Accurate anatomic descriptions of vertebra are necessary for the diagnosis of various spinal diseases. Many studies have investigated the morphometry of the vertebrae using different methods like direct measurements, X-rays with plain films, CT scan, and MRI [14-17]. In adults whom growth is completed and no degenerative change has occurred, it is difficult to know the anatomical features. Because of recent development of spinal instruments many anatomical studies focused on the pedicle [15,18]. The anatomical study of spinal canal is as important as the pedicle. The cross-sectional areas of the spinal canal are of clinical importance in traumatic, degenerative, and inflammatory conditions. An increased risk of injury to spinal cord is associated with small canal diameter [17]. So the present study was done to measure the various morphometric parameters of thoracic vertebral body and neural canal.

MATERIALS AND METHODS

The present study was conducted in department of anatomy of RMCH Bareilly and VAMCRH, Sahjahanpur. Total 100 sets of dry human thoracic vertebra were obtained from both the medical colleges. These are of unknown age and sex. Damaged bones were excluded from study. All Morphometric parameters were measured by digital Vernier caliper of accuracy of 0.01mm. Following parameters were measured;(Fig 1)

Fig. 1: A. Superior view of Thoracic Vetebra showing measurements: VBAPD (anterioposterior diameter of vetebral body), VCAPD (anterioposterior diameter of vetebral canal), VCTD (transverse diameter of vetebral canal), B. Laterla veiew VABH (anterior height of vetebral body),



Anterior height of the body (VBAH): Vertical distance measured between superior and inferior surface of body in the midline anteriorly in mm.

Posterior height of the body (VBPH): Vertical distance measured between superior and inferior surface of body in the midline posteriorly in mm.

Antero-posterior Diameter of Vertebral body (VBAPD): Distance measured between anterior border and posterior border of the superior surface of vertebral body in midline in mm.

Transverse Diameter of Vertebral body (VBTD): Maximum transverse diameter of the vertebral body measured at the superior surface in mm.

Anteroposterior diameter of Vertebral Canal (VCAPD): It was measured as the midsagittal diameter at the cephalic border of vertebral arches in mm.

Transverse diameter of Vertebral Canal (VCTD): It was measured as the maximum distance between the inner surfaces of the two pedicles in mm.

All parameters were entered into excel sheet and analysis was done by SPSS.

RESULTS

Morphometric parameters were recorded on hundred sets of thoracic vertebrae. Mean anterior vertebral body height of T1 was minimum (13.17±1.35 mm) while that of T12 was maximum (17.92±2.25 mm). With increasing thoracic vertebrae level, an increase in body height was observed. Except for T10 (17.02±2.09 mm) which had mean value higher than T11 (16.95±1.91 mm), for all the other vertebrae, the body height was higher than the preceding vertebrae. Statistically, a significant difference in vertebral heights of different vertebrae was observed (p<0.001). (Table 1 & Fig 2)

Posterior vertebral body height for different thoracic vertebrae ranged from 12.54 (T1) to 32.06 mm (T12). Mean value for VBPH ranged from 15.01±1.27 mm (T1) to 20.92±4.58 mm (T12). An incremental trend in mean VBPH was observed with each successive thoracic vertebra except for T11 (19.28±2.24 mm) which had mean value smaller than T10 (19.41±4.08 mm). Statistically, there was a significant difference in mean posterior vertebral body height of different vertebrae (p<0.001). (Table 1 & Fig 2)

Anteroposterior diameter of vertebral body (VBAPD) ranged from 7.50 mm (T1) to 30.37 mm (T10 & T12). Mean anteroposterior diameter of vertebral body ranged from 11.62 mm (T1) to 18.12±5.71 mm (T12). A gradual increase in VBAPD was observed with each successive vertebrae, however, this trend was interrupted by T4 (14.11±4.03 mm) which had higher mean value as compared to T5 (13.17±3.25 mm) and T8 (16.05±4.70 mm) which had higher mean value as compared to T9 (15.39±3.06 mm). Statistically, there was a significant inter-thoracic vertebrae difference in VBAPD (p<0.001).(Table 1 & Fig3)

Transverse diameter of vertebral body (VBTD) ranged from 12.58 mm (T1) to 37.09 mm (T11 & T12). Mean transverse diameter of vertebral body ranged from 24.28±5.68 mm (T1) to 28.59±5.97 mm (T12). Though an incremental trend in mean VBTD were observed yet their increment was of slower order showing minor differences between two successive vertebrae which did not show a perfectly linear increment. Statistically, there was a significant inter-thoracic vertebrae difference in VBTD (p<0.001). (Table 1 & Fig 3)

Anteroposterior diameter of vertebral foramina (neural canal) ranged from 9.68 to 23.88 mm. Mean diameter ranged from 12.46±1.30 mm (T1) to 16.25±2.04 mm (T11) respectively. An incremental trend in foramina diameter was observed from T1 till T4 followed by a decline at T5 and a nominal incline at T6 & T7. This inclining trend further showed an incline at T8 and continued till T11 followed by a decline at T12. Statistically, there was a significant difference in anteroposterior diameter of canal among different thoracic vertebrae (p<0.001). (Table 1 & Fig 4)

Transverse diameter of vertebral foramina ranged from 12.87 (T1) to 31.98 mm. Mean diameter ranged from 17.15±2.91 mm (T1) to 20.11±3.74 mm (T12) respectively. Mean diameter of four vertebrae (T1 to T4) was below 18 mm (between 16.58±2.67 mm to 17.74±2.53 mm), mean diameter of another four was between 18 to 19mm (18.06±2.61 to 18.66±3.2 mm) (T5 to T8) while remaining four vertebrae had mean diameter in the range 19.44±4.33 (T9) to 20.11±3.74 mm (T12). Statistically, there was a significant difference in transverse diameter of canal among different thoracic vertebrae (p<0.001). (Table 1 & Fig 4)

Table 1: Various Morphometric Parameters of Thoracic Vertebral Body & Vertebral Canal.

	VBAH (mm±SD)	VBPH (mm±SD)	VBAPD (mm±SD)	VTDB (mm±SD)	VCAPD (mm±SD)	VCTD (mm±SD)
T1	13.17±1.35	15.01±1.27	11.62±1.96	24.28±5.68	12.46±1.30	17.15±2.91
T2	13.45±1.18	15.07±1.14	12.50±2.39	23.53±5.24	12.66±1.20	16.58±2.67
T3	13.93±1.24	15.34±1.06	12.96±2.26	23.94±5.13	12.95±1.18	17.29±2.50
T4	14.27±1.26	15.91±1.48	14.11±4.03	25.31±6.57	14.25±2.40	17.74±2.53
T5	14.64±1.32	16.14±1.32	13.75±2.61	25.16±5.22	13.95±1.43	18.06±2.61
T6	15.18±1.60	16.75±1.57	14.17±3.25	25.52±5.46	14.19±1.36	18.81±2.99
T7	15.47±1.42	16.99±1.32	15.38±4.25	25.90±5.36	14.18±1.46	18.34±2.90
T8	16.07±1.71	17.66±1.45	16.05±4.70	26.31±5.40	14.54±1.59	18.66±3.23
T9	16.21±1.81	17.74±1.70	15.39±3.06	25.53±5.24	15.02±1.54	19.44±4.33
T10	17.02±2.09	19.41±4.08	16.93±5.09	26.63±5.39	15.34±1.91	19.45±3.49
T11	16.95±1.91	19.28±2.24	17.13±4.51	28.56±6.52	16.25±2.04	19.83±3.49
T12	17.92±2.25	20.92±4.58	18.12±5.71	28.59±5.97	16.05±2.41	20.11±3.74

Fig. 2: Chart Showing Anterior posterior height of body of thoracic vertebrae.

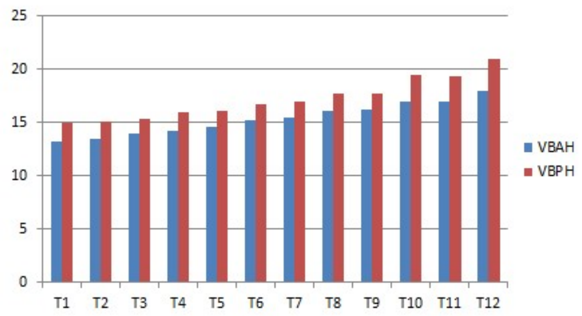
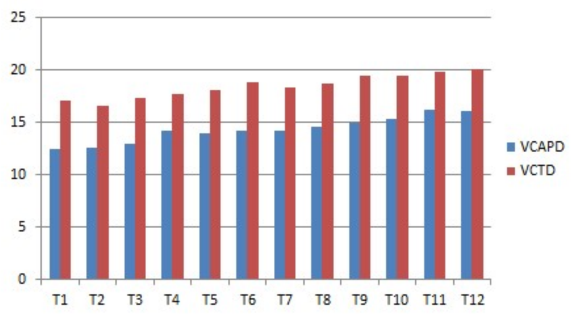


Fig. 3: Chart Showing Anterior and Transverse diamenter of body of thoracic vertebrae.

Fig. 4: Chart Showing Anterior and Transverse diamenter of vertebral canal of thoracic vertebrae.



DISCUSSION

Several quantitative studies have investigated the external of the vertebrae of different regions of the human spine. Morphometric measurements with cadaveric vertebrae have been taken directly from bony specimens or have been obtained from medical images (e.g. plain radiographs, computed tomography (CT) or magnetic resonance imaging (MRI)). However, these in vitro studies have focused on only a specific anatomical structure such as the vertebral body [19], spinal canal[20, 21, 22], pedicle [23] and articular facet joints [14,24] in a limited set of structures [14], in a limited segment of the spine such as thoracic [24] or lumbar [14], or in a specific population group such as South African negroes [21], Italians [22], Japanese [25], Koreans [17] and Indians [26]. The most complete collection of quantitative three-dimensional (3D) surface anatomy of the main vertebral parameters of the entire human spine was provided in Panjabi et al.[27, 28, 29].

In present study, for thoracic spine, anterior vertebral body height for different thoracic vertebrae ranged from 10.35 mm (T1) to 22.33 mm (T12). With increasing movement from T1 to T12, the mean vertebral body height showed an increasing trend from 13.17±1.35 mm (T1) to 17.92±2.25 mm (T12). A number of workers have reported such incremental trend for thoracic anterior vertebral body height using different methodologies [14,26,30]. In a study by Singh R et al.(2011)[26] anterior vertebral body height of thoracic vertebra showed a far high change in mean anterior vertebral body height up to 200% between T1 and T12.

In present study, we observed only 36% increase

Table 2: Thoracic Vertebral Body anterior & posterior height reported by different authors.

	Kunkel M E et al (2011)[31]		Singh R et al (2011)[26]		Present study	
	VBAH mm±sd	VBPH mm±sd	VBAH mm±sd	VBPH mm±sd	VBAH mm±sd	VBPH mm±sd
T1	14.49±1.23	15.28±1.14	14.94±1.25	15.86±1.51	13.17±1.35	15.01±1.27
T2	15.01±1.51	16.11±1.67	16.25±1.59	16.66±1.51	13.45±1.18	15.07±1.14
T3	15.65±1.85	17.41±1.12	16.72±1.34	17.08±1.41	13.93±1.24	15.34±1.06
T4	15.42±1.46	18.15±1.54	17.12±1.21	17.46±1.35	14.27±1.26	15.91±1.48
T5	15.84±1.07	17.33±2.16	17.08±1.29	18.22±1.34	14.64±1.32	16.14±1.32
T6	16.04±1.43	18.22±1.38	17.71±1.32	18.80±1.30	15.18±1.60	16.75±1.57
T7	15.94±1.61	18.67±1.64	17.89±1.43	19.28±1.29	15.47±1.42	16.99±1.32
T8	16.99±1.70	20.05±1.77	18.93±1.34	19.80±1.49	16.07±1.71	17.66±1.45
T9	18.26±2.12	20.25±2.44	19.94±1.52	20.40±1.71	16.21±1.81	17.74±1.70
T10	18.98±1.40	20.35±1.89	20.33±1.42	21.10±1.68	17.02±2.09	19.41±4.08
T11	19.60±1.92	22.67±1.39	21.23±1.73	35.60±3.42	16.95±1.91	19.28±2.24
T12	20.80±1.96	23.12±1.94	22.21±1.81	29.65±5	17.92±2.25	20.92±4.58

in anterior vertebral body height from T1 to T12. In another study, Kunkel et al. (2011) [31] reported the anterior vertebral body height (Anterior disc height) as 4.5 mm at T1 and 6 mm at T12, thus showing an increase of 33.3%. In present study, for thoracic vertebrae, measurements ranged from 10.35 mm (T1) to 22.33 mm (T12) whereas Singh et al.[26] reported these values to range from 14.94 mm to 29.65 mm and Kunkel et al. (2011) [31] reported them to range from 4.5 mm to 7.2 mm. These findings indicate that there is lack of consensus regarding exact landmarks to define the anterior vertebral body height. All these studies concluded to the fact that the anterior vertebral height shows an incremental trend from T1 to T12 and this increment is close to 30-40% range. (Table 2)

In present study, posterior vertebral body height for different thoracic vertebrae ranged from 12.54 mm (T1) to 32.65 mm (T10) respectively. With increasing movement from T1 to T12, mean posterior vertebral body height showed an increasing trend from 15.01±1.27 mm (T1) to 20.92±4.58 mm (T12). The findings suggest a similar incremental trend in mean values as observed for anterior vertebral body height of thoracic vertebra. Singh et al. (2011) [26] reported the mean values of vertebral body posterior height to range from 15.86±1.51 mm (T1) to 29.65±1.60 mm (T12) respectively. However, the present study did not show this much variation. The findings of present study are in more proximity to the observations of Tan et al. (2004) [30], reported the range of mean vertebral body posterior height to be 14.0±0.2 mm (T1) to 21.5±0.2 mm (T12) for thoracic spine. (Table 2)

Masharawi Y et al(2008)[32] reported that width of superior surface of thoracic vertebra decreases from T1 (26.5±3mm mm in men and 23.5±2.2mm in women) to T4 level (25.5±3.3mm in men and 22.2±3.5mm in women) and then increases continuously. Singh R et al (2011)[26] also reported slight decreasing width of VB from T1 to T4, and minimal value at level of T4 with the mean of 24.75mm for whole series and from T4 it increases to reach maximum at T12 with mean of 36.5mm for whole series. In present study width of VB decreases from T1 (24.28±5.68) to T3 (23.94±5.13) and then increases from T4 (25.31±6.57) to T12 (28.59±5.97). (Table 3)

Anteroposterior length of thoracic vertebrae increases from T1 to T12 reported by Masharawi Y (2008) [32]. In present study a gradual increase in VBAPD was observed with each successive vertebrae, however, this trend was interrupted by T4 (14.11±4.03 mm) which had higher mean value as compared to T5 (13.17±3.25 mm) and T8 (16.05±4.70 mm) which had higher mean value as compared to T9 (15.39±3.06 mm). Statistically, there was a significant interthoracic vertebrae difference in VBAPD ($p<0.001$). Singh et al found VBAPD relatively stable between T1

(13.82 mm) to T12 (15.87 mm). Tan et al. [30] also reported similar findings with mean values of 11.6 mm at T1 to 12.4 mm at T12, but all levels the canal dimensions were wider reported by Singh et al compared to than that reported in Chinese Singaporeans.

Table 3: Comparison of vertebral Body width by different authors.

	Gupta R et al (2011)[40]	Singh R et al (2011)[26]	Present study
T1	28.80+ 4.44	24.97+2.63	24.28+5.68
T2	27.64+3.54	24.98+3.10	23.53+5.24
T3	26.84+3.96	24.34+2.66	23.94+5.13
T4	26.48+3.20	23.74+1.93	25.31+6.57
T5	27.28+3.78	23.99+2.01	25.16+5.22
T6	27.48+3.77	24.69+2.34	25.52+5.46
T7	28.59+3.18	25.85+2.44	25.90+5.36
T8	29.03+3.35	26.65+2.69	26.31+5.40
T9	30.66+3.67	27.39+3.30	25.53+5.24
T10	32.80+4.42	29.07+2.82	26.63+5.39
T11	34.82+4.32	32.07+3.80	28.56+6.52
T12	36.75+4.39	34.31+2.96	28.59+5.97

Kang *et al.* (2011)[33] analyzed the T1–L5 vertebrae with CT scans. CT-vertebral body transverse diameter (CT-VBD), were measured up to T1-L5, and the T9–L5 vertebrae of the same participants were investigated with plain radiographs (X-VBD). The average CT-VBD was smallest at T4 (mean ± SD 26.97 ± 2.69 mm) and largest at L5 (mean ± SD 53.30 ± 4.95 mm). The average CT-VBD gradually decreased from T1 to T4 and increased from T5 to L5.

Singh et al [26] reported, VCTD decreased from T1 to T5 with mean value of 15.48 ± 1.24 mm at T5 and then gradually increased from T6 to T12 with mean value of 18.96 ± 2.17 mm at T12. The similar trend was observed by Ugur et al. [34], Panjabi et al. [27], Scoles et al. [35], Berry et al. [14], Tan et al. [30], and McCormack et al. [36]. However, the studies by Datir and Mitra [37] and Chaynes et al. [38] showed higher values at all levels and with uniformly increasing trend from T1 to T12. In present study mean VCTD increases gradually from T1 (17.15+2.91) up to T12 (20.11+3.74) with slight dip at T2, T7 & T8 level. (Table 4)

Table 4: Comparison of Anteroposterior and transverse diameter of Vertebral canal by different authors.

	Gupta R et al (2011)[40]		Marchesi et al,1988[23] (swiss)		Singh R et al (2011)[26]		Present Study	
	TD mm+sd	AP mm+sd	TD mm+sd	AP mm+sd	TD mm+sd	AP mm+sd	TD mm+sd	AP mm+sd
T1	18.70+3.58	14.86+1.70	-	-	19.76+1.57	13.82+1.39	17.15+2.91	12.46+1.30
T2	17.56+2.39	15.07+1.52	-	-	17.09+1.41	13.80+1.09	16.58+2.67	12.66+1.20
T3	16.95+1.73	15.50+1.76	-	-	16.19+1.19	13.87+1.07	17.29+2.50	12.95+1.18
T4	16.94+1.84	15.53+1.65	-	-	15.80+1.32	14+1.26	17.74+2.53	14.25+2.40
T5	16.99+1.87	15.64+1.80	-	-	15.48+1.24	14.16+1.21	18.06+2.61	13.95+1.43
T6	16.98+1.85	15.79+2.02	17	16.4	15.52+1.30	14.28+1.18	18.81+2.99	14.19+1.36
T7	16.93+1.94	15.68+2.03	16.6	15.5	15.65+1.52	14.23+1.10	18.34+2.90	14.18+1.46
T8	17.05+2.13	15.97+2.09	17	16	15.86+1.47	14.07+1.29	18.66+3.23	14.54+1.59
T9	17.45+1.97	15.88+2.10	16.9	15.7	15.95+1.48	14.02+1.18	19.44+4.33	15.02+1.54
T10	17.84+2.12	16.23+2.21	17.3	15.8	15.96+1.62	14.03+1.34	19.45+3.49	15.34+1.91
T11	18.55+2.42	16.86+2.23	18.8	16.3	16.96+2.08	14.92+1.25	19.83+3.49	16.25+2.04
T12	20.83+2.69	17.71+2.24	22.7	17.7	18.96+2.17	15.87+1.59	20.11+3.74	16.05+2.41

The mid-thoracic region is important because it is critical vascular zone for the spinal cord. It has the narrowest opening, and blood supply to the spinal cord is least perfuse. Surgical situation in this site is further compounded by the fact that this is the area of least pedicle width also. Any medial misdirection of the pedicle screw during surgery is going to cause nerve root damage, dura tear, or spinal cord damage.

Kang M S et al (2012)[39] reported in the thoracic spine, the AP diameter of neural canal gradually decreased from T1 (16.1±1.2mm) to T8 (14.6±1.3mm) and increased to T12 (16.7±1.2mm). Berry et al. reported AP diameters of neural canal 15.0mm at T2, 16.6 mm at T7, 17.2 mm at T12.[14] Singh R et al[28]shows the cephalic anteroposterior diameter of neural canal from T1 to L5. It increased from

14.86+1.70mm at T1 (Range: 11.12-18.37mm) to 17.71±2.24mm at T12 (Range: 15.05-22.06mm) with slight dips at T7 and T9. In present study VCAPD gradually increases from T1 (12.46±1.30) to T12 (16.05±2.41) with mild dip at T5, T6 & T7 level. (Table 4)

CONCLUSION

The results of the present study may help in designing implants and instrumentations; understanding spine pathologies; and management of spinal disorder. Thus, a comprehensive data set has been presented which provides quantitative anatomy of vertebral body of thoracic vertebrae. The differences in the results of the present study and of the previous studies with respect to some of the parameters may be due to differences in race, ethnicity, environmental factors as well as methods used for the studies. In the future, the scope of the study can be further extended to study the vertebral column with respect to individual vertebral levels.

Conflicts of Interests: None

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