Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2024i1.1260
*Biol. Clin. Sci. Res. J., Volume, **2024**: 1260*
Original Research Article

A DETAILED MORPHOMETRIC STUDY OF THORACIC VERTEBRAE ANATOMY: UNDERSTANDING THE VARIATIONS IN VERTEBRAL STRUCTURE AND THEIR IMPORTANCE FOR SPINAL SURGERY AND TREATMENT OF SPINAL DISORDERS

KHAN QUA[1*], ASGHAR SS[2], MALIK F[1], NOREEN N[1], AKHTAR N[3], SABA N[4]

[1]Department of Anatomy, Liaquat College of Medicine and Dentistry Karachi, Pakistan
[2]Sir Syed College of Medical Sciences for Girls Karachi, Pakistan
[3]Department of Surgery, Ajk Medical College Muzaffarabad, Pakistan
[4]Department of Orthopedic Physical Therapy, Sheik Zayed Hospital Lahore, Pakistan
**Corresponding author`s email address: drquratulainkhan2024@gmail.com*

(Received, 04th September 2024, Revised 30th October 2024, Published 5th November 2024)

Abstract: *Thoracic vertebrae anatomy is critical for understanding spinal mechanics and for surgical interventions in treating spinal disorders. Morphometric variations in vertebral structure can influence the outcomes of spinal surgeries and the management of various spinal conditions.* ***Objective:*** *This study aims to provide a detailed morphometric analysis of thoracic vertebrae, focusing on the variations in vertebral structure. The goal is to enhance the understanding of these variations and their implications for spinal surgery and treatment.* ***Methods:*** *This analytical study was conducted at the Private Hospital of Karachi from Feb 2024 to August 2024. Data were collected from 85 patients. Utilizing morphometric methodology, different parameters of morphometric dimensions were conducted and screened to reveal patterns and variations among the sample.* ***Results:*** *Data were collected from 85 patients, which indicates a progressive increase in vertebral body dimensions from T1 to T12, with height, width, and depth all showing a notable rise as one moves down the thoracic spine. Specifically, vertebral body height increases from 15.5 mm at T1 to 23.2 mm at T12, while width and depth expand from 24.3 mm to 34.7 mm and 20.1 mm to 30.8 mm, respectively. This gradual increase suggests an adaptation to greater load-bearing demands in the lower thoracic region, likely providing enhanced structural support as the spine transitions toward the lumbar area.* ***Conclusions:*** *The observed morphometric variations in thoracic vertebrae have significant implications for spinal surgery, particularly in areas like implant design and surgical approach. A comprehensive understanding of these structural differences can aid in improving surgical outcomes and in developing personalized treatment strategies for spinal disorders.*

Keywords: Thoracic Vertebrae, Morphometric Analysis, Spinal Surgery, Vertebral Structure, Spinal Disorders, Anatomy

Introduction

The thoracic spine, consisting of twelve vertebrae (T1-T12), plays a pivotal role in maintaining spinal stability, protecting the spinal cord, and providing an anchor point for the rib cage. All of the thoracic vertebrae are classified individually as regards their architecture and role in the functionality of the spinal segment; the added flexibility, as well as rigidity of this section of the spine, is uniformly attributable to the specific make-up of the spinal body and its associated elements (1). The thoracic vertebral body can withstand different kinds of loads and stress as well as give a limited degree of motion that isili for day-to-day activities. It is important to notice that these vertebrae are dissimilar in form, size and position which emphasizes specific changes that the element has undergone and the load applied to it. Due to the intricate structure of the thoracic spine, the further development of surgical procedures in this area depends on the detailed morphometric analysis of this area, the development of spinal treatment methods, as well as the study of spinal pathologies (2). In the morphometric analysis of the thoracic vertebrae, the measurements include vertebral body height and width, pedicle diameter, transverse and spinous process and the intervertebral disc space. These dimensions are important for the development of spinal implant products and in performing meticulous and complex surgical procedures in spine surgery including deformity correction, fracture management, and degenerative pathologies (3). In particular, the necessity of detailed knowledge regarding structural variations of the vertebrae arises from the increasing role of individual techniques in spinal surgery. For instance, scoliosis and kyphosis which are diseases affecting the spine need surgical interventions and here implant fit as well as vertebrae alignment is vital. Similarly, in vertebroplasty or spinal fusion operations, it is possible to determine screws, rods and other implants accurately, if the dimensions of the vertebrae are precisely known (4).

For this purpose, there is a need to get more accuracy in measurements than usual, especially in spinal surgeries that involve the thoracic vertebrae since the spinal cord and ribs are close to the operation site. There is no better example than intraoperative navigation and minimally invasive techniques that stand to equally benefit from an accurate understanding of the thoracic vertebrae (5). Conventional and latest modalities including CT scans and MRI help surgeons in evaluating the vertebral morphology preoperatively. However, having a complete morphometric database improves preoperative planning since the surgeon is expected to have reference measurements to work from (6). In addition, knowledge about the specific differences reflecting each vertebra can be useful in predicting

[Citation Khan, Q.U.A., Asghar, S.S., Malik, F., Noreen, N., Akhtar, N., Saba, N. (2024). A detailed morphometric study of thoracic vertebrae anatomy: understanding the variations in vertebral structure and their importance for spinal surgery and treatment of spinal disorders. *Biol. Clin. Sci. Res. J.*, **2024***: 1260*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1260]

difficulties and minimizing intraoperative adverse outcomes as well as enhancing the postoperative results. There is also the importance of knowledge about the thoracic vertebral structures for non-operative spinal pathology management (7). Diseases like osteoporosis, spondylolisthesis, and slipped discs plague the thoracic vertebrae, rendering most patients immobile and in severe pain most of the time (8). In conservative treatments morphometric data allow accessing the zones with a higher propensity to fractures or degeneration will help in preventive care. Moreover, such analyses in morphometry help construct an algorithm for evaluating the risk factors accounting for spinal disorders based on measurements of vertebral columns. For instance, they include smaller pedicle diameters or less height of vertebral bodies, which the latter may be associated with higher fracture rates or spinal instability in patients with osteoporosis (9). **Objective** This study aims to provide a detailed morphometric analysis of thoracic vertebrae, focusing on the variations in vertebral structure. The goal is to enhance the understanding of these variations and their implications for spinal surgery and treatment.

Methodology

This analytical study was conducted at Private Hospital of Karachi from Feb 2024 to August 2024. Data were collected from 85 patients. Utilizing morphometric methodology, different parameters of morphometric dimensions were conducted and screened to reveal patterns and variations among the sample. This methodological framework was developed for the improvement of morphological knowledge of the thoracic vertebrae which can be used for findings to improve surgical planning, spinal treatments and anatomic study. Any participant diagnosed with either congenital or acquired spinal deformity like scoliosis or kyphosis was not included in the study to avoid confounding the natural variability of spinal structures by spinal pathologies. Furthermore, data were collected only from patients with nearly full and outstanding quality thoracic spine imaging to enhance the measures' validity. HWithContextation, high-resolution CT scans of the thoracic spine region only were taken with a view of getting accurate measurements. Ct imaging was chosen because it proved to provide detailed anatomical information on the vertebral structural morphology of the pedicles and spinous process. Individual thoracic vertebrae were studied and due to the importance of the shape and sizes of these vertebrae, measurements from both the transverse and the axial points of view were made.

The following key structural parameters were recorded for each vertebra:

Vertebral Body Height: Measured from the superior to the inferior endplate in the sagittal plane.

Vertebral Body Width and Depth: Width was measured across the transverse plane at the widest point of the vertebral body, while depth was measured from the anterior to the posterior aspect.

Pedicle Dimensions: The height and width of each pedicle were measured in the axial plane, given their importance in surgical planning and instrumentation.

Transverse and Spinal Processes Lengths: To further assess morphological variations, measurements of the transverse and spinous processes were also taken to understand their contribution to the thoracic spine's stability and function.

Data Analysis and Statistical Methods

The collected data were organised by thoracic level (T1-T12) to identify patterns in vertebral morphology across the thoracic spine. Statistical analysis was conducted using statistical software to determine the presence of significant differences between vertebrae at different levels.

Results

Data were collected from 85 patients, which indicates a progressive increase in vertebral body dimensions from T1 to T12, with height, width, and depth all showing a notable rise as one moves down the thoracic spine. Specifically, vertebral body height increases from 15.5 mm at T1 to 23.2 mm at T12, while width and depth expand from 24.3 mm to 34.7 mm and 20.1 mm to 30.8 mm, respectively. This gradual increase suggests an adaptation to greater load-bearing demands in the lower thoracic region, likely providing enhanced structural support as the spine transitions toward the lumbar area.

The results demonstrate a steady increase in pedicle height and width from T1 to T12, with pedicle height growing from 6.3 mm at T1 to 9.4 mm at T12, and pedicle width expanding from 5.2 mm to 8.9 mm over the same range. These dimensions reflect anatomical adjustments in the lower thoracic vertebrae, likely to accommodate increased structural demands and support for spinal instrumentation.

The results reveal a gradual decrease in transverse process length from T1 (23.1 mm) to T12 (18.4 mm), indicating a structural shift as the thoracic spine transitions toward the lumbar region. In contrast, the spinous process length remains relatively constant across thoracic levels, averaging around 20 mm.

The correlation analysis indicates a strong positive relationship (r = 0.76) between vertebral body height and width, suggesting that vertebrae with greater height tend to also be wider, likely contributing to enhanced structural stability. Additionally, a moderate positive correlation (r = 0.65) was observed between pedicle height and vertebral body depth, which may imply that deeper vertebrae are associated with larger pedicles, potentially supporting increased load-bearing capacity.

Table 1: Vertebral Body Dimensions across Thoracic Levels (Mean ± SD)

Thoracic Level	Height (mm)	Width (mm)	Depth (mm)
T1	15.5 ± 1.2	24.3 ± 1.1	20.1 ± 1.3
T2	16.2 ± 1.3	25.1 ± 1.2	21.0 ± 1.4
T3	17.0 ± 1.4	26.0 ± 1.2	22.2 ± 1.5
T4	18.1 ± 1.3	26.8 ± 1.3	23.4 ± 1.5
T5	19.0 ± 1.4	27.5 ± 1.4	24.2 ± 1.4
T6	19.8 ± 1.5	28.1 ± 1.3	25.5 ± 1.4
T7	20.5 ± 1.4	29.0 ± 1.5	26.7 ± 1.6
T8	21.4 ± 1.6	29.6 ± 1.3	27.9 ± 1.7
T9	22.1 ± 1.7	30.4 ± 1.4	28.5 ± 1.5
T10	22.8 ± 1.6	31.2 ± 1.3	29.3 ± 1.6
T11	23.1 ± 1.5	32.5 ± 1.4	30.2 ± 1.5
T12	23.2 ± 1.6	34.7 ± 1.3	30.8 ± 1.6

[Citation Khan, Q.U.A., Asghar, S.S., Malik, F., Noreen, N., Akhtar, N., Saba, N. (2024). A detailed morphometric study of thoracic vertebrae anatomy: understanding the variations in vertebral structure and their importance for spinal surgery and treatment of spinal disorders. *Biol. Clin. Sci. Res. J.,* **2024***: 1260*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1260]

Table 2: Pedicle Dimensions across Thoracic Levels (Mean ± SD)

Thoracic Level	Pedicle Height (mm)	Pedicle Width (mm)
T1	6.3 ± 0.8	5.2 ± 0.7
T2	6.6 ± 0.7	5.4 ± 0.6
T3	6.8 ± 0.8	5.6 ± 0.6
T4	7.1 ± 0.7	5.9 ± 0.5
T5	7.3 ± 0.6	6.1 ± 0.6
T6	7.6 ± 0.8	6.3 ± 0.6
T7	7.9 ± 0.9	6.5 ± 0.5
T8	8.1 ± 0.8	6.7 ± 0.6
T9	8.5 ± 0.9	7.0 ± 0.7
T10	8.8 ± 1.0	7.4 ± 0.6
T11	9.1 ± 0.9	8.1 ± 0.7
T12	9.4 ± 1.1	8.9 ± 0.8

Table 3: Transverse and Spinous Process Lengths across Thoracic Levels (Mean ± SD)

Thoracic Level	Transverse Process Length (mm)	Spinous Process Length (mm)
T1	23.1 ± 1.5	20.3 ± 1.3
T2	23.0 ± 1.4	20.5 ± 1.2
T3	22.8 ± 1.3	20.4 ± 1.4
T4	22.6 ± 1.2	20.3 ± 1.5
T5	22.1 ± 1.1	20.2 ± 1.4
T6	21.5 ± 1.2	20.1 ± 1.4
T7	20.9 ± 1.3	20.3 ± 1.3
T8	20.2 ± 1.4	20.2 ± 1.5
T9	19.8 ± 1.3	20.1 ± 1.4
T10	19.2 ± 1.2	20.2 ± 1.3
T11	18.6 ± 1.3	20.4 ± 1.2
T12	18.4 ± 1.3	20.5 ± 1.4

Table 4: Correlation between Key Morphometric Parameters

Parameter 1	Parameter 2	Correlation Coefficient (r)
Vertebral Body Height	Vertebral Body Width	0.76
Pedicle Height	Vertebral Body Depth	0.65
Transverse Process Length	Other Dimensions	No significant correlation

Discussion

This morphometric study of thoracic vertebrae aimed to explore anatomical variations across different thoracic levels, focusing on key structural parameters such as vertebral body dimensions and pedicle size. The findings of this work can be useful in understanding how these structural differences can affect the treatment and utilization of the spinal vertebrae, particularly in vertebral surgery (10). This study presents positive changes in vertebral body height, width and depth beginning from the upper axial levels (T1-T4) up to the lower axial region (T9-T12). These observations imply that lower thoracic vertebrae are biomechanically more robust to sustain higher loads that correspond with the change in the kind of vertebrae at the lumbar region that bears more body weight and experiences more stress (11). The statistically significant differences, observed in upper and lower thoracic vertebrae suggest that surgeons need to take into consideration such differences especially when positioning implants or stabilising structures in the lower thoracic segment. These variations are similar to observations made in other studies that have found the dimensions of the vertebrae in the lower thoracic and lumbar spine to also increase, all of which support the notion of structural adaptation at the mechanical level (12). Concerning pedicle size and morphology marked differences in height and width measurements of the thoracic vertebrae were observed with pedicle height and width gaining closer to the lower end of the thoracic spine (13). This increase may be necessitated by the need for stronger, stout pedicles in the lower thoracic region given that it is an area that is most likely to receive spinal instrumentation and support. Larger pedicle dimensions in T9-T12 might explain the stable anatomical constructions for osculating pedicle screws that are commonly used in spinal fusion and the treatment of spinal deformity (14). These perceptions can alert surgeons engaging in spinal fusion or carrying out corrective surgeries to select implant sizes and Type appropriate for the lower thoracic levels which require better hold on the bone. Conclusions regarding transverse process length—maximally in the upper thoracic region followed by a decline in the lower thoracic—propose a progressive change in the thoracic structure to the lumbar region that provides mechanical loading. This may be functionally useful where the thoracic spine changes to suit the functional requirements of the lumbar spine. From a clinical point of view, these findings may be advantageous during preoperative planning, especially in cases that require an approach via the lateral plane (15).

What has been observed in the maximum and minimum vertebral and pedicle dimensions emphasizes the need to develop individual treatment plans in surgical practices. Focused treatment for the thoracic spine may not require a traditional one-size-fits-all approach for spinal surgery because the structure of the thoracic spine has no similarities. Customized pedicle screws and vertebral cages could also have better efficacy in thoracic surgeries because the implant could be more suited to the entry point of the spinal column (16). Furthermore, preoperative imaging may well help to locate these variations, so that optimum implant selection and placement may be achieved for every affected person. Another clinical consideration which is relatively speculative to an extent is the connection between vertebral size and possible vulnerability to developing fractures or degenerative problems (17). For instance, asymptomatic subjects who have less than 6.5 mm pedicle diameter are reported to have potential fracture risk possibly because the upper thoracic spine has less structural support. The results of this study can also be used to help quite identify those patients who may have increased susceptibility to spinal ailments and hence come up with preventive measures or even early management plans. According to our study results, the pattern of vertebral body height and pedicle width enlargement towards lower thoracic levels as revealed in this study is supported by similar morphometric studies which have been done that have also revealed a similar scalene increase. However, our study adds further understanding by breaking down the comparison at all thoracic levels and also examining other not previously discussed relations such as the relationship between vertebral body dimension and pedicle size. These correlations indicate that dimensions of the thoracic vertebrae may grow commensurate with the need for mechanical stability, making them important findings for spinal instrumentation procedures.

Conclusion

It is concluded that thoracic vertebrae exhibit significant anatomical variations across different levels, with increasing vertebral body and pedicle dimensions from T1 to T12. These structural differences underscore the necessity for personalized surgical approaches and tailored implant selection to enhance stability and improve outcomes in thoracic spine procedures. This study provides critical data that can inform both clinical practices and future research in spinal anatomy and surgery.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-TC-03/23)
Consent for publication
Approved
Funding
Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

QURAT UL AIN KHAN (Assistant professor)
Coordination of collaborative efforts.
Study Design, Review of Literature.
SARAH SUGHRA ASGHAR (Assistant professor)
Conception of Study, Development of Research Methodology Design, Study Design, Review of manuscript, final approval of manuscript.
Conception of Study, Final approval of manuscript.
FARAH MALIK (Assistant professor)
Manuscript revisions, critical input.
Coordination of collaborative efforts.
NIMRA NOREEN (Lecturer)
Data acquisition, and analysis.
Manuscript drafting.
NAHEED AKHTAR (Assistant professor)
Data entry and Data analysis, drafting article.
NOOR US SABA (Orthopedic physical therapy)
Data acquisition, and analysis.
Coordination of collaborative efforts.

References

1. Ashish S, Kalluraya P, Pai M, Murlimanju BV, Rao Y, Prabhu L, Agrawal A. Morphometric study of the lumbar vertebrae in dried anatomical collections. F1000Res. 2023 Dec 28;11:1408. doi: 10.12688/f1000research.126879.2. PMID: 37990689; PMCID: PMC10660310.
2. Rivkin, M. A., Okun, J. F., & Yocom, S. S. (2014). Novel free-hand T1 pedicle screw method: Review of 44 consecutive cases. Journal of Neurosciences in Rural Practice, 5, 349–354. https://doi.org/10.4103/0976-3147.139974
3. Berry, J. L., Moran, J. M., Berg, W. S., et al. (1987). A morphometric study of human lumbar and selected thoracic vertebrae. Spine, 12, 362–367. https://doi.org/10.1097/00007632-198705000-00010
4. Panjabi, M. M., Goel, V., Oxland, T., et al. (1992). Human lumbar vertebrae: Quantitative three-dimensional anatomy. Spine, 17, 299–306. https://doi.org/10.1097/00007632-199203000-00010
5. Julin, M., Saukkonen, J., Oura, P., et al. (2). Association between vertebral dimensions and lumbar modic changes. Spine (Phila Pa 1976), 46(46), E415–E425. https://doi.org/10.1097/BRS.0000000000003797
6. Kot, A., Polak, J., Klepinowski, T., et al. (2022). Morphometric analysis of the lumbar vertebrae and intervertebral discs about abdominal aorta: CT-based study. Surgical and Radiologic Anatomy, 44, 431–441. https://doi.org/10.1007/s00276-021-02865-9
7. Singh, R., Srivastva, S. K., Prasath, C. S., et al. (2011). Morphometric measurements of cadaveric thoracic spine in Indian population and its clinical applications. Asian Sne Journal, 5, 20–34. https://doi.org/10.4184/asj.2011.5.1.20
8. Kwan, M. K., Chiu, C. K., Gani, S. M. A., et al. (2017). Accuracy and safety of pedicle screw placement in adolescent idiopathic scoliosis patients: A review of 2020 screws using computed tomography assessment. Spine, 42, 326–335.
9. Krag, M. H., Weaver, D. L., Beynnon, B. D., et al. (1988). Morphometry of the thoracic and lumbar spine related to transpedicular screw placement for surgical spinal fixation. Spine, 13, 27–32. https://doi.org/10.1097/00007632-198801000-00007
10. Prameela, M. D., Prabhu, L. V., Murlimanju, B. V., et al. (2020). Anatomical dimensions of the typical cervical vertebrae and their clinical implications. European Journal of Anatomy, 24, 9–15.
11. Gleinert-Rożek, M. Ł., Kosiński, A., Kaczyńska, A., et al. (2020). Metric analysis of the lumbar region of human vertebral column. Folia Morphologica (Warsz), 79, 655–661. https://doi.org/10.5603/FM.a2020.0008
12. Kapoor, Y., Anil, S., Krishnaiah, M., et al. (2014). Morphometry of the lumbar vertebrae and its clinical significance. Scholars Journal of Applied Medical Sciences, 2, 1045–1052.

[Citation Khan, Q.U.A., Asghar, S.S., Malik, F., Noreen, N., Akhtar, N., Saba, N. (2024). A detailed morphometric study of thoracic vertebrae anatomy: understanding the variations in vertebral structure and their importance for spinal surgery and treatment of spinal disorders. *Biol. Clin. Sci. Res. J.,* **2024***: 1260*. doi: https://doi.org/10.54112/bcsrj.v2024i1.1260]

13. Aly, T., & Amin, O. (2013). Geometrical dimensions and morphological study of the lumbar spinal canal in the normal Egyptian population. Orthopedics, 36, e229–e234. https://doi.org/10.3928/01477447-20130122-27
14. Nayak, G., Panda, S. K., & Chinara, P. K. (2020). Morphometry of lumbar spine: A holistic comparative study between typical and atypical lumbar vertebrae. International Journal of Anatomy Radiology and Surgery, 9, AO04-AO07.
15. Priya, A., Narayan, R. K., Ghosh, S. K., et al. (2023). Analysing lumbar pedicle morphometry observed via traditional and recent modalities. Journal of Orthopaedics, 43, 17–24. https://doi.org/10.1016/j.jor.2023.07.022
16. Sani, H. Y. (2018). The morphometric description of the thoracic and lumbar vertebral pedicles in European, African and mixed populations of South Africa (dissertation).
17. Pai, M. (2022). LUMBAR VERTEBRAE MORPHOMETRIC DATA.xlsx. figshare. https://doi.org/10.6084/m9.figshare.21307917.v1.