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Morphometric examination of vertebrae prominens with computed tomography images

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Abstract

The seventh cervical vertebra, also known as the vertebra prominens, possesses a distinctive structure with the most prominent spinous process among the cervical vertebrae. This study aims to assess the morphometric properties of the vertebra prominens concerning gender and age. In a retrospective analysis, computed tomography (CT) images from 200 individuals (100 females, 100 males), aged 18 to 75, devoid of cervical pathologies, were utilized. These images were sourced from the Picture Archiving and Communication System (PACS) archive of the Department of Radiology at Tokat Gaziosmanpaşa University. Participants were divided into two age groups: 18-30 years and 31-74 years. Measurements were obtained from 1.25 mm thick CT images using the Sectra program. Statistically significant differences in spinal dimensions were observed based on gender ($p<0.001$). Typically, males exhibited larger spinal dimensions compared to females, indicating a gender-based influence on spinal morphology. Age-wise analysis revealed significant gender-based disparities ($p<0.001$), illustrating age-gender variations. The antero-posterior length of the vertebra body showed gender-related differences in median values ($p<0.001$), with males having a median value of 15 mm and females 12.7 mm. Gender-based distinctions in the width of the right pediculus vertebral arch ($p<0.001$) were observed, with median values of 7.16 mm for males and 6.23 mm for females. Similarly, the left pediculus vertebral arch width displayed gender-related discrepancies in median values ($p<0.001$). Significant sex-related variations in spinal dimensions were noted ($p<0.001$), with males having larger vertebrae compared to females, indicating the impact of gender on spinal morphology. Age-related analysis also revealed significant gender-based differences ($p<0.001$), underscoring age-gender variations. These findings highlight the importance of considering both gender and age when assessing spinal morphometry. Understanding these variations contributes to a comprehensive comprehension understanding of spinal anatomy, potentially informing clinical interventions and treatment strategies tailored to individual characteristics.

Keywords: vertebrae prominens, computed tomography, morphometry, cervical

1. Introduction

The spinal column, made up of 33-34 vertebrae with intervertebral discs between them, consists of 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 4-5 coccygeal vertebrae. In the neck, there are 7 cervical vertebrae, with 4 (C3-6) being typical and 3 (C1, C2, and C7) atypical. Each typical vertebra has several parts including the vertebral body, pedicles, articular processes, laminae, and spinous processes, which form a neural arch. The specific features of cervical vertebrae are crucial for maintaining the normal curve and movement of the neck (1).

The structure of the cervical spine bones plays a vital role in maintaining the natural curvature and flexibility of the neck spine. Any morphological change resulting from factors like trauma, pathological disorders, or lesions in this region can lead to instability, constriction of the spinal canal, and compression of neurovascular structures in the cervical spine. These vertebrae safeguard crucial structures in the region and facilitate neck mobility and flexibility. Injuries to cervical vertebrae can stem from various causes. Swift and accurate treatments are necessary to protect the vital structures in this region when the cervical spine is compromised. Post-injury, a range of surgical techniques are employed for cervical spine treatment. Pedicle screws represent the most robust fixation method in cervical spine surgery, underscoring the importance of understanding not only the pedicular structure but also other relevant structures in these procedures. Morphology and morphometry of the cervical vertebrae offer critical parameters to consider both before and during operations in the respective area. Thus, a detailed examination of cervical vertebra morphology is pivotal in enhancing the success rate of spinal operative interventions (2, 3).

Studies have highlighted gender as a significant factor in vertebral morphology. Various studies have associated larger vertebrae in males with weight, exercise, and muscle mass in the body (4, 5, 6).

Recently, various screw fixation methods have been employed for correcting and immobilizing vertebral deformities. In operative procedures like transpedicular screw fixation, suitable implants underscore the significance of vertebral morphometrics (7, 8).

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Preserving the neurovascular structures during surgical operations for cervical vertebrae fixation necessitates a comprehensive understanding of the spinal column. These specific pieces of information significantly impact the safety and precision of operative interventions (9). The reason for choosing this vertebra is that the spinosus process is the only cervical vertebrae that can be seen or felt by hand when the head is flexed. Additionally, being the only cervical vertebrae without bifurcation and having the smallest transvers foramen among cervical vertebrae have also influenced my choice. Furthermore, the fact that the vertebral artery, vertebral vein does not pass through these openings, but only the accessory vertebral vein does, is a distinguishing feature of this vertebra from the others. These characteristics are consistent with current research that highlights the importance of C7. Therefore, my selection of the C7 vertebra aims to address existing gaps in the literature and expand knowledge in this area. The aim of this study is to evaluate the morphometric properties of vertebrae prominens according to gender and age.

2. Material and Methods

The retrospective study, approved by the Tokat Gaziosmanpaşa University Ethics Committee under Approval No: 23-KAEK-069, obtained permission to utilize computed tomography (CT) images of cervical vertebrae from 200 individuals (100 females, 100 males) who had visited the hospital between 2018 and 2023. Following Ethics Committee approval (Approval No: 23-KAEK-069), access to CT images was provided through the PACS system by the Department of Radiology. Patients with pathologies or surgical histories were excluded, resulting in a cohort of 200 individuals aged 18-74 who had not undergone prior interventions. CT images were analyzed using SECTRA (Sectra IDS7, Sweden) software with a slice thickness of 1.25 mm, enabling detailed morphometric measurements. The cohort was divided into two age groups (18-30 years as group 1, 31-74 years as group 2) to explore potential age-related differences. These steps laid the foundation for the study's comprehensive database. In our study, a total of 200 individuals, comprising 100 females and 100 males, were included. The mean age for males was 33.54±13.46, while for females, it was 34.62±11.62. Mann-Whitney U test was applied to assess the data related to gender and age. The median age for males was 29 (range 18-74) and for females, it was 34 (range 18-63). No significant difference was observed in median ages based on gender (p=0.242)

2.1. Morphometric Measurements of Vertebra Prominens

The width of the pedicle of the vertebral arch (WPVA); Defined as the distance between the medial border of the transvers foramen and the medial border of the pedicle in the axial section. The width of the right pedicle of the vertebral arch is indicated as c-d in Fig. 1. The width of the left pedicle of the vertebral arch is indicated as a-b in Fig. 2.

C: medial border of the transvers foramen

D: medial border of the pedicle in the axial section

A: medial border of the transvers foramen

B: medial border of the pedicle in the axial section

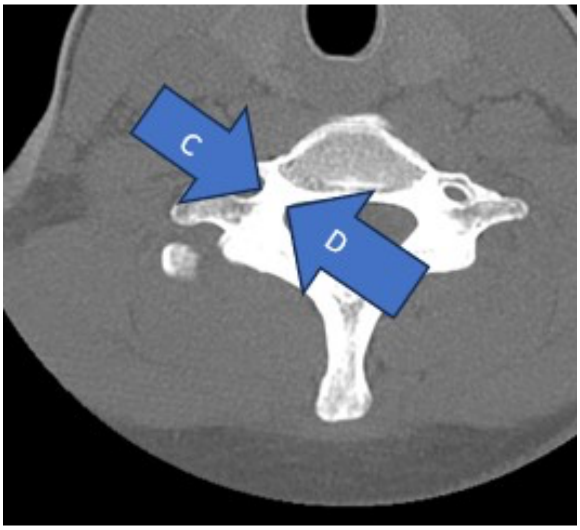

Fig. 1. Width of the right pedicle of vertebral arch

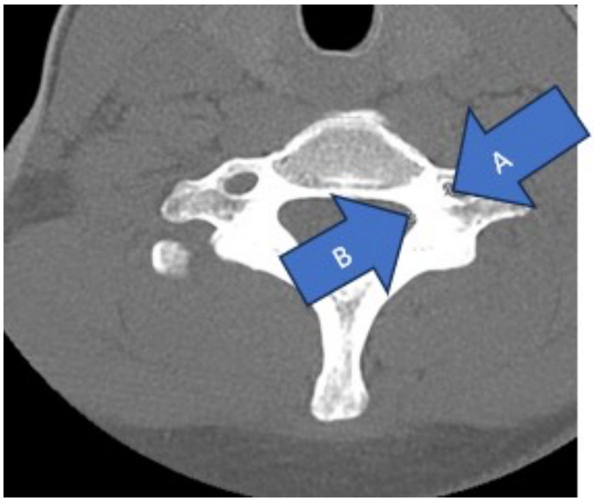

Fig. 2. Width of the left pedicle of vertebral arch

Transverse Pedicle Angle; The transverse angle of the pedicle refers to the angle between the pedicle axis and a line parallel to the vertebral midline, measured within the transverse plane. This concept is illustrated in Fig. 3 and 4.

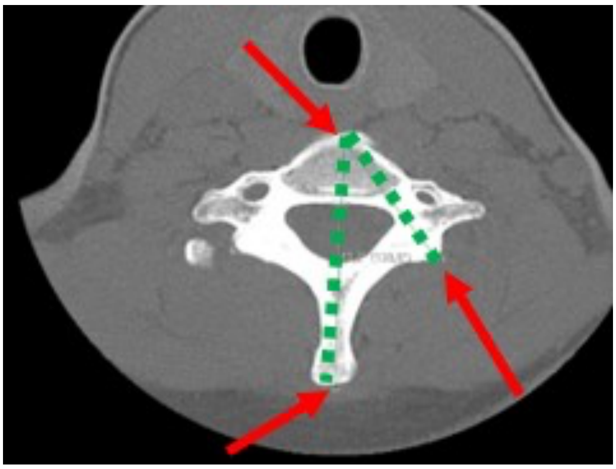

Fig. 3. Right Transverse Pedicle Angle

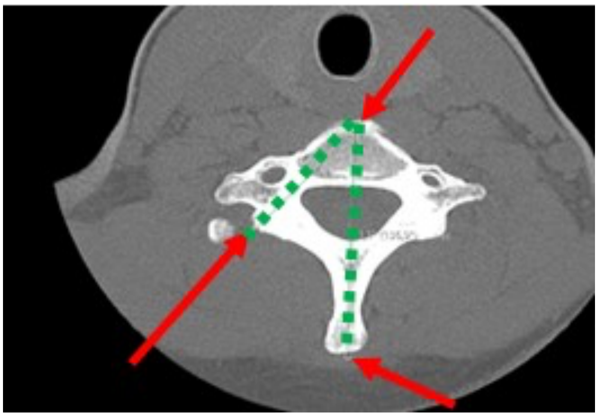

Fig. 4. Left Transverse Pedicle Angle

The anteroposterior length of the vertebral body (CVAP); was determined as the distance between the anterior vertebral body (CVA) and the posterior vertebral body (CVP). It is shown in Fig. 5.

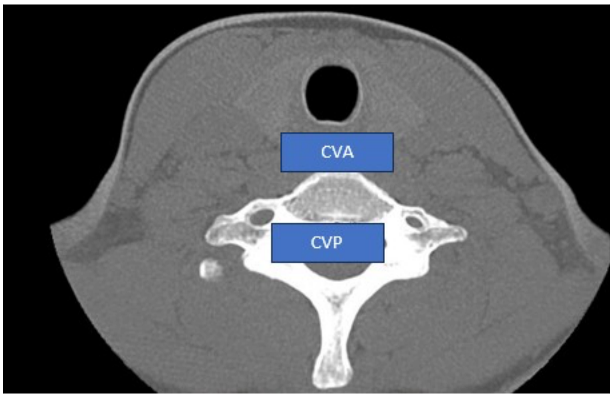

Fig. 5. The anteroposterior length of the vertebral body (CVAP)

The maximum width of the vertebral body (CVM) was defined as the distance between the medial and lateral aspects of the vertebral body. It is shown in Fig. 6.

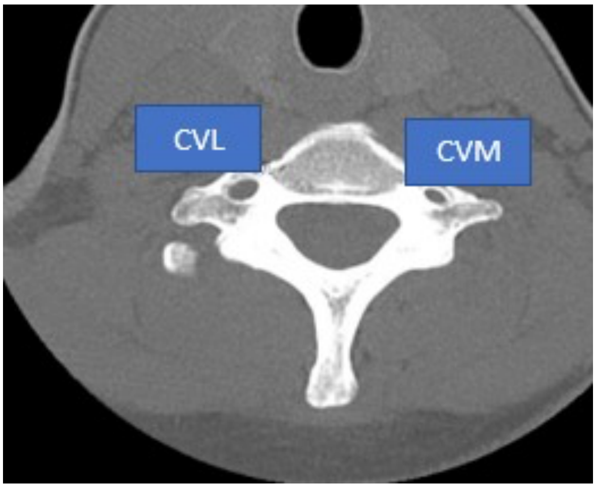

Fig. 6. The maximum width of the vertebral body (CVM)

The area of the vertebral body (CVA) was measured using the 'area' measurement option in the Sectra program by delineating the boundaries of the vertebral body on axial sections. It is depicted in Fig. 7.

Fig. 7. The area of the vertebral body (CVA)

2.2. Statistical Analysis

The data were analyzed using IBM SPSS Statistics version 23 software. First of all, the normality of the data was evaluated using Shapiro-Wilk and Kolmogorov-Smirnov tests. Subsequently, independent samples t-tests were used for normally distributed data, while Mann-Whitney U tests were utilized for non-normally distributed data when comparing two groups. Mann-Whitney U test was applied to assess the data related to gender and age. Analysis results were presented as mean ± standard deviation for quantitative data and as median (minimum - maximum) values. The significance level was set at $p < 0.050$. Comparison of normally distributed data based on gender was conducted using independent samples t-tests and Mann-Whitney U tests for non-normally distributed data based on gender. Furthermore, Spearman's rho correlation coefficient was employed to examine the relationship between age and measurement values across genders. The outcomes of these analyses were reported as mean (standard deviation) and median (minimum - maximum) values. The significance level was set at $p < 0.05$.

3. Results

To compare parameters related to the vertebra prominens based on gender, Mann-Whitney U test and independent samples t-test were utilized. The data are presented with standard deviation (SD) values. Analysis results are presented in Table 1.

The median values of the anteroposterior length of the vertebral body vary significantly based on gender ($p<0.001$). The median value for males was 15 mm, whereas for females, it was 12.7 mm. Similarly, the maximum width of the Vertebral body shows significant differences in median values by gender ($p<0.001$), with a median value of 31 mm for males and 28.7 mm for females. The area of the vertebral body exhibits varying median values by gender ($p<0.001$), measuring 351.55 mm^2 for males and 282.48 mm^2 for females. Both the right and left pediculus vertebral arch widths show significant differences in median values by gender ($p<0.001$). The median value for the right pediculus vertebral arch was 7.16 mm for males and 6.23 mm for females, while for the left, it was 7.01 for males and 6.11 for females. The right transverse pedicle angle doesn't indicate significant differences in median values by gender ($p=0.981$), measuring 41.05° for males and 41.35°

for females. Similarly, the left transverse pedicle angle shows no significant differences in median values by gender (p=0.093), with a median value of 41.06 º for males and 41.76 º for females.

Table 1. Comparisons by gender

Variable	Male (n=100)		Female (n=100)		Test Statistic	p
	Mean± (SD)	Median (min-max)	Mean± (SD)	Median (min-max)		
Anteroposterior length of vertebral body	15.01 (±1.79)	15 (11.5 - 19.7)	12.98 (1.47)	12.7 (10 - 17.8)	1899.5	<0.001[a]
Maximum width of vertebral body	31.18 (2.43)	31 (26 - 37.9)	29.05 (2.18)	28.7 (24.5 - 35.9)	2510.5	<0.001[a]
Area of vertebral body	351.55 (50.29)	353 (239 - 472)	282.48 (41.07)	277 (204 - 471)	10.6	<0.001[b]
Right pediculus arcus vertebra width	7.16 (0.95)	7.15 (4.8 - 9.6)	6.23 (0.89)	6.3 (4 - 9.8)	7.1	<0.001[b]
Left pediculus arcus vertebra width	7.01 (0.9)	7.1 (4.8 - 9.2)	6.11 (0.83)	6.1 (4.2 - 9.1)	7.4	<0.001[b]
Right transverse pedicle angle	41.03 (3.3)	41.05 (32.7 - 49.9)	40.99 (2.82)	41.35 (34.9 - 48.1)	4990.0	0.981[a]
Left transverse pedicle angle	41.06 (2.92)	41.35 (35.7 - 47.7)	41.76 (2.96)	41.4 (35.2 - 49.5)	-1.7	0.093[b]

a Mann-Whitney U test; b Independent samples t-test; SD: standard deviation

In examining the relationship between age and measurement values within genders, Spearman's rho correlation coefficient was utilized. The analysis results were presented as mean (SD) and median (min-max). A significance level of p<0.05 was considered. They were displayed in Table 2.

Table 2. Correlation Analysis Results between Age and Measurement Parameters within Each Gender

	Male (n=100)		Female (n=100)	
	r	p	r	p
Anteroposterior length of vertebral bodye	**0.252**	**0.011**	**0.418**	**0.000**
Maximum width of vertebral bodye	0.192	0.055	**0.218**	**0.029**
Area of vertebral bodye	**0.393**	**0.000**	**0.517**	**0.000**
Right pediculus vertebral arch width	-0.098	0.333	-0.097	0.339
Left pediculus vertebral arch width	-0.041	0.682	0.018	0.857
Right transverse pedicle angle	**-0.209**	**0.036**	**-0.244**	**0.015**
Left transverse pedicle angle	**-0.373**	**0.000**	**-0.368**	**0.000**

r: Spearman's rho correlation coefficient

In males, there is a statistically significant, weak positive correlation between age and the anteroposterior length of the vertebral body and the area of the vertebral body (r values of 0.252 and 0.393, respectively). Conversely, a weak negative correlation was observed between age and the right and left transverse pedicle angles (r values of -0.209 and -0.373, respectively). In females, a moderate and statistically significant positive correlation exists between age and the anteroposterior length of the Vertebral body (r=0.418). Similarly, there is a moderate and statistically significant positive correlation between age and the area of the vertebral body in females (r=0.517). Conversely, a weak negative correlation was found between age and the right and left transverse pedicle angles (r values of -0.244 and -0.368, respectively).

The identification of negative correlations between age and certain angle measurements, such as the transverse pedicle angle, is noteworthy. Consideration has been given to the reasons behind this phenomenon, with support sought from the literature. Among the potential reasons outlined in the literature are anatomical changes, physiological variations, and the intricate nature of spinal biomechanics.

Comparisons of normally distributed data between two paired groups were examined using Independent Samples t-test, while non-normally distributed data were analyzed using the Mann-Whitney U test. Analysis results were presented as mean ± standard deviation for quantitative data and as median (minimum - maximum). A significance level of p<0.050 was considered. They were displayed in Table 3.

In terms of gender comparisons, differences were noted in the anteroposterior length of the vertebral body in males (p=0.035) and females (p=0.001). However, no overall difference was observed in the maximum width of the vertebral body in males (p=0.166) and females (p=0.194). Gender-based differences were identified in the vertebral body area in both males (p=0.001) and females (p<0.001). Yet, no overall differences were found in the width of the right pedicle of the arc of the vertebra in males (p=0.26) and females (p=0.733). Similarly, no overall differences were detected in the width of the left pedicle of the arc of the vertebra in males (p=0.203) and females (p=0.887). Differences were seen in the right transverse pedicle angle in males (p=0.018) but not in females (p=0.053). However, differences were noted in both males (p<0.001) and females (p=0.007) concerning the left transverse pedicle angle. Regarding gender differences within groups, significant differences were found in the anteroposterior length, maximum width, vertebral body area, right pedicle width, and left pedicle width in both Group 1 and Group 2 (all p-values < 0.001). Conversely, no significant gender-based differences were observed in the right transverse pedicle angle in either Group 1 or Group 2 (p=0.812 and p=0.614, respectively). Similarly, no significant differences were seen in the left transverse pedicle angle concerning gender within Group 1 (p=0.443), but differences were identified in Group 2 (p=0.02).

Table 3. Comparison of Parameters between and within Groups

	Gender	Age group				Test static	p
		Group 1		Group 2			
		Mean ± (SD)	Median (min-max)	Mean ± (SD)	Median (min-max)		
Anteroposterior length of Corpus vertebrae	Male	14.71±1.84	14.60 (11.60 - 19.70)	15.35±1.70	15.40 (11.50 - 18.90)	U=939.5	**0.035**
	Female	12.51±1.24	12.30 (10.70 - 16.60)	13.34±1.54	13.40 (10.00 - 17.80)	U=744.5	**0.001**
	Test statistic	U=313.5		U=509			
	p	**<0.001**		**<0.001**			
Maximum width of Corpus vertebrae	Male	30.86±2.61	30.80 (26.00 - 37.90)	31.54±2.19	31,30 (27.60 - 36.60)	t=-1.397	0.166
	Female	28.73±2.19	28.60 (24.50 - 34.80)	29.30±2.15	28,80 (25.40 - 35.90)	t=-1.306	0.194
	Test statistic	t=4.274		t=5.23			
	p	**<0.001**		**<0.001**			
Area of Corpus vertebrae	Male	335.42±46.98	334.00 (239.00 - 426.00)	369.,74±48.07	365.00 (276.00 - 472.00)	U=779.5	**0.001**
	Female	266.23±33.78	262.00 (211.00 - 367.00)	294.74±42.08	294.00 (204.00 - 471.00)	U=693.5	**<0.001**
	Test statistic	U=263		U=272.5			
	p	**<0.001**		**<0.001**			
Right pediculus arcus vertebrae width	Male	7.27±0.83	7.20 (6.10 - 9.60)	7.03±1. 07	7.10 (4.80 - 9.30)	U=1082.5	0.260
	Female	6.25±0.86	6.30 (4.00 - 8.00)	6.20±0.92	6.30 (4.40 - 9.80)	U=1176.5	0.733
	Test statistic	U=443		U=751.5			
	p	**<0.001**		**<0.001**			
Left pediculus arcus vertebrae width	Male	7.12±0.86	7.10 (5.00 - 9.20)	6.89±0.93	7.10 (4.80 - 9.00)	t=1.282	0.203
	Female	6.10±0.80	6.10 (4.20 - 8.30)	6.12±0.86	6.10 (4.30 - 9.10)	t=-0.142	0.887
	Test statistic	t=5.966		t=4.388			
	p	**<0.001**		**<0.001**			
Right transverse pedicle angle	Male	41.76±3.11	42.00 (34.50 - 49.90)	40.21±3.34	38.80 (32.70 - 47.20)	t=2.405	**0.018**
	Female	41.62±2.74	42.00 (36.50 - 48.10)	40.51±2.81	40.60 (34.90 - 46.00)	t=1.962	0.053
	Test statistic	t=0.238		t=-0.506			
	p	0.812		0.614			
Left transverse pedicle angle	Male	42.17±2.61	42.30 (36.50 - 47.50)	39.81±2.76	39.40 (35.70 - 47.70)	U=655	**<0.001**
	Female	42.78±3.08	42.80 (37.40 - 49.50)	40.99±2.64	41.00 (35.20 - 47.10)	U=840	**0.007**
	Test statistic	U=1035.5		U=984			
	p	0.443		**0.020**			

t: Independent two-sample t-test statistic, U: Mann-Whitney U test statistic

4. Discussion

Although the typical features found in each region of the spinal column share similarities, they can vary based on factors such as gender, ethnicity, and genetic makeup (9, 10, 11). Moreover, detailed anatomical and morphological knowledge is essential for selecting appropriate instrumentation and ensuring its precise placement during cervical spine surgeries (10, 12). This study includes detailed morphometric data on vertebral body, pedicle arch vertebra and transpedicular angle in the prominence vertebra according to gender and age.

There are relevant studies in the literature with vertebral bodye morphometry (9, 10, 13, 14, 15).

Matveeva et al. recorded the anteroposterior length of the vertebral bodye as an average of 14.03 ± 1.04 mm in women and 16.55 ± 1.26 mm in men (16). Abuzayed et al. noted in their study that the anteroposterior length of the vertebral bodye at the C7 level had an average of 17.6±2.38 mm (14). Bazaldúa et al. in their study on dry bone from a population in northeastern Mexico, determined that the anteroposterior length of the vertebral bodye at the C7 level averaged 17.42±1.33 mm (15). Acar et al. in their study based on computerized tomography images, recorded the anteroposterior length of the vertebral bodye for C7 as an average of 15.00±1.96 mm in females and 17.38±2.22 mm in males (17). Prabavathy et al. found the anteroposterior length of the C7 vertebral bodye to be an average of 16.12±0.57 mm in their study conducted on the South Indian population (9). Raveendranath et al. recorded the anteroposterior length of the vertebral bodye, specifically for C7, as an average of 15.70±2.43 mm in a study they conducted. (3). In our study, we found the anteroposterior length of the vertebral bodye to be an average of 12.98±1.47 mm in females and 15.01±1.79 mm in males.

Abuzayed et al. determined the maximum width of the vertebral body to be an average of 26.7±3.1 mm for C7 (14). Bazaldúa and their team, in their study on dry bones in the population of Northeastern Mexico, found the maximum width of the vertebral body to be an average of 23.44±3.48 mm for C7 (15). Acar et al. reported in their research that the maximum width of the vertebral body was an average of 24.13±3.80 mm for C7 in females. For males, they found it to be an average of 26.25±3.48 mm for C7 (17). Raveendranath et al. recorded the maximum width of the vertebral body for the seventh cervical vertebra as 22.59±3.55 mm (3). Prabavathy et al. found the maximum width of the vertebral body for the seventh cervical vertebra (C7) to be an average of 26.12±3.76 mm in their morphometric study within the South Indian population (9). In our study, we found the maximum width of the vertebral body to be an average of 29.05±2.18 mm in females and an average of 31.18±2.43 mm in males.

The pedicle morphometrics of cervical vertebrae are crucial in determining the dimensions of instrumentation used in surgeries. Measurements of the lamina, which play a role in cervical vertebral balance, provide significant information in surgical procedures like laminoplasty and the ossification of the posterior longitudinal ligament.

Kumar et al. in their study using computer tomography images within the Indian population, found the average right pedicle width of the vertebral arch for C7 to be 6.20±0.85 mm, and the average left pedicle width to be 6.08±0.87 mm. In the same study, they recorded the average pedicle width for C7 among males as 6.33±0.74 mm and among females as 5.60±0.72 mm (18). Rao et al. in their study conducted in 2008, determined the pedicle width of the vertebral arch to be an average of 7.6 ± 1.0 mm in males and 6.5 ± 0.9 mm in females (19). Munusamy et al. recorded the pedicle width of the vertebral arch in various populations as follows: in the Chinese population, the average was 7.16 ± 0.68 mm for males and 6.30 ± 0.66 mm for females; in the Malaysian population, it was 7.17 ± 0.63 mm for males and 6.15 ± 0.47 mm for females; and in the Indian population, it was 5.73 ± 1.09 mm for males and 6.48 ± 0.85 mm for females. (20). In our study, we found the average right pedicle width of the vertebral arch to be 6.23±0.89 mm in females and 7.16±0.95 mm in males. Additionally, the average left pedicle width was 6.11±0.83 mm in females and 7.01±0.9 mm in males.

Rao et al. found the mean transverse pedicle angle for C3 to be 46.6° ± 3.2° in females and 47.4° ± 3.4° in males, for C4 it was 47.8° ± 2.9° in females and 47.8° ± 3.6° in males, for C5 it was 46.9° ± 4.2° in females and 45.9° ± 3.6° in males, for C6 it was 42.5° ± 4.5° in females and 41.8° ± 4.3° in males, and for C7 it was 33.8° ± 5.7° in males and 33.0° ± 5.6° in females (19). Additionally, Herrero et al. in their study on the Brazilian population, recorded the transverse pedicle angle in degrees as follows: for C3, the mean was 45.6° ± 3.79 in males and 45.1° ± 3.54 in females, for C4 it was 46.3° ± 3.97 in males and 45.7° ± 3.31 in females, for C5 it was 46.4° ± 4.57 in males and 46.0° ± 3.75 in females, for C6 it was 45.3° ± 5.46 in males and 44.4° ± 3.86 in females, and for C7 it was 43.8° ± 7.16 in males and 41.0° ± 4.64 in females (21). In our study, we found the mean right transverse pedicle angle to be 40.99° ± 2.82° in females and 41.03° ± 3.3° in males. Additionally, we determined the mean left transverse pedicle angle to be 41.76° ± 2.96° in females and 41.06° ± 2.92° in males. Our study aligns with the existing literature.

Considering the limitations of our study, which is based on a retrospective design, it encompasses certain constraints in the data collection process. Owing to its retrospective nature, uncertainties regarding the accuracy and completeness of the data may arise. Furthermore, there are certain limitations pertaining to the reliability and standardization of the measurement tools utilized in the study. The sample size and representativeness may exhibit disparities in a cohort study encompassing a broad age range, thereby limiting the generalizability of the findings. Nevertheless, notwithstanding these limitations, it is anticipated that the data furnished by the study will contribute to the existing body of knowledge and provide guidance for pertinent research endeavors.

Conflict of interest

The authors declared no conflict of interest.

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None to declare.

Authors' contributions

Concept: M.A.G, M.F.Ö, Design: M.F.Ö, Data Collection or Processing: M.F.Ö., Analysis or Interpretation: M.B., M.A.G., Literature Search: M.F.Ö., M.A.G., Writing: M.F.Ö.

Ethical Statement

This study was found ethically appropriate by the Tokat Gaziosmanpaşa University Clinical Research Ethics Committee on 16.03.2023 with the decision number 23-KAEK-069 . No budget was used for the study.

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