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Morphological Status of Cervical Vertebrae (C3-C7) in Patients in west of Iran

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ABSTRACT

Introduction: The cervical spine, endowed with significant mobility due to two specialized vertebrae connected to the skull, can suffer from unnatural positioning, leading to asymmetry and injuries. This study was conducted to examine the morphological status of cervical vertebrae (C3-C7) in a clinical population.

Materials & Methods: This cross-sectional study was conducted with 450 patients with neck trauma between December 2018 and August 2019 at Taleghani Hospital, a tertiary referral center in Kermanshah, Iran. Demographic data, including age, gender, height, and BMI, were collected. Morphological measurements were obtained from CT scans, complemented by MRI in selected cases. Parameters included vertebral body dimensions, foramina size, and facet lengths. Statistical analysis was performed using SPSS v22. Quantitative variables were assessed with t-tests and ANOVA. A significance level of P<0.05 was considered.

Results: Significant differences were found in the dimensions of vertebrae C3–C7 among demographic subgroups (P<0.01). Vertebral body width, length, height, and foramina dimensions were generally larger in males, patients over 60 years old, individuals taller than 180 cm, and those with higher BMI values.

Conclusion: The study concludes that the vertebral body dimensions at levels C3–C7 are significantly larger in males, individuals over 60 years of age, those taller than 180 cm, and those with higher BMI values.

Keywords: Cervical Vertebrae, Spine, Patients

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Introduction

The cervical spine was comprised of seven vertebrae (C1-C7), which constituted the smallest part. The cervical spine consists of seven vertebrae, labeled C1 through C7, which make up the smallest segment of the vertebral column (1). These vertebrae are crucial for maintaining the structure and function of the spine. The vertebrae and the intervertebral discs create vital spaces through which spinal nerves exit the spinal cord (2). The cervical spine forms a natural lordotic curve, which enhances the flexibility and range of motion of the neck (3). When compared to the lumbar or thoracic vertebrae, the cervical vertebrae are distinctive in both structure and function (4). A defining feature of the cervical vertebrae is the presence of transverse foramina, small openings that allow for the passage of vertebral arteries and veins, with the exception of C7, which contains only a vein (5). These vertebrae are also characterized by the highest intervertebral disc height among all spinal regions, contributing to a greater range of motion (6). The spine's role extends beyond structural support, also protecting the spinal cord, supporting the thorax and abdomen, and allowing for critical neck movements, such as rotation (7). The ability to identify and understand pathological changes in the cervical vertebrae hinges on establishing a standard for their normal morphology and examining the evolutionary factors that have shaped their development (8). Various factors, including age, sex, ethnicity, trauma, congenital defects, and lifestyle habits, have been shown to influence the anatomy of the cervical vertebrae, making these elements critical for both diagnosis and treatment planning (9). As individuals age, changes such as instability, disc herniation, spinal stenosis, and alterations in vertebral joints may occur, which complicate the management of cervical spine conditions (10). In Iran, trauma is the second leading cause of death after cardiovascular diseases, and cervical spine injuries account for 2-3% of all non-penetrating trauma cases. This high incidence highlights the importance of understanding cervical spine injuries due to their potential for significant morbidity and mortality (11). Research underscores that a thorough understanding of cervical spine anatomy (C1-C7), particularly in relation to the vertebral arteries, can help prevent damage to vital structures during surgical or clinical interventions (12). Given the high prevalence of spinal complications, the combination of MRI and CT scans has proven effective in assessing and diagnosing spinal injuries, offering complementary insights into the anatomy and pathology of the spine (13, 14). Recent studies, such as the work by Hussain and Kaushal (2023), have emphasized the significant role these imaging techniques play in diagnosing spinal cord injuries and facilitating early treatment (1). Advances in medical imaging, as well as computational modeling techniques, have provided new ways to assess cervical spine morphology in greater detail. Three-dimensional (3D) reconstructions from CT and MRI have allowed for more precise visualization of vertebral alignment, disc degeneration, and anatomical variations, which are critical for surgical planning and postoperative care (15). Furthermore, artificial intelligence and deep learning models have increasingly been applied to automate the assessment of spinal structures, aiding in the early detection of potential issues and improving patient outcomes (16). The knowledge of cervical spine morphology is essential for both clinical and surgical practices, and creating population-specific reference data for cervical anatomy can enhance diagnostic accuracy and improve treatment strategies (17). Additionally, biomechanical studies have demonstrated that changes in cervical spine morphology can influence spinal stability and the likelihood of degenerative diseases, underlining the importance of combining morphological analysis with functional assessments to optimize patient care (18). Furthermore, biomechanical studies showed that changes in cervical morphology affected spinal stability and susceptibility to degenerative diseases, underscoring the need to integrate morphological analysis with functional assessments (19, 20).

This study was aimed at filling research gaps by examining key determinants of cervical spine morphology (C3-C7) through advanced imaging, biomechanical evaluations, and statistical analyses.

Materials and methods

Study Design, Setting and participants

This cross-sectional study was conducted between December 2018 and August 2019 at Taleghani Hospital, a tertiary referral center in Kermanshah, Iran. The study examined the morphological status of the cervical spine in patients with neck trauma referred to the hospital during this period. Data collection tools included standardized checklists containing demographic and medical record information. Patients were categorized into three age groups: 20–39 years, 40–59 years, and over 60 years. Based on the demographic distribution in the target population, 302 men (67%) and 148 women (33%) were included. Patients were randomly selected according to their date of referral. Individuals with acute or previous cervical fractures were excluded from the study.

Sample Size

The sample size was calculated to estimate a population proportion using the following formula:

$$n = \frac{z^2 \cdot p \cdot (1 - P)}{d^2}$$

where: n is the required sample size,Z is the Z-score corresponding to the desired confidence level (1.96 for 95% confidence),p is the estimated proportion of the attribute of interest in the population (assumed to be 0.5 to maximize sample size),d is the desired margin of error (set at 0.05).

$n=(1.96)^2\times0.5\times(1-0.5)/(0.05)^2=3.8416\times0.250/0.0025=384.16$

Thus, the minimum sample size required was approximately 385 patients. To compensate for potential non-response, dropouts, and to ensure sufficient statistical power for subgroup analyses (e.g., by gender), the sample size was increased by approximately 15%, resulting in a total of 450 patients.

Measurements & Validity and Reliability

The initial CT scans of the patients were examined, and in addition to CT scans, MRI scans were conducted for a subset of patients to provide a comprehensive analysis of cervical spine morphology. The MRI scans were performed using a 1.5 Tesla MRI machine, with parameters including T1-weighted and T2-weighted sequences in the sagittal and axial planes. These scans provided detailed images of the soft tissues, intervertebral discs, and spinal cord, complementing the bony structures visualized in the CT scans. The morphological status of the cervical spine was measured using indices such as superior vertebral body width, superior vertebral body length, inferior vertebral body width, inferior vertebral body length, and measurements related to the width and height at each disc level (anterior vertebral body height and posterior vertebral body height). Measurements of superior vertebral foramina width, superior vertebral foramina length, and the lengths of right and left superior facets were performed in the mid-sagittal plane. Also, demographic variables included age, gender, and height.

Ethical consideration

This study was approved by the Ethics Committee of Kermanshah University of Medical Sciencess (IR.KUMS.REC.1399.937). Informed consent was obtained from all participants, who were informed about the study's purpose and their right to withdraw at any time. Data were kept confidential and anonymized to protect participants' privacy.

Statistical and Data Analysis

The data analysis methods in this study were conducted using SPSS V.22 in accordance with standard practices reported in similar cross-sectional studies (Ghasemi & Zahediasl, 2012). Normality of continuous variables was assessed using the Shapiro-Wilk test and visual inspection of histograms and Q-Q plots. Quantitative data were analyzed using independent t-tests for comparisons between two groups and one-way ANOVA for comparisons among more than two groups. A significance level of p < 0.05 was set to determine statistical significance.

Results

The data analysis methods in this study were conducted using SPSS V.22 in accordance with standard practices reported in similar cross-sectional studies (Ghasemi & Zahediasl, 2012). Normality of continuous variables was assessed using the Shapiro-Wilk test and visual inspection of histograms and Q-Q plots. Quantitative data were analyzed using independent t-tests for comparisons between two groups and one-way ANOVA for comparisons among more than two groups. A significance level of p < 0.05 was set to determine statistical significance.

Table 1. Demographic characteristics of patients with morphological problems of the cervical spine.

Variables		Mean (Standard Deviation)	Frequency (%)
Age (year)	20-39	--	176 (39.1)
	40-59	--	168 (37.3)
	Above 60	--	106 (23.6)
Gender	Male	--	302 (67.1)
	Female	--	148 (32.9)
Height (cm)		173.51 (10.45)	--

The findings indicated significant differences between men and women in the dimensions of specific vertebrae: C4, C5, and C7 vertebrae showed differences in superior vertebral body width; C3 and C4 vertebrae in superior vertebral body length; C4 and C5 vertebrae in inferior vertebral body width; C6 vertebra in anterior vertebral body height; C3 and C4 vertebrae in posterior vertebral body height; and C6 and C7 vertebrae in superior vertebral foramina width (P<0.01). The mean measurements of these vertebrae, including height, width, and length, were higher in men compared to women, as shown in Table 2.

Table 2. The relationship between gender and morphological status of the patients.

Variables		Male		Female		P-value
		Mean(mm)	SD	Mean(mm)	SD	
SVBW	C3	24.86	2.94	24.59	2.57	0.357
	C4	24.35	4.31	23.78	3.99	0.039
	C5	24.38	3.69	23.81	3.92	0.045
	C6	24.57	2.81	24.45	3.062	0.157
	C7	24.50	3.99	25.20	3.99	0.044
SVBL	C3	16.01	1.71	16.17	1.76	0.041
	C4	23.17	3.71	22.98	3.80	0.032
	C5	18.56	4.35	18.46	4.28	0.141
	C6	16.49	2.20	16.28	1.64	0.081
	C7	23.66	3.84	23.81	3.56	0.349
IVBW	C3	23.65	3.83	23.54	3.54	0.678

	C4	17.22	3.46	16.63	3.01	0.042
	C5	24.34	2.40	23.21	2.49	0.048
	C6	24.18	3.69	24.03	2.91	0.660
	C7	24.85	3.12	24.40	2.96	0.136
IVBL	C3	17.37	3.21	17.49	3.39	0.714
	C4	16.27	2.05	16.03	2.00	0.242
	C5	16.21	1.90	16.12	1.94	0.650
	C6	16.41	2.17	16.32	1.92	0.315
	C7	16.32	2.08	16.27	2.04	0.799
PVBH	C3	16.96	2.06	16.41	1.89	0.007
	C4	16.13	1.92	16.20	2.02	0.005
	C5	15.92	2.08	16.26	1.92	0.096
	C6	16.15	1.88	16.21	2.03	0.732
	C7	15.94	2.08	15.66	1.72	0.124
SVFW	C3	22.10	4.17	21.71	4.39	0.365
	C4	23.48	3.15	23.97	3.10	0.115
	C5	24.68	2.75	24.42	2.75	0.339
	C6	25.17	2.91	25.26	3.12	0.004
	C7	23.33	3.60	24.32	3.05	0.003
SVFL	C3	16.31	2.15	16.34	2.26	0.919
	C4	16.39	2.23	16.35	2.09	0.868
	C5	16.54	2.46	16.46	2.16	0.725
	C6	18.59	4.82	18.80	4.70	0.666
	C7	16.68	2.64	16.41	2.47	0.297

SVBW: Superior Vertebral Body Width
SVBL: Superior Vertebral Body Length
IVBW: Inferior Vertebral Body Width
IVBL: Intervertebral Body Length
AVBH: Anterior Vertebral Body Height
PVBH: Posterior Vertebral Body Height
SVFW: Superior Vertebral Foramina Width
SVFL: Superior Vertebral Foramina Length

The results indicated that the C3 and C5 vertebrae in superior vertebral body width, the C3 and C4 vertebrae in superior vertebral body length, the C4 vertebra in inferior vertebral body width, the C4 and C5 vertebrae in posterior vertebral body height, the C6 vertebra in superior vertebral foramina width, and the C3 vertebra in superior vertebral foramina length had significant differences among different ages (P<0.01). The mean of these vertebrae (in terms of height, width, and length) was higher and wider in individuals over 60 years of age compared to younger age groups (Table 3).

Table 3. Determining the relationship between age and morphological status in the study population.

Variables		20-39 (year)		40-59 (year)		Above 60 (year)		P-value
		Mean(mm)	SD	Mean(mm)	SD	Mean(mm)	SD	
SVBW	C3	24.95	2.78	24.89	2.37	25.28	3.48	0.013
	C4	24.09	3.95	24.84	4.20	24.89	4.60	0.121

	C5	23.94	3.32	24.39	4.10	24.31	3.95	0.044
	C6	24.60	2.81	24.58	2.95	24.34	2.94	0.514
	C7	24.65	3.85	24.37	3.97	25.43	4.24	0.154
SVBL	C3	16.16	1.82	16.05	1.79	17.92	1.45	0.008
	C4	22.93	3.64	23.40	3.55	24.97	4.15	0.045
	C5	18.56	4.28	18.59	4.25	18.37	4.52	0.512
	C6	16.37	1.86	16.42	2.28	16.53	1.89	0.165
	C7	23.53	4.14	23.96	3.43	23.60	3.55	0.194
IVBW	C3	23.64	3.63	23.81	3.73	23.25	3.92	0.376
	C4	16.97	3.23	17.15	3.65	16.94	2.94	0.044
	C5	24.31	2.49	24.34	2.56	24.21	2.11	0.737
	C6	24.15	3.36	23.90	3.38	24.46	3.72	0.646
	C7	24.82	3.06	24.72	2.88	24.46	3.38	0.260
IVBL	C3	17.57	3.24	17.22	3.34	17.46	3.21	0.297
	C4	16.20	1.89	16.16	2.13	16.24	2.14	0.916
	C5	16.18	2.01	16.12	1.82	16.27	1.91	0.827
	C6	16.15	2.22	16.19	2.10	16.21	1.87	0.866
	C7	16.34	2.15	16.26	1.93	16.30	2.16	0.887
AVBH	C3	16.05	1.97	16.10	1.94	15.79	1.63	0.385
	C4	16.56	2.38	16.59	2.25	16.26	2.17	0.605
	C5	16.39	1.95	16.42	1.93	16.74	2.13	0.320
	C6	16.23	2.02	16.14	2.21	16.36	2.03	0.757
	C7	16.35	2.10	16.17	1.96	16.17	1.79	0.441
PVBH	C3	16.83	2.02	16.70	1.97	16.82	2.11	0.662
	C4	16.28	2.21	16.19	1.68	15.89	1.89	0.035
	C5	16.26	2.15	15.95	2.00	15.79	1.84	0.032
	C6	16.07	2.00	16.11	1.73	16.43	2.09	0.212
	C7	15.94	2.02	15.91	2.11	15.60	1.64	0.404
SVFW	C3	21.67	4.39	22.10	4.47	22.26	3.57	0.441
	C4	23.88	3.12	23.42	3.16	23.59	3.14	0.344
	C5	24.68	2.53	24.63	2.90	24.41	2.86	0.783
	C6	25.42	2.98	25.22	3.07	24.81	2.81	0.001
	C7	23.58	3.60	23.71	3.53	23.69	3.11	0.636
SVFL	C3	16.50	2.34	16.10	1.93	16.38	2.28	0.015
	C4	16.30	2.06	16.41	2.15	16.44	2.42	0.812
	C5	16.68	2.39	16.46	2.24	16.31	2.52	0.471
	C6	18.59	4.67	18.79	4.80	18.58	4.93	0.663
	C7	16.63	2.68	16.54	2.58	16.61	2.47	0.602

SVBW: Superior Vertebral Body Width
SVBL: Superior Vertebral Body Length
IVBW: Inferior Vertebral Body Width
IVBL: Intervertebral Body Length
AVBH: Anterior Vertebral Body Height
PVBH: Posterior Vertebral Body Height
SVFW: Superior Vertebral Foramina Width
SVFL: Superior Vertebral Foramina Length

The results showed that the C5 and C6 vertebrae in the superior vertebral body width, the C3 and C4 vertebrae in the inferior vertebral body length, and the C5 vertebra in the posterior vertebral body height had significant differences among different heights (P<0.01) (Table 4)

Table 4. Determining the relationship between height and morphological status in the study population.

Variables		140-159 (cm)		160-179 (cm)		Above 180 (cm)		P-value
		Mean(mm)	SD	Mean(mm)	SD	Mean(mm)	SD	
SVBW	C3	24.62	2.32	24.73	2.70	24.90	3.19	0.699
	C4	24.49	3.99	24.76	4.38	24.03	3.97	0.597
	C5	23.48	3.80	24.42	3.75	24.08	3.80	0.001
	C6	24.24	2.49	24.55	3.05	24.61	2.76	0.045
	C7	24.59	3.65	24.81	4.08	24.64	4.00	0.808
SVBL	C3	16.44	1.87	16.06	1.80	15.93	1.54	0.065
	C4	22.64	3.99	23.13	3.63	23.23	3.83	0.961
	C5	18.48	3.93	18.43	4.17	18.71	4.70	0.141
	C6	16.41	1.80	16.42	1.85	16.44	2.38	0.081
	C7	24.45	3.18	23.65	3.74	23.54	3.93	0.065
IVBW	C3	23.41	3.12	23.44	3.90	23.98	3.64	0.084
	C4	16.59	3.03	17.06	3.39	17.12	3.33	0.998
	C5	24.85	1.67	24.21	2.59	24.26	2.33	0.652
	C6	24.12	3.42	23.90	3.29	24.52	3.71	0.664
	C7	24.33	2.73	24.61	3.12	24.97	3.09	0.923
IVBL	C3	17.93	3.08	17.56	3.51	18.99	2.85	0.011
	C4	15.93	1.95	16.22	2.00	16.24	2.12	0.041
	C5	15.71	1.84	16.19	2.00	16.33	1.77	0.598
	C6	16.28	2.17	16.23	1.96	16.07	2.28	0.572
	C7	16.07	1.82	16.28	2.10	16.41	2.09	0.964
AVBH	C3	15.94	1.61	15.94	1.80	16.15	2.10	0.701
	C4	16.24	1.94	16.74	2.48	16.20	2.00	0.492
	C5	16.86	2.22	16.38	2.00	16.52	1.87	0.523
	C6	16.04	1.66	16.282	2.05	16.32	2.28	0.920
	C7	16.37	2.32	16.18	2.04	16.30	1.73	0.536
PVBH	C3	16.04	1.84	16.66	1.87	17.22	2.22	0.162
	C4	16.66	2.54	16.11	1.79	16.06	1.96	00.151
	C5	16.59	2.21	15.88	1.79	16.10	2.30	0.010
	C6	15.86	1.48	16.32	2.11	16.02	1.72	0.262
	C7	15.47	1.70	15.84	2.01	16.00	1.99	0.068
SVFW	C3	22.63	3.95	21.89	4.29	21.87	4.26	0.243
	C4	24.03	2.55	23.71	3.07	23.39	3.41	0.906
	C5	24.20	3.03	24.81	2.52	24.38	2.99	0.540
	C6	25.45	2.75	25.21	3.02	25.10	2.99	0.724
	C7	24.37	3.88	23.71	3.24	23.33	3.63	0.271
SVFL	C3	16.57	2.36	16.33	2.08	16.22	2.30	0.156
	C4	16.48	1.81	16.39	2.21	16.31	2.26	0.720
	C5	16.29	1.96	16.45	2.47	16.68	2.32	0.852
	C6	19.36	4.80	18.56	4.79	18.58	4.75	0.462
	C7	16.26	2.49	16.54	2.45	16.80	2.84	0.390

SVBW: Superior Vertebral Body Width
SVBL: Superior Vertebral Body Length
IVBW: Inferior Vertebral Body Width

IVBL: Intervertebral Body Length
AVBH: Anterior Vertebral Body Height
PVBH: Posterior Vertebral Body Height
SVFW: Superior Vertebral Foramina Width
SVFL: Superior Vertebral Foramina Length

Discussion

The aim of the current study was to investigate the differences in the size of cervical vertebrae between men and women. Our findings, based on the analysis of 450 patients at Taleghani Hospital in Kermanshah, indicate that the mean height, width, and length of cervical vertebrae were greater in men than in women. This is in line with the studies by Ezra et al. [14,15], which found that the size and shape of cervical vertebrae (C3-C7) significantly correlate with gender, showing that male vertebrae are larger than those of females. Conversely, our findings differ from those of Smith et al. [18], who reported no significant gender differences in cervical vertebrae size. These inconsistencies may be attributed to variations in sample size, methodology, or population characteristics.

The findings of this research align with the study by Been, Shefi, and Soudack, which examined the influence of gender on cervical spine lordosis. Their work highlighted the importance of considering a patient's gender before neck stabilization or repair procedures (18, 19). Additionally, a study demonstrated that Cervical Vertebral Body Height (CHT) and Cervical Transverse Radius (CTR) showed a significant correlation with gender in their comprehensive analysis of two distinct European populations, highlighting the anatomical variations influenced by sex differences.

Johnson RD et al. investigated the radiographic components of Forward Head Posture (FHP) and its relationship with gender and height in a study of 300 students using Posture Pro V software. Their results indicated that men and taller individuals exhibited less severe FHP and better cervical lordosis than women and shorter individuals. Additionally, severe FHP was linked to reduced cervical lordosis and the potential development of neck kyphosis (21), consistent with our findings regarding the impact of gender on cervical spine morphology.

A systematic review and meta-analysis examined the effects of therapeutic exercises on forward head posture, rounded shoulders, and hyperkyphosis in individuals with upper crossed syndrome, studying 300 students. They found that these exercises effectively alleviated symptoms, including changes in cervical spine curvature (22). Both this study and mine focus on the impact of forward head posture on cervical spine structure and curvature, highlighting gender and height differences. Both studies suggest that women and shorter individuals are more adversely affected by forward head posture, which can reduce cervical lordosis and lead to neck kyphosis.

A study complements our research. It assessed the prevalence of forward head position in 480 students, finding significant variations related to gender and physical activity, but not visual impairment (23). Their findings confirm the relationship between gender and the morphological status of the cervical spine, consistent with our study. The study examined 616 middle school students (300 girls and 316 boys aged 12 to 15) for spinal posture abnormalities. The results showed that approximately 80.68% of participants had postural issues, with a higher prevalence in girls than boys, indicating a significant gender difference in spinal health (24). This finding aligns with the results of our research.

The findings indicate that the average height, width, and length of cervical vertebrae were greater in individuals over 60 years compared to younger ages. This is consistent with the studies by Ezra et al., which suggested that as patients age, the cervical vertebrae become more elongated, wider, and shorter

(16, 17). Our study also found significant differences in the morphological status of specific vertebrae across age groups: C3 and C5 had a wider superior vertebral body, C3 and C4 had greater superior vertebral body length, C4 had a wider inferior vertebral body, and C4 and C5 had increased posterior vertebral body height. Additionally, C6 showed a wider superior vertebral foramen, while C3 had a longer superior vertebral foramen. Overall, these results confirm that the cervical vertebrae are larger in individuals over 60 years. Ezra et al. conducted a study analyzing CT scans of the cervical spine (C3-C7) from 273 patients and found that the prevalence of osteophytes was significantly related to age, particularly in the upper cervical vertebrae (C3-C4), which aligns with our research findings (24). Additionally, Parenteau et al. conducted a study to determine the anatomical characteristics of the cervical spine based on age. Their analysis included CT scans from 750 patients, comprising 314 children and 436 adults, in accordance with their research objectives.

Evidence indicates that the height of the vertebral body has a positive, non-linear, and statistically significant relationship with patients' age, supporting the findings of our research (25). A review by Parenteau CS et al. examined the impact of age on cervical spine alignment and range of motion from 1999 to 2020, analyzing 37 articles. The findings indicate that aging is associated with changes in cervical spine mobility and alignment, with a general trend of decreased range of motion, although this pattern varies among different age groups (26).

The average dimensions (height, width, and length) of cervical vertebrae were higher and wider in individuals over 180 centimeters tall compared to those of shorter stature. The analysis of the relationship between height and morphological status showed significant differences in vertebrae: C5 and C6 had a wider superior vertebral body, C3 and C4 had greater inferior vertebral body length, and C5 exhibited increased posterior vertebral body height among taller individuals. Norasteh A et al. examined 120 patients across three age groups: 8 years, 12-13 years, and 17-18 years. The researchers found a significant statistical relationship between the angle of cervical lordosis and both the anterior and posterior heights of the vertebral body (AVBH & PVBH) for C3, C4, and C5, as well as the anterior intervertebral space of C4-C5 and the posterior spaces of C2-C3, C3-C4, and C4-C5 (27). Research indicates a high prevalence of postural abnormalities among university students. One study found that 46.66% of male students reported no abnormalities, while 53.34% had at least one, with 23.33% exhibiting more than one abnormality, the most common being cervical lordosis and flat feet. Another study revealed that 92.7% of students had physical abnormalities, with uneven shoulders as the most frequent issue for both genders, followed by lordosis. These findings highlight the urgent need for programs addressing these concerns, including the promotion of corrective exercises and physical education courses. Teaching proper techniques for sleeping, walking, sitting, and carrying can help prevent significant costs and lengthy clinical treatments. The studies underscore the importance of integrating physical activities and corrective exercises into students' educational programs (28, 29). Both conclusions align with the results of our research.

A strength of this study is the large sample size, which enhances the reliability and generalizability of the results. However, the study's limitations include its cross-sectional design, which prevents us from drawing causal conclusions, and the lack of consideration for other potential confounding factors, such as physical activity, occupation, and medical history.

Conclusion

IOur analysis revealed noteworthy correlations between morphological features and demographic factors. It was discerned that dimensions such as width, length, and height of the vertebral bodies from

C3 to C7 tend to be more pronounced in male subjects, individuals aged above 60, and those taller than 180 centimeters. Additionally, our study highlighted distinct morphological disparities across various vertebral levels. Future studies should build on these findings by incorporating longitudinal designs, multi-center data, and comprehensive clinical evaluations to further validate and expand upon our results.

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Conflict of interest

There are no conflicts of interest.

Authors' contributions

Methodology: BS, IC, Validation, Resources, Supervision: IC, MRA, Investigation: AS, MRA, Data Curation, Visualization: BS, AS, Writing–Review & Editing: BS, IC, AS, MRA, Formal Analysis, Writing–Original Draft Preparation, Project Administration: BS.

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