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RESEARCH

Radiological and anatomical evaluation of the cervical spinal cord, spinal canal, and intervertebral disc morphometry in healthy adults

Sağlıklı yetişkinlerde servikal spinal kord, spinal kanal ve intervertebral disk morfometrisinin radyolojik ve anatomik değerlendirmesi

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Abstract

Purpose: The aim of this study was to examine the normal values of the cervical spinal cord, spinal canal, and intervertebral disc morphometry of healthy subjects in this study

Materials and Methods: Cervical magnetic resonance imaging of 83 healthy subjects were examined retrospectively. The anterior and posterior height of each cervical vertebra body, anterior and posterior height of each intervertebral disc between C3-T1, and spinal canal and cord diameters were measured. Additionally, the height ratios of the cervical vertebra body and intervertebral disc were calculated.

Results: There was no significant difference between genders in spinal cord diameters from C1 to C7, whereas there was a significant difference between genders in spinal canal diameters from C1 to C4. There were significant differences between genders in terms of anterior and posterior vertebral body height from C3 to C7 level. Moreover, significant differences between genders in terms of anterior and posterior intervertebral height from C3-4 to C7-T1 level (except C6-7 intervertebral anterior height) were found.

Conclusion: We would like to stress that the cervical region is a clinically important structure because of its location, surgical importance, its exposure to a large number of injuries, Gender plays the most important role in spinal canal morphometry, following vertebral body heights and intervertebral heights.

Keywords:. Cervical spine, spinal cord, spinal canal, intervertebral disc

Öz

Amaç: Bu çalışmada, sağlıklı bireylere ait servikal spinal kord, spinal kanal ve discus intervertebralis morfometrisinin normal değerlerini değerlendirmek amaçlandı

Gereç ve Yöntem: Sağlıklı 83 bireyin regio cervicalis manyetik rezonans görüntüleri retrospektif olarak incelendi. Her bir corpus vertebrae anterior ve posterior yüksekliği, C3-T1 arasındaki her bir discus intervertebralis anterior ve posterior yüksekliği, spinal kanal ve spinal kord çapları ölçülmüştür. Ayrıca, corpus vertebra (vertebrae cervicales) ve discus intervertebralis yükseklik oranları hesaplanmıştır.

Bulgular: C1'den C7'ye kadar spinal kord çapları açısından cinsiyetler arasında anlamlı fark bulunmazken, C1'den C4'e kadar spinal kanal çapları açısından cinsiyetler arasında anlamlı fark vardı. C3 seviyesinden C7 seviyesine kadar anterior ve posterior corpus vertebrae yüksekliği açısından cinsiyetler arasında anlamlı farklılıklar vardı. Ayrıca, C3-4'ten C7-T1 seviyesine kadar (C6-7 discus intervertebralis anterior yükseklik hariç) anterior ve posterior discus intervertebralis yükseklik açısından cinsiyetler arasında anlamlı farklılıklar bulundu..

Sonuç: Regio cervicalis konumu, cerrahi önemi, çok sayıda yaralanmaya maruz kalması gibi nedenlerle klinik olarak önemli bir yapı olduğunu vurgulamak isteriz. Cinsiyet, öncelikle spinal kanal morfometrisinde önemli bir rol oynarken, bunu corpus vertebrae ve discus intervertebralis yükseklik parametreleri takip eder.

Anahtar kelimeler: Servikal omurga, spinal kord, spinal kanal, intervertebral disk

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INTRODUCTION

The 33-bone vertebral column also forms the subcranial part of the axial skeleton. It is divided into five regions according to curvature and morphology: The cervical region is one of these regions and comprises seven vertebrae referred to as C1 to C7[1-3]. The cervical spine has many critical roles such as supporting the head on the trunk and allowing the head and neck to move in three axes: flexion, extension, lateral flexion, and rotation to two sides. It protects the spinal cord and nerve roots with its joints and complex musculature[1,3-8]. Besides, the intervertebral discs play a critical role in this mobility and, along with the laminae and the articular processes of adjacent vertebrae, create a space where spinal nerves exit. The decreased size of the cervical vertebra permits the largest range of motion of all segments[3]. The cervical region is subject to many problems ranging from degenerative, and traumatic to inflammatory conditions. Also, many factors including age and gender, should be kept in mind when performing spinal cord and canal measurements, which may be necessary for the detection and diagnosis of potential pathologies[1,3,5]. Also, it was reported that it was possible to reveal the vertebral structures and deformity by using some measurements made from the vertebral body and the indices obtained by using these measurements[4,9]. Spine and intervertebral discs may show a decrease in load-carrying capacity due to various reasons such as aging and overload. It is one of the most common areas where degenerative changes are seen[4,10,11]. Therefore, the critical importance of this region is increasing day by day. Additionally, the Magnetic Resonance Imaging (MRI) method is the most effective and widely preferred method for the evaluation of spinal canal and cord dimensions as well as reflecting vertebral morphometry more accurately[4,5,12].[4,5,12].

The cervical vertebrae's body is the lowest. Also, tumors, infections, trauma, and degenerative changes such as intervertebral disc herniation, and osteophytes can induce the cervical canal to narrow[13]. Morishita et al. suggested that a cervical spinal canal diameter of less than 13mm might predispose to the development of pathological changes in the cervical intervertebral discs, and the presence of a congenitally narrow canal may be an important reason for the development of cervical spinal stenosis[14]. The spinal cord size might be different among individuals and between different vertebral levels[15-17]. A congenital narrowness of this canal, with herniated discs, osteophytic spurs, and hypertrophy of the ligamenta flava or facet joints, rather than pathological changes, is a major obstacle for the development of spinal cord compression, resulting in a greater mechanical load on the lower cervical segments[14].

The cervical region is a clinically important structure due to the relation of important structures, its location, its surgical importance, and its exposure to a large number of injuries, allowing very wide movements of the head and neck. Also, this region is a very critical region for the continuation of daily life activities. So, we hypothesized that the structures of the cervical region may be affected by many factors such as gender or aging. Therefore, we aimed to evaluate the normal values of the cervical region morphology and morphometry between C3-T1. Also, we researched whether these structures were affected by gender and aging or not.

MATERIALS AND METHODS

Study design and sample

This retrospective observational study was carried out on 83 healthy adult subjects (females 40; males 43) aged between 21 and 75 years (mean 49.52±13.52) in the Department of Radiology at Izmir Bozyaka Education and Research Hospital in Türkiye. The study protocol was approved by the Ethics Committee of Çukurova University, with Decision No: 2023/136-45. Firstly, the records of 115 healthy subjects were obtained. However, 18 individuals not meet the study criteria and 14 subjects with images having unclear measurement points were excluded from the study. The study was conducted over 4 years between January 2018 and 2022 December. Archive records were scanned carefully. The records that not fulfill the required criteria and and unclear images were not used. Also, image analyses were performed randomly by two senior observers (MÖ; FYÖ). All observers reviewed MR images and performed all measurements in consensus. The means of measurement were taken and used for the final value of all measured regions.

Exclusion criteria were having a history of cancer related to the cervical or brain region like spinal cord tumor or any metastasis, having surgical operation

related to the cervical region or head and neck, or having any neurological diseases. Also, the inclusion criteria were no anatomical and spinal abnormalities such as scoliosis, or kyphosis, no previous cervical region surgery or trauma that may affect the normal measurements of vertebrae, and no disk hernia or spinal stenosis.

Protocol of MRI and measurements

MRI scans were investigated and measured on the computer screen with an electronic caliper. The values were stated as millimeters. These measurements include spinal cord and canal diameter from vertebrae cervicales C1 to C7 (C1-CVII); vertebral body anterior heights (VBAH) from C3-C7; vertebral body posterior heights (VBPH) from C3-C7; intervertebral anterior heights at C3-C4, C4-C5, C5-C6, C6-C7, and C7-T1; intervertebral posterior heights at C3-C4, C4-C5, C5-C6, C6-C7 and C7-T1 were measured (Figure 1). Furthermore, the data were divided into both two groups according to genders (healthy adult females and males), and ages (21-39 years; 40-59 years, and 60 years and over)

Statistical analysis

Statistical analysis was performed using the SPSS 22.0 software package (SPSS Inc, Chicago, IL). The normality assumption was decided by the Shapiro-Wilk test. In all statistical analyses; a p-value under 0.05 was considered to be statistically significant. A Mann-Whitney U test was applied for comparisons. Also, from these measurements, means, standard deviations (SD), and minimum and maximum values were calculated. The Spearman correlation analysis (r) was used to determine the strength of the relationship.

RESULTS

The means, standard deviation (SD), minimum (min), and maximum (max) values of the vertebrae cervicales in both genders were shown in Table 1. In addition, the data was divided according to gender, and the results were shown in Table 2. There was no significant difference between genders in spinal cord diameters [(except C3; p=0.007)] at C1 (p=0.939), C2 (p=0.411), C4 (p=0.504), C5 (p=0.844), C6 (p=0.557), C7 (p=0.793), whereas there was a significant difference between genders in spinal canal diameters from C1 (p<0.001), C2 (p<0.001), C3 (p=0.020) to C4 (p=0.014). There were significant differences between genders in terms of anterior and posterior vertebral body height from C3 to C7 in vertebrae cervicales (p<0.001).

Figure 1. The Anterio-posterior (AP) spinal canal, spinal cord diameters, vertebral body anterio-posterior heights and intervertebral disc anterio-posterior heights at cervical vertebrae
A, Vertebral body anterior height; B, Vertebral body posterior height; C, intervertebral disc anterior height; D, intervertebral disc posterior height; E, spinal cord diameter; F, spinal canal diameter

Moreover, there were significant differences between genders in terms of anterior and posterior intervertebral height from C3-4 (p=0.004 and p<0.001), C4-5 (p<0.001 and p<0.001), C5-C6 (p<0.001 and p<0.001), C6-7 (posterior height p=0.004), and to C7-T1 level (p<0.001 and p<0.001), respectively. Conversely, a significant difference was not found at C6-7 intervertebral anterior height (p=0.059).

There was a significant difference in only three measurements including the C3-4 intervertebral posterior height (p=0.043), spinal canal diameter at C5 (p=0.007), and C7 vertebral body posterior height (p=0.016) between Group 1 (21-39 years) and Group 2 (40-59 years) and Group 3 (60 years and over). Additionally, the ratios of cervical body heights and intervertebral disc heights did not show statistical difference (p value=0.104 for C3 vertebral body anterior height (VBAH)/C3 vertebral body posterior height (VBPH), p value=0.112 for C4 VBAH/C4 VBPH, p value=0.981 for C5 VBAH/C5 VBPH, p value=0.375 for C6 VBAH/C6 VBPH, and p

value=0.948 for C7 VBAH/C7 VBPH). There were no significant differences in the ratio of intervertebral disc anterior height to intervertebral disc posterior height at C3-4 (p=0.151), C4-5 (p=0.335), C5-6 (p=0.376), C7-T1 (p=0.146). Some values were higher in males than females such as C3 body anterior height /C3 body posterior height, C3-4 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C4 body anterior height /C4 body posterior height, C4-5 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C7 body anterior height /C5 body posterior height), while some were found lower in males than females including C5 body anterior height /C5 body posterior height, C5-6 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C6 body anterior height /C5 body posterior height, C6-7 intervertebral disc anterior height/ C6-7 intervertebral posterior height, C7-T1 intervertebral disc anterior height/ C7-T1 intervertebral posterior height (Table 4).

Table 1. The mean, standard deviation, minimum and maximum values of cervical region measurements in 83 healthy subjects

Measurements	N	Mean (n=83)	Standard Deviation (SD)	Minimum (Min.)	Maximum (Max.)
Age	83	49.52	13.52	21.00	75.00
Spinal Cord Diameter at C1	83	8.53	0.70	5.10	9.90
Spinal Canal Diameter at C1	83	18.07	2.65	13.00	23.20
Spinal Cord Diameter at C2	83	7.00	0.68	5.70	9.50
Spinal Canal Diameter at C2	83	15.47	2.35	10.70	20.10
Spinal Cord Diameter at C3	83	7.76	0.63	6.40	9.70
Spinal Canal Diameter at C3	83	13.19	1.64	10.40	18.60
C3 Corpus Anterior Height	83	11.79	1.54	8.60	14.90
C3 Corpus Posterior Height	83	11.83	1.57	8.90	15.90
C3-4 Intervertebral Anterior Height	83	3.49	0.70	1.90	5.90
C3-4 Intervertebral Posterior Height	83	3.23	0.78	2.10	6.20
Spinal Cord Diameter at C4	83	7.50	0.67	5.20	8.80
Spinal Canal Diameter at C4	83	12.78	1.15	10.80	15.40
C4 Corpus Anterior Height	83	11.35	1.39	8.50	13.70
C4 Corpus Posterior Height	83	11.69	1.32	8.70	14.70
C4-5 Intervertebral Anterior Height	83	3.59	0.78	2.30	6.10
C4-5 Intervertebral Posterior Height	83	3.20	0.62	2.10	4.60
Spinal Cord Diameter at C5	83	7.31	0.84	3.10	8.90
Spinal Canal Diameter at C5	83	12.78	1.24	9.90	16.10
C5 Corpus Anterior Height	83	11.05	1.50	8.80	15.00
C5 Corpus Posterior Height	83	11.55	1.47	9.20	14.40
C5-6 Intervertebral Anterior Height	83	3.52	0.69	2.40	5.70
C5-6 Intervertebral Posterior Height	83	3.11	0.73	1.60	4.90
Spinal Cord Diameter at C6	83	7.27	0.65	5.00	8.70
Spinal Canal Diameter at C6	83	13.01	1.36	10.50	17.10
C6 Corpus Anterior Height	83	11.07	1.24	7.80	13.60
C6 Corpus Posterior Height	83	11.33	1.09	9.60	13.40
C6-7 Intervertebral Anterior Height	83	3.53	0.82	2.10	6.10
C6-7 Intervertebral Posterior Height	83	3.08	0.59	1.60	4.40
Spinal Cord Diameter at C7	83	6.71	0.53	5.50	8.10
Spinal Canal Diameter at C7	83	13.15	1.60	7.20	18.50
C7 Corpus Anterior Height	83	12.33	1.23	9.80	15.20
C7 Corpus Posterior Height	83	12.32	1.17	10.10	15.00
C7-T1 Intervertebral Anterior Height	83	3.37	0.65	1.90	4.70
C7-T1 Intervertebral Posterior Height	83	2.89	0.71	1.30	4.50

N: Subject number, S.D.: Standard deviation, Min.: Minimum, Max.: Maximum

Table 2. Distribution of cervical measurements according to gender

Measurements	Gender	N	Mean	S.D.	P value
Age	Male	43	49.56	14.70	0.925
	Female	40	49.85	13.30	
Spinal Cord Diameter at C1	Male	43	8.56	0.86	0.939
	Female	40	8.49	0.49	
Spinal Canal Diameter at C1	Male	43	19.40	2.29	<0.001
	Female	40	16.63	2.24	
Spinal Cord Diameter at C2	Male	43	8.06	0.73	0.411
	Female	40	7.93	0.62	
Spinal Canal Diameter at C2	Male	43	8.06	0.73	<0.001
	Female	40	7.93	0.62	
Spinal Cord Diameter at C3	Male	43	7.94	0.68	0.007
	Female	40	7.57	0.52	
Spinal Canal Diameter at C3	Male	43	13.73	1.67	0.020
	Female	40	12.61	1.42	
C3 Body Anterior Height	Male	43	12.79	0.96	<0.001
	Female	40	10.71	1.31	
C3 Body Posterior Height	Male	43	12.70	1.27	<0.001
	Female	40	10.90	1.32	
C3-4 Intervertebral Anterior Height	Male	43	3.70	0.75	0.004
	Female	40	3.26	0.58	
C3-4 Intervertebral Posterior Height	Male	43	3.56	0.81	<0.001
	Female	40	2.88	0.58	
Spinal Cord Diameter at C4	Male	43	7.55	0.84	0.504
	Female	40	7.46	0.43	
Spinal Canal Diameter at C4	Male	43	13.08	1.16	0.014
	Female	40	12.46	1.06	
C4 Body Anterior Height	Male	43	12.24	0.97	<0.001
	Female	40	10.40	1.14	
C4 Body Posterior Height	Male	43	12.43	1.09	<0.001
	Female	40	10.89	1.07	
C4-5 Intervertebral Anterior Height	Male	43	3.89	0.79	<0.001
	Female	40	3.26	0.62	
C4-5 Intervertebral Posterior Height	Male	43	3.43	0.66	<0.001
	Female	40	2.96	0.47	
Spinal Cord Diameter at C5	Male	43	7.32	1.05	0.844
	Female	40	7.29	0.55	
Spinal Canal Diameter at C5	Male	43	13.03	1.16	0.052
	Female	40	12.50	1.33	
C5 Body Anterior Height	Male	43	11.96	1.26	<0.001
	Female	40	10.07	1.08	
C5 Body Posterior Height	Male	43	12.50	1.04	<0.001
	Female	40	10.53	1.15	
C5-6 Intervertebral Anterior Height	Male	43	3.79	0.69	<0.001
	Female	40	3.22	0.56	
C5-6 Intervertebral Posterior Height	Male	43	3.46	0.78	<0.001
	Female	40	2.74	0.46	
Spinal Cord Diameter at C6	Male	43	7.31	0.76	0.557
	Female	40	7.26	0.51	
Spinal Canal Diameter at C6	Male	43	13.20	1.45	0.190
	Female	40	12.81	1.24	
C6 Body Anterior Height	Male	43	11.58	0.93	<0.001
	Female	40	10.52	1.30	
C6 Body Posterior Height	Male	43	11.98	0.90	<0.001

	Female	40	10.63	0.83	
C6-7 Intervertebral Anterior Height	Male	43	3.69	0.88	0.059
	Female	40	3.35	0.73	
C6-7 Intervertebral Posterior Height	Male	43	3.26	0.55	0.004
	Female	40	2.88	0.58	
Spinal Cord Diameter at C7	Male	43	6.72	0.51	0.793
	Female	40	6.69	0.56	
Spinal Canal Diameter at C7	Male	43	13.46	1.63	0.074
	Female	40	12.83	1.52	
C7 Body Anterior Height	Male	43	13.04	1.02	<0.001
	Female	40	11.57	0.9	
C7 Body Posterior Height	Male	43	13.01	0.95	<0.001
	Female	40	11.58	0.89	
T1-C7 Intervertebral Anterior Height	Male	43	3.59	0.59	0.001
	Female	40	3.13	0.64	
T1-C7 Intervertebral Posterior Height	Male	43	3.17	0.67	<0.001
	Female	40	2.59	0.62	

N: Subject number; S.D.: Standard deviation, p: Significance level

Table 3. Distribution of cervical measurement according to ages

Measurements	**21-39 years (21 subjects)**	**40-59 years (38 subjects)**	**60 and over years (24 subjects)**
	Mean±SD Min.-Max.	Mean±SD Min.-Max.	Mean±SD Min.-Max.
Spinal Cord Diameter at C1	8.59±0.86 7.00-9.50	8.50±0.75 5.10-9.40	8.51±0.67 7.10-9.90
P value	0.903		
Spinal Canal Diameter at C1	18.53±2.09 14.30-23.20	17.67±2.64 14.10-22.50	18.29±3.08 13.00-22.60
P value	0.438		
Spinal Cord Diameter at C2	8.07±0.88 6.70-9.50	7.87±0.55 5.70-8.70	8.13±0.65 7.20-9.10
P value	0.294		
Spinal Canal Diameter at C2	16.49±1.75 13.70-20.10	15.20±2.47 10.70-20.10	15.01±2.44 12.50-19.80
P value	0.065		
Spinal Cord Diameter at C3	7.89±0.73 6.40-9.10	7.59±0.49 6.60-8.30	7.91±0.70 7.00-9.70
P value	0.082		
Spinal Canal Diameter at C3	13.17±1.01 11.50-15.50	13.05±1.32 10.90-18.00	13.42±2.42 10.40-18.60
P value	0.695		
C3 Body Anterior Height	12.05±1.13 10.20-14.20	11.79±1.71 8.90-15.90	11.54±1.59 9.10-14.20
P value	0.545		
C3 Body Posterior Height	12.20±1.24 10.20-14.20	11.73±1.76 8.90-15.90	11.66±1.51 9.10-14.20
P value	0.442		
C3-4 Intervertebral Anterior Height	3.53±0.94 2.20-6.20	3.39±0.55 2.10-4.00	3.61±0.68 2.10-5.00
P value	0.451		
C3-4 Intervertebral Posterior Height	3.59±0.98 2.20-6.20	3.07±0.55 2.10-4.00	3.16±0.83 2.10-5.00
P value	0.043		
Spinal Cord Diameter at C4	7.57±0.63	7.45±0.51	7.53±0.91

	6.30-8.70	6.40-8.80	5.20-8.80
P value	0.786		
Spinal Canal Diameter at C4	12.94±1.08 11.30-15.40	12.92±1.09 10.80-15.40	12.42±1.25 10.80-15.40
P value	0.194		
C4 Body Anterior Height	11.22±1.08 9.40-13.30	11.56±1.37 9.00-13.70	11.15±1.67 8.50-13.60
P value	0.473		
C4 Body Posterior Height	11.91±1.28 9.90-14.70	11.70±1.42 8.70-13.90	11.46±1.21 9.60-13.60
P value	0.522		
C4-5 Intervertebral Anterior Height	3.77±1.15 2.30-6.10	3.44±0.62 2.50-5.10	3.66±0.55 2.90-5.00
P value	0.258		
C4-5 Intervertebral Posterior Height	3.42±0.60 2.30-4.60	3.11±0.52 2.40-4.20	3.15±0.75 2.10-4.50
P value	0.152		
Spinal Cord Diameter at C5	7.43±0.54 6.50-8.40	7.19±0.85 3.10-8.90	7.37±1.04 3.50-8.60
P value	0.525		
Spinal Canal Diameter at C5	13.27±0.97 12.00-15.90	12.89±1.16 10.60-14.90	12.16±1.37 9.90-16.10
P value	0.007		
C5 Body Anterior Height	11.02±1.38 9.10-13.60	11.12±1.57 8.80-14.00	10.96±1.56 8.80-15.00
P value	0.918		
C5 Body Posterior Height	11.48±1.23 9.30-13.80	11.25±1.33 9.20-13.40	11.55±1.47 9.20-14.40
P value	0.379		
C5-6 Intervertebral Anterior Height	3.58±0.83 2.50-5.70	3.54±0.65 2.40-4.80	3.43±0.63 2.40-4.80
P value	0.752		
C5-6 Intervertebral Posterior Height	3.39±0.83 2.10-4.90	3.05±0.63 2.20-4.40	2.97±0.76 1.60-4.40
P value	0.120		
Spinal Cord Diameter at C6	7.13±0.51 6.10-8.10	7.43±0.63 6.20-8.70	7.13±0.75 5.00-8.10
P value	0.118		
Spinal Canal Diameter at C6	13.53±1.43 11.10-17.00	12.97±1.22 11.00-16.20	12.63±1.41 10.50-17.10
P value	0.083		
C6 Body Anterior Height	11.12±1.32 8.50-13.60	11.19±0.94 9.40-12.70	10.84±1.55 7.80-13.10
P value	0.551		
C6 Body Posterior Height	11.39±1.04 10.10-13.40	11.29±1.18 9.60-13.30	11.34±1.05 10.10-13.40
P value	0.951		
C6-7 Intervertebral Anterior Height	3.84±0.92 2.10-6.10	3.39±0.74 2.10-5.20	3.48±0.82 2.20-5.50
P value	0.116		
C6-7 Intervertebral Posterior Height	3.01±0.64 2.10-4.00	3.16±0.60 1.60-4.40	3.00±0.55 2.30-4.40
P value	0.485		
Spinal Cord Diameter at C7	6.61±0.51 5.90-8.10	6.69±0.61 5.50-8.10	6.82±0.41 6.10-7.30
P value	0.398		

Spinal Canal Diameter at C7	13.05±1.80 9.80-18.50	13.22±1.67 7.20-15.90	13.14±1.36 11.20-17.40
P value	0.933		
C7 Body Anterior Height	12.62±1.31 9.80-15.20	12.46±1.23 10.60-14.80	11.88±1.07 9.80-13.10
P value	0.091		
C7 Body Posterior Height	12.68±1.12 10.80-15.00	12.47±1.09 10.80-14.40	11.76±1.18 10.10-13.80
P value	0.016		
T1-C7 Intervertebral Anterior Height	3.30±0.71 1.90-4.70	3.42±0.67 2.00-4.60	3.34±0.58 2.50-4.40
P value	0.775		
T1-C7 Intervertebral Posterior Height	2.69±0.74 1.80-4.20	3.01±0.59 1.30-4.40	2.88±0.82 2.00-4.50
P value	0.251		

N: Subject number, S.D.: Standard deviation, p: Significance level, Min:Minimum, Max:Maximum

Table 4. The ratios of cervical body heights and intervertebral disc heights

Measurement	Females (n=40)	Males (n=43)	P value
C3 body anterior height /C3 body posterior height	0.98±0.72 (0.80-1.18)	1.01±0,08 (0.85-1.17)	0.104
C3-4 intervertebral disk anterior height/ C3-4 intervertebral posterior height	1.08±0.27 (0.84-2.04)	1.16±0.28 (0.71-1.81)	0.151
C4 body anterior height /C4 body posterior height	0.96±0.87 (0.81-1.15)	0.99±0.08 (0.86-1.19)	0.102
C4-5 intervertebral disk anterior height/ C3-4 intervertebral posterior height	1.11±0.20 (0.68-1.45)	1.16±0.26 (0.78-2.00)	0.335
C5 body anterior height /C5 body posterior height	0.9591±0.07 (0.78-1.07)	0.9587±0.08 (0.72-1.15)	0.981
C5-6 intervertebral disk anterior height/ C3-4 intervertebral posterior height	1.20±0.24 (0.79-1.95)	1.14±0.31 (0.78-2.18)	0.376
C6 body anterior height /C5 body posterior height	0.99±0.12 (0.74-1.21)	0.97±0.09 (0.80-1.19)	0.375
C6-7 intervertebral disk anterior height/ C6-7 intervertebral posterior height	1.195±0.326 (0.81-2.05)	1.176±0.398 (0.77-2.65)	0.806
C7 body anterior height /C5 body posterior height	1.002±0.08 (0.86-1.17)	1.003±0.06 (0.91-1.17)	0.948
C7-T1 intervertebral disc anterior height/ C7-T1 intervertebral posterior height	1.27±0.38 (0.63-2.62)	1.16±0.25 (0.74-1.71)	0.146

DISCUSSION

Cervical vertebral morphology is important in order to address cervical spine problems that may be encountered by different racial populations[8]. The size, shape, and orientation of the vertebrae affect the strength and adaptability of the spine. Various activities such as prolonged sitting, posture disorder or industrial accidents, occupational risks, and working conditions that are not based on ergonomic principles both adversely affect the spine and will cause the development of many spine-related problems that will require the application of several surgical procedures such as transpedicular screw

fixation in the future when left untreated. When assessing the clinical of cervical instability, the most important subject is to know the normal biomechanical characteristics of the cervical spine[8]. In a study performed with 30 Nigerian cadavers, the means for the C3–C7 vertebral bodies were as follows: VBAH: 13.88mm, VBPH: 12.83mm, respectively. The measurements of the C7 level were found higher than others, and the possible reason for this may be that the seventh cervical vertebra has different morphology in that it has relatively larger pedicles[8]. Additionally, knowing the normal development of the cervical spine for both gender and age groups is critical in determining treatments like cervical spine instrumentation and fusion[18]. The narrowness in the cervical spinal canal can lead to the development of many neurological symptoms such as a predisposition to spinal cord injury, neck pain, headache, and weakness. Due to the developmental morphological structure in females, the cervical spinal canal is more prone to degeneration and less able to withstand trauma[19]. MRI gives detailed knowledge. The most important feature of MRI is its high sensitive to notice elusive/obscure abnormalities in both soft tissue and bones for the detection of any pathology. It can provide more accurate morphometric markers[14,15]. Additionally, tumors, trauma, and degenerative changes such as intervertebral disc herniation, and osteophytes can may lead to narrowness of the cervical canal. Several signs including pain, numbness, weakness, gait disorders, and paresthesia, and sometimes irreversible paraplegia can develop. These can increase cord compression, spinal cord ischemia, and histopathologic alterations of spinal cord[7]. These damages in the cervical region must be diagnosed and treated immediately to avoid long-term disabilities due to irreversible spinal cord injury. Also, in Sisodia et al's study conducted with 90 subjects, There were no significant differences in the dimensions of Vertebral body diameter, Spinal cord diameter, Vertebral canal diameter, and transverse canal diameter at C3, C4, C5, C6, and C7 levels and there were no statistically significant differences between genders[7]. The highest and lowest values of the vertebral body diameter were obtained at C7, and C3 levels, respectively. Spinal cord diameter was higher at C7, and lower at C6 levels, respectively. The highest and lowest values of the vertebral canal diameter at C6 and C7 levels, respectively. The same values of transverse canal diameter were at C3 and C6 levels, respectively[7].

In this paper, the normal values of the cervical spinal canal and spinal cord diameter the anterior and posterior height of each cervical vertebra body, anterior and posterior height of each intervertebral disc between C3-T1 of 83 healthy subjects aged between 18-73 years were evaluated according to age and gender by MRI. In our study, the spinal cord diameter took the highest value at the C1 level, whereas, the lowest value was obtained at the C7 level. Also, our spinal cord diameter values decreased from C3 to C7 level similar to Australian and Japanese studies. Our spinal canal diameter showed changes according to level. The corresponding measurement took the greatest value at the C1 level. There was a reduction from C1 to C5 level. From this level, there was an increase until the C7 level. Similar to the study by Dağ et al., our spinal cord value at the C6 level was lower than at the C3 level regardless of gender. A decrease in spinal canal diameter and an increase in spinal cord diameter from cranial to caudal direction can be thought a risk factor for comprehensive traumatic injury at the lowest cervical vertebrae.

In a study performed by Okada et al. with 96 healthy subjects and 74 subjects having cervical spondylotic myelopathy, the spinal canal size has been reported to play an important role in the development of CSM Also, spinal cord compression may be predicted at any level of cervical spine is 10 mm and less. When the spinal canal diameter is greater than 13 mm, cord compression may develop because of spondylotic changes[12,20]. Due to the relatively reduced space around the spinal cord at the lower cervical level, it is acceptable that a pathology at this level is more likely. However, it should not be overlooked that age, height, gender, body weight, and population differences are extremely important in morphometric measurements[5,12]. In our study similar to the literature, the canal and cord measurements were higher in males than in females[5,21]. In the values obtained in our study, although the age factor does not seem to make a significant difference in the spinal canal and cord measurements (except for the C5 level), there was a decrease in all levels above the age of 60 (except for the C3 level)[12]. In a study performed in Switzerland with healthy subjects, spinal cord and spinal canal measurements are more valuable in cord compression. It can be a reason of developping to spinal cord dysfunction. A decrease in the spinal canal diameter may also be a reason for Cervical Cord Compression (CCC). However, spinal canal dimensions show a wide variability between C1 and

C7 levels[12]. When we look at the studies evaluated by MRI and conducted with healthy subjects, it was found that the spinal canal diameter at the C3 level was between 12.4mm-14.4mm, while the same measurement at the C6 level was between 12.2mm and 14mm[12,14]. Different vertebral level and population leads to the changes in the spinal cord size[15].

In a retrospective study performed in Macedonia with 50 subjects aged between 19 and 64 years. Additionally, sagittal canal diameters (SCDs) ranged from 11.20mm to 17.80mm in males and from 12.90mm to 17.60mm in females, respectively. the corresponding values were 14.59mm±1.01mm in males and 15.26mm±1.11mm in females. There were no significant gender differences in the same measurements, although, at C6 and C7 males had a larger spinal canal. The means of the same values were the least at C5 in both sexes. The overall and interquartile ranges of the SCDs were greater in males than in females. Mean SCDs were the biggest from C3 to C5 because of the cervical cord enlargement, 7.57mm±0.42 in males and 7.67mm±0.95 in females at C3. At C6 and C7 the average SCDs were of lower values, 6.43mm±0.72 in males and 6.66mm±0.73 in females[15-17]. In healthy adults, the spinal canal anteroposterior diameter at the C1 level is 22mm (ranging from 20–26 mm), which decreases to 20mm at C2, and to 14mm and 22mm between C3–7. The same values of the adult cervical spinal cord at C1 measure as 10.4mm (7–11 mm), which decreases to 9mm (ranging from 7 to 10mm) at C2, with an average of 8.5mm (6–9 mm) between C3–7. The transverse cervical cord measures 10–14mm[15]. Also, canal form and size have always been a topic of interest to both anatomists and clinicians connecting clinical and anatomical data in terms of treatment planning or choices of neck region. The smaller the space for neural structures, the greater the risk of neurological symptoms. The sagittal diameter of the cervical spinal canal is therefore a reliable and decisive parameter. Moreover, some diversities are possible because of genetics, race, posture, and muscle structure[18].

The intervertebral disc is a fibrocartilage formation and located between two vertebral bodies. It is composed of annulus fibrosus, nucleus pulposus, and cartilaginous end plate. It distributes the load on the joint surfaces equally and acts as a cushion. IVDs, which are generally 2/5 of the vertebral height, consist of nucleus pulposus in the inner part and annulus fibrosus in the outer part[1-4,13,22-27]. Early recognition and diagnosis of any pathology or deviation from normality involving the cervical intervertebral disc can help prevent and delay morphological deterioration that may pose a serious risk in the future[27]. Also, cervical intervertebral disk deformity is associated with age, gender, body mass index (BMI), and cervical vertebrae[27].

Radiological degenerative changes are known to occur mostly at the C5-C6 level. The intervertebral discs are the major factor causing pain. This is also a consequence of aging. In addition, some proportional calculations from the vertebral body, such as the ratio of the anterior height of the cervical vertebra to the posterior height and the ratio of the anterior height of the intervertebral disc to the posterior height, may help reveal the vertebral structures and vertebral deformities[4]. Cheng et al.' study showed that the ratio of the anterior height of the cervical vertebra to the posterior height was lower in males than in females. The corresponding value was similar to both genders in Barut el.'s study. This was explained by Barut et al. that the anterior and posterior parts of this region of the cervical spine undergo similar changes, i.e. the cervical region is subjected to less load than the lower levels of the spine. In the same study, there was a positive relation between the ratio of the anterior height of the intervertebral disc to the posterior height and age in C3-4, C4-5, C5-6, C6-7, and C7-T1 levels of females. Changes in these structures may be thought to cause an increase in cervical lordosis in women with age[4,24]. In this paper, the values of the intervertebral disc were shown significant between genders, whereas there was no significant difference between ages. Additionally, the ratios of cervical body heights and intervertebral disc heights were not shown statistically difference ($p>0.05$), and some values were higher in males than females (C3 body anterior height /C3 body posterior height, C3-4 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C4 body anterior height /C4 body posterior height, C4-5 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C7 body anterior height /C5 body posterior height), while some were found lower in males than females (C5 body anterior height /C5 body posterior height, C5-6 intervertebral disc anterior height/ C3-4 intervertebral posterior height, C6 body anterior height /C5 body posterior height, C6-7 intervertebral disc anterior height/ C6-7 intervertebral posterior height, C7-T1 intervertebral disc anterior height/ C7-

T1 intervertebral posterior height). Although the basic characteristics of the vertebrae are similar, these morphometric characteristics may differ depending on region, race, genetic and gender parameters[28-34]. The knowledge of cervical vertebrae morphology is also critical for prevent damage to the vertebral artery, spinal medulla, or nerve roots during fixation process[29,34]. Also, success in cervical vertebrae surgery can be ensured by detailed anatomical knowledge for the selection and installment of proper screw, plate, or surgical instruments[30,34].

We have some limitations about this study. Although we know from the records that our subjects do have not any neurological, oncological, psychiatric, or systemic diseases, one of our limitations was the lack of demographic characteristics including the weight and height of the patients. Second, since our main goal was to ensure that the subjects included in the study were optimally healthy, our sample size was very small and data were collected from a single center.

In conclusion, the cervical spinal canal and spinal cord dimensions of healthy subjects showed changes according to gender and age (especially 60 and over). C3 level and C6 level can play an important role in cervical morphometric measurements. Our values can be used as reference values of Turkish healthy subjects. Additionally, cervical morphology can be influenced by many factors such as race, age, gender, neurological disease, posture disorders, non-ergonomic working conditions, and is important to determine cervical spine problems. The size, shape, and orientation of the vertebrae affect the strength and adaptability of the spine. Early recognition and diagnosis of any pathology or deviation from normality involving the cervical region can help prevent and delay morphological deterioration that may pose a serious risk in the future.

We think that our study will contribute to the literature by presenting reference values in terms of the comparison of cervical region measurements in terms of gender and age group. As a result, we believe that the data obtained in this study can provide crucial information for clinicians such as radiologists, neurologists, brain surgery, or therapists about cervical rehabilitation and surgery treatments and options and they can be used as reference values for evaluating cervical area morphometry and relation with gender and age groups.

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