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Morphometry of Thoracic Vertebrae Using Dry Specimens

Morfometría de Vértebras Torácicas Utilizando Especímenes Secos

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SUMMARY: The study aimed to analyse the morphometric characteristics of dry thoracic vertebrae from the Anatolian (AP) and British populations (BP) to evaluate the differences between these populations and to provide a database for clinicians in clinical practices, especially during surgical procedures. The study examined 183 dry thoracic vertebrae (age, sex, and level unknown). 59 were excluded (morphological deformities or reference points), and 124 were analyzed (Anatolian: 14; British: 110). All measurements were taken with digital calipers (0.01 mm) and a goniometer. Play-dough was used to elevate and position each vertebra according to its anatomical position. The accuracy of posture was checked using a spirit level. Statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, Version 28.0), and a p-value <0.05 was considered significant. Corpus vertebral width, anteroposterior distance, foramen transverse distance, left pedicle height, pedicle screw path length, and transverse angle were significantly different between populations. While corpus vertebra width, anteroposterior distance, left pedicle height, screw path length, and left pedicle transverse angle were found to be higher in the Anatolian population (p<0.05), significant positive correlations were found between left pedicle screw path length and pedicle angles in the British population (r=0.21, p=0.027). This study showed that there were significant differences in the morphometric properties of thoracic vertebrae between Anatolian and British populations. These results emphasize the importance of population-specific reference values in pedicle screwing and spinal deformity surgeries.

KEY WORDS: Dry bones; Thoracic vertebrae; Morphometry; Racial differences.

INTRODUCTION

The twelve thoracic vertebrae in the thoracic region maintain the structural and functional integrity of the spine. They articulate with the ribs, forming the thoracic cage that protects vital organs like the heart, lungs, and great vessels, supports respiration, and connects to the upper limbs (Moore *et al*., 2018).

Knowledge of vertebral morphometric properties is crucial in anthropological and forensic approaches (Yu *et al*., 2008; Srithawee *et al*., 2024). Accurate evaluation of thoracic vertebrae morphometry during surgical interventions in orthopaedics & traumatology directly influences surgeons' operation planning (Kaur *et al*., 2016). Understanding both normal and abnormal spinal morphology is vital in assessing conditions like scoliosis, kyphosis, spinal deformities, and osteoporosis (Bettany-Saltikov *et al*., 2017). Additionally, knowing vertebral body width and pedicle length is critical for developing implantable devices for spinal instrumentation (Das *et al*., 2018).

Several studies have explored thoracic vertebrae morphometry using various methods, including X-rays, CT scans, and MRI (Goh *et al*., 2000; Guglielmi *et al*., 2008; Shetty *et al*., 2019; Grünwald *et al*., 2024). However, dry bone measurements are valuable for examining vertebral morphometry with anatomical accuracy, accounting for individual variations, and avoiding the influence of textural changes, which is important for forensic applications (Brothwell, 1981; Banik *et al*., 2022). Additionally, morphometric evaluations of dry bones help understand how vertebral structure varies with age, gender, environmental, geographical, genetic, and biomechanical factors, contributing to personalized treatment plans in clinical practice (Singh *et al*., 2011; Ashish *et al*., 2022).

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The purpose of this study is to describe the anatomical structures of the thoracic vertebrae in the Anatolian Population (AP) and the British Population (BP), to analyse theircharacteristics and to compare the data both geographically and with the literature using detailed morphometric measurements on dry bone samples. The results are expected to contribute to a better understanding of the anatomical structure and clinical significance of the thoracic vertebrae and to increase the utility of this information in clinical practice, specifically in spinal surgery and orthopaedic procedures.

MATERIAL AND METHOD

The study included the morphometric evaluation of thoracic vertebrae of unknown sex, age and level at the Anatomy Laboratory of two universities in two different countries. Following ethics committee approval (IRB: 2024/10.1347), a total of 183 thoracic vertebrae were examined, 14 from AP and 169 from BP. Of the 183 thoracic vertebrae, 59 were excluded from the study because their morphology had changed for various reasons (fracture, abrasion, loss of integrity, etc.) and reference points could not be determined.

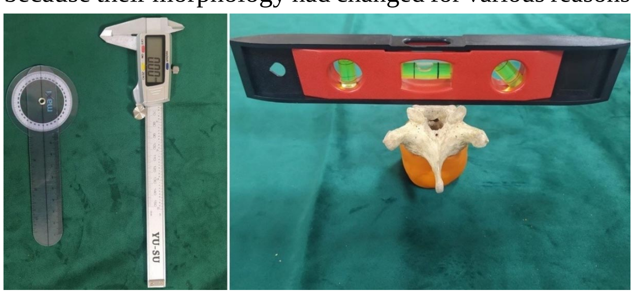

Fig. 1. Measurement Tools.

All measurements were made with a digital caliper (Insize 1112-150, Insize Co. Ltd, Germany) with an accuracy of 0.01 mm. A goniometer was used for angle measurements. During the measurements, each vertebra was elevated and positioned with the help of play dough in accordance with the anatomical position with the corpus surface horizontal and the accuracy of the posture was checked with a spirit level placed on the corpus vertebra (Fig. 1).

In the study, morphometric measurements of the vertebral body and vertebral foramen of the thoracic vertebrae, as well as those of the pedicles (Fig. 2), were performed. The measured parameters and reference points are shown in Table I.

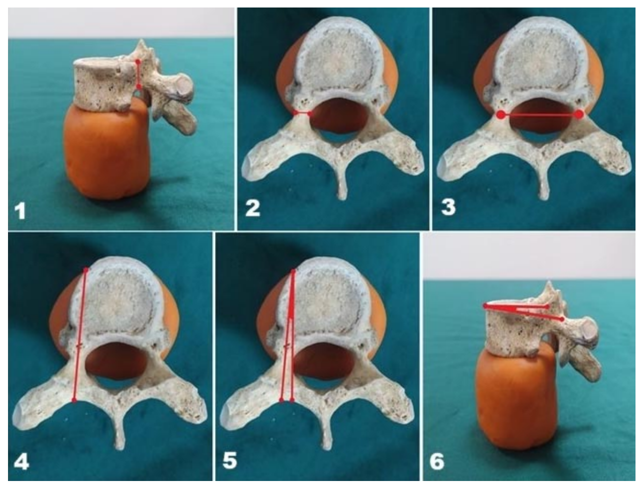

Fig. 2. Pedicle measurements. 1-PH (mm); 2- PW (mm); 3- IPD (mm); 4- CL (mm) 5- PTA (°); 6- PSA (°).

Table I. Parameters of measurement and reference points.

Parameters *Width, Height, Lenght, Distance→ mm* *Angle → (°)*	**Measurement references**
Vertebral Body Width (VBW)	The transverse plane at the widest point of the vertebral body's superior surface.
Vertebral Body Height (VBH)	The vertical distance between superior and inferior endplates in the anterior midline.
Anteroposterior length of Vertebral Body (VB_{APL})	The length between anterior border and posterior border of the superior surface of vertebral body in midline.
Anteroposterior Distance of Vertebral Foramen (VF_{APD})	The midsagittal diameter at the cephalic border of vertebral arches.
Transverse Distance of Vertebral Foramen (VF_{TD})	The maximum distance between the inner surfaces of the two pedicles.
Pedicle Height (PH)	The vertical length between the superior border and inferior border of the pedicle at its mid-point.
Pedicle Width (PW)	The length between medial and lateral surfaces of the pedicle at its midpoint, measured at right angles to the long axis of the pedicle.
Interpedicular Distance (IPD)	The distance between the pedicles from the middle (according to the guide lines on the ruler) part of the pedicles.
Chord Length (CL)	The posterior cortical entry point of the pedicle to the anterior vertebral cortex along the axis of the pedicle (Chord=Pedicle Screw Path)
Pedicle Transverse Angle (PTA)	The angle between the pedicle axis and al ine parallel to the vertebral midline measured in the transverse plane
Pedicle Sagittal Angle (PSA)	The angle between the pedicle axis and the superior border of vertebral body in the sagittal plane.

Statistical Analysis. The Shapiro-Wilk test assessed normality. Continuous variables were presented as median (min: max) and mean±SD. For comparisons between two independent groups, the Mann-Whitney U test was used. Correlations between continuous variables were analyzed with Pearson's correlation, based on normality. Statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, Version 28.0), and a p value <0.05 was considered significant.

Table II. Morphometric measurements of thoracic vertebrae

n=124 *Width, Height, Lenght, Distance → mm* *Angle → (°)*	**Mean±SD**	**Range**
VBW	29.08±4.62	19.54-40.49
VBH	18.83±2.39	13.54-24.59
VB_{APL}	22.59±5.16	13.32-33.22
VF_{APD}	15.50±1.71	12.37-19.92
VF_{TD}	17.73±2.51	13.81-24.93
Right Pedicle Height (R-PH)	12.05±2.38	6.62-17.51
Left Pedicle Height (L-PH)	11.90±2.42	6.54-18.07
Right Pedicle Width (R-PW)	5.93±1.89	1.67-10.88
Left Pedicle Width (L-PW)	6.08±1.86	1.73-10.58
IPD	23.92±4.09	15.02-35.64
Right Chord Length (R-CL)	32.85±6.56	14.82-48.27
Left Chord Length (L-CL)	33.70±6.32	13.27-48
Right Pedicle Transverse Angle (R-PTA)	10.31±2.48	6-19
Left Pedicle Transverse Angle (L-PTA)	10.40±2.40	6-17
Right Pedicle Sagittal Angle (R-PSA)	9.28±1.63	7-15
Left Pedicle Sagittal Angle (L-PSA)	9.19±1.63	7-17

Table III. Comparison of morphometric measurements between populations.

	AP	**BP**	**p-value[a]**
VBW (mm)	30.81(23.93-39.85)	28.06(19.54-40.49)	**0.049**
VBH (mm)	19.96(16.71-24.52)	18.55(13.54-24.59)	0.169
VB_{APL} (mm)	26.27(16.34-32.24)	22.67(13.32-33.22)	**0.031**
VF_{APD} (mm)	14.86(13.06-17.56)	15.60(12.37-19.92)	0.064
VF_{TD} (mm)	15.93(14.73-17.78)	17.40(13.81-24.93)	**0.019**
R-PH (mm)	12.98(9.55-17.38)	11.49(6.62-17.51)	0.083
L-PH (mm)	13.01(9.91-17.76)	11.14(6.54-18.07)	**0.028**
R-PW (mm)	6.03(3.48-10.15)	5.76(1.67-10.88)	0.423
L-PW (mm)	6.07(3.98-8.76)	5.89(1.73-10.58)	0.586
IPD (mm)	22.94(20.62-26.92)	23.02(15.02-35.64)	0.962
R-CL (mm)	40.30(25.02-48.27)	31.69(14.82-46.78)	**<0.001**
L-CL mm	40.40(25.48-46.48)	33.17(13.27-48)	**<0.001**
R-PTA (°)	9(6-11)	10(6-19)	**0.022**
L-PTA (°)	8.50(6-10)	11(7-17)	**<0.001**
R-PSA (°)	9(7-11)	9(7-15)	0.564
L-PSA (°)	8.50(7-11)	9(7-17)	0.171

Data are expressed median(minimum-maximum). a:Mann-Whitney U Test

RESULTS

A total of 124 thoracic vertebrae were used in the study, 14 from the AP and 110 from the BP. The morphometric measurements of the thoracic vertebrae are shown in Table II.

Statistical comparison of the morphometric measurement results of both populations is shown in Table III.

The VBW, VBAPL, VFAPD, L-PH, R-CL, L-CL and, R-PTA, L-PTA showed statistically significant differences between the populations. Accordingly, VBW, VBAPL, L-PH, R-CL, L-CL and L-PTA were found to be higher in AP than in BP (p=0.049, p=0.031, p=0.028, p<0.001, p<0.001, p<0.001, p<0.001, respectively). The VFTD and R-PTA were found to be higher in BP than in AP (p=0.019, p=0.022, respectively) (Table III).

Correlation analyses of the data of Anatolian and British populations are shown in Tables IV-VI.

In both populations, there was a statistically significant positive correlation between VBW values and VBH (AP: r=0.75, p<0.001; BP: r=0.68, p<0.001) and VBAPL (AP: r=0.83, p<0.001; BP: r=0.60,

Table IV. Correlation analysis of morphometric measurements of vertebrae in AP and BP

		VBW		**VBH**		**VB_{APL}**		**VF_{APD}**	
		r	p-value	r	p-value	r	p-value	r	p-value
VBH	**AP**	0.75	**<0.001**						
	BP	0.68	**<0.001**						
VB_{APL}	**AP**	0.83	**<0.001**	0.78	**<0.001**				
	BP	0.60	**<0.001**	0.81	**<0.001**				
VF_{APD}	**AP**	-0.01	0.989	-0.20	0.484	-0.07	0.825		
	BP	0.37	**<0.001**	0.40	**<0.001**	0.26	**0.007**		
VF_{TD}	**AP**	0.12	0.690	-0.05	0.858	0.11	0.705	0.21	0.474
	BP	0.24	**0.013**	-0.14	0.142	-0.25	**0.010**	0.21	0.474

p<0.001). Thus, it can be said that as the VBW increases, the VBH and VBAPL also increase. A similar relationship was observed between the VBH and the VBAPL (AP: r=0.78, p<0.001; BP: r=0.81, p<0.001). In both populations, the VBAPL increased as the VBH increased (Table IV).

In BP, there was a statistically significant positive correlation between the VBW and the VFAPD and VFTD. (r=0.37, p<0.001); (r=0.24, p=0.013), respectively). Therefore, as the VBW increases, the VFAPD and VFTD also increase. A significant positive correlation was found between VBH and VFAPD and between VBAPL and VFAPD (r=0.40, p<0.001; r=0.26, p=0.007 respectively). Accordingly, as VBH increased, VFAPD increased and as VBAPL increased, VFAPD increased. On the other hand, there was a statistically negative correlation between VBAPL and the VFTD (r= -0.25, p=0.010). Accordingly, as the VBAPL increases, the VFTD decreased (Table IV).

In both populations, there was a statistically significant positive correlation between R-PH and R-PW, L-PH and L-PW (AP: (r=0.70, p<0.001) BP: (r=0.34, p<0.001); AP: (r=0.97, p<0.001) BP: (r=0.93, p<0.001); AP: (r=0.59, p=0.026) BP: (r=0.29, p=0.002)). As R-PH increased, so did R-PW, L-PH and L-PW (Table V).

R-PW was correlated with L-PH, L-PW and IPD in both populations (AP: (r=0.70, p=0. 005) BP: (r=0.39, p<0.001); AP: (r=0.88, p<0.001) BP: (r=0.86, p<0.001); AP: (r=0.82, p<0.001) BP: (r=0.63, p<0.001)) statistically significant positive correlation was found. It can be said that if the R-PW is increased, then both the L-PH, the L-PW and the IPD will also be increased (Table V).

In AP, the L-PH was statistically significantly positively correlated with L-PW and IPD (r=0.64, p=0.013); (r=0.83, p<0.001). As L-PH increased, L-PW and IPD also increased. At BP, there was no statistically significant correlation between L-PH and IPD (p=0.985), but there was a significant positive correlation with L-PW (r=0.39, p<0.001). Correspondingly, as L-PH increased at BP, so did L-PW (Table V).

In both populations, there was a significant positive correlation between L-PW and IPD (AP: r=0.66, p<0.001) BP: (r=0.68, p<0.001). As L-PW increased, so did IPD (Table V).

In AP and BP, there was a statistically significant positive correlation between R-CL and L-CL (AP: r=0.99, p<0.001), (BP: (r=0.91, p<0.001)). There was also a significant positive correlation between R-CL with R-PSA and L-PSA in BP (r=0.31, p<0.001; r=0.26, p=0.006, respectively) (Table VI).

There was a significant positive correlation between R-PTA and L-PTA in both populations (AP: (r=0.73,

Table V. Correlation analysis of pedicle measurements in AP and BP.

		R-PH		**R-PW**		**L-PH**		**L-PW**	
		r	p-value	r	p-value	r	p-value	r	p-value
R-PW	**AP**	0.70	**<0.001**						
	BP	0.34	**<0.001**						
L-PH	**AP**	0.97	**<0.001**	0.70	**0.005**				
	BP	0.93	**<0.001**	0.39	**<0.001**				
L-PW	**AP**	0.59	**0.026**	0.88	**<0.001**	0.64	**0.013**		
	BP	0.29	**0.002**	0.86	**<0.001**	0.39	**<0.001**		
IPD	**AP**	0.44	0.113	0.82	**<0.001**	0.83	**<0.001**	0.66	**<0.001**
	BP	-0.05	0.593	0.63	**<0.001**	-0.01	0.985	0.68	**<0.001**

Table VI. Correlation between pedicle path and angle in AP and BP.

		R-CL		**R-PTA**		**R-PSA**		**L-CL**		**L-PTA**	
		r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
R-PTA	**AP**	0.01	0.968								
	BP	-0.08	0.381								
R-PSA	**AP**	0.03	0.930	-0.14	0.640						
	BP	0.31	**<0.001**	0.44	**<0.001**						
L-CL	**AP**	0.99	**<0.001**	0.01	0.997	0.05	0.855				
	BP	0.91	**<0.001**	-0.23	**0.018**	0.21	**0.022**				
L-PTA	**AP**	-0.13	0.662	0.73	**0.003**	0.07	0.816	-0.09	0.757		
	BP	-0.05	0.574	0.57	**<0.001**	0.09	0.351	-0.15	0.118		
L-PSA	**AP**	0.08	0.797	-22	0.461	0.92	**<0.001**	0.09	0.766	-0.14	0.644
	BP	0.26	**0.006**	0.14	0.153	0.22	**0.022**	0.21	**0.027**	0.37	**0.001**

p=0.003) BP: (r=0.57, p<0.001). Accordingly, as R-PTA increased, so did L-PTA. A significant positive correlation was also found between R-PTA and R-PSA in BP (r=0.44, p<0.001). On the other hand, a statistically significant negative correlation was found between R-PTA and L-CL in BP (r= -0.23, p=0.018). This means that as R-PTA increased, L-CL decreased (Table VI).

Statistically significant positive correlations were found between R-PSA and L-PSA in both populations (AP: (r=0.92, p<0.001) BP: (r=0.22, p=0.022)). There was a significant positive correlation between R-PSA and L-CL in BP (r=0.21, p=0.022). In BP, there was a significant positive correlation between L-CL and L-PSA (r=0.21, p=0.027) and between L-PTA and L-PSA (r=0.37, p<0.001) (Table VI).

DISCUSSION

A detailed study of thoracic vertebrae morphometry is crucial for clinical and surgical applications. These vertebrae provide thoracic stability and protect vital structures like the spinal cord. Accurate anatomical data in surgeries such as pedicle screw placement, deformity correction, and tumour resection enhances surgeon safety and reduces patient complications (Vaccaro *et al*., 1995; Datir & Mitra, 2004). Pedicle width and height are key parameters for screw placement, with significant individual and population differences (Lehman *et al*., 2003; Smorgick *et al*., 2005). Dry bone studies enable precise anatomical and morphometric analysis by removing soft tissue, allowing direct measurement of parameters like pedicle width, vertebral body volume, and spinal canal diameter (Chaynes *et al*., 2001; Morales-Avalos *et al*., 2014; Shetty *et al*., 2019). Unlike radiological methods, dry bone studies avoid measurement errors and artefacts, offering true morphometric values (Varol *et al*., 2006; Shetty *et al*., 2019).

This study compared the dry thoracic vertebrae morphometric measurements from the AP and BP with existing literature (Table VII) to highlight population differences, material effects, and method impact, providing a valuable database for clinicians, particularly in surgical procedures.

The VBW measured in the AP (30.81 mm) was significantly higher than that measured in the BP (28.06 mm). We believe that this difference reflects the effect of genetic and environmental factors. The VBW values measured by Desdicioglu *et al*. (2017) and Tuncer (2017) in the AP (29.93 mm and 33.31 mm, respectively) were compatible with the measurements of the AP in our study. The tighter vertebral body in the BP may indicate genetic variation between different populations. In the literature, two different studies conducted within the Indian Population in 2022 reported an average VBW of 44 mm by Ashish *et al*., (2022), and 28.22 mm by Moulya *et al*. (2022). In the same population, Yadav *et al*. (2023) reported 25.58 mm, Jha & Sethi (2018) 26.97 mm, Vasantha *et al*. (2017), 24.4 mm. This difference in the same population may be due to the difference in the sample size used in the studies. VBW affects pedicle screw placement and implant stability (Vaccaro *et al*., 1995). A wider vertebral body allows for larger implants, whereas a tighter body may increase the risk of surgical complications.

The VBH was 19.96 mm in the AP as compared to 18.55 mm in the BP. This difference is consistent with the higher vertebral morphology in the AP. In the Indian Population Ashish *et al*. (2022) found the mean VBH to be 24.6 mm, Moulya *et al*. (2022) 18.17 mm, Yadav *et al*. (2023) 16.24 mm, Jha & Sethi (2018) 17.06 mm, Vasantha *et al*. (2017) 17.71 mm. Desicioglu *et al*. (2017) reported a mean VBH of 18.63 mm for the AP and Tuncer (2017) reported 19.29 mm. Thus, these differences, both between populations and within the same population, may be due to the number of samples and environmental and genetic influences. The VBH is an important factor in kyphosis deformities and spinal stability (Shin *et al*., 2021). Vertebrae included in studies with higher vertebral body height may be considered to belong to individuals with stronger load-bearing capacity.

In the present study, the VBAPL was 26.27 mm in the AP and 22.67 mm in the BP. In two different studies conducted in AP, this value was reported as 24.01 mm and 15.3 mm on average (Desdicioğlu *et al*., 2017; Tuncer, 2017). On the other hand, different values ranging from 18.53 mm to 30.1 mm were reported in studies conducted in the Indian Population (Vasantha *et al*., 2017; Ashish *et al*., 2022; Moulya *et al*., 2022). Accordingly, it is thought that such a wide range of variation in the anteroposterior distance of the vertebral body may be due to individual differences (such as lifestyle, working style, age and gender) rather than population differences.

The VFTD is an important parameter affecting the width of the spinal canal and the pedicle screw insertion angle (Ashish *et al*., 2022). The VFTD was measured as 15.93 mm in the AP and 17.40 mm in the BP. Desicioglu *et al*., reported the mean VFTD as 18.77 mm, and the results were compatible with the BP (Desdicioğlu *et al*., 2017). This difference in the AP may be due to the smaller sample size. On the other hand, Ashis *et al*., (2022) reported a mean VFTD of 21.6 mm and Tuncer (2017) reported a mean value of 20.38 mm. It may be considered that wider transverse distance provides more space for the structures in the spinal canal. The Anatolian, British and Indian populations all have the same value for the VFAPD (Table VII).

Table VII. Compared to all parameters to literature.

		Present Study AP	Present Study BP	Ashish *et. al.*	Panjabi *et al.*	Tan et. *al.*	Patil *et. al.*	Garg *et. al.*	Tuncer	Desdicioglu *et al.*	Yadav *et. al.*	Jha and Sethi	Vasantha *et. al.*	Shetty *et. al*	Das et *al.*	Singh *et al.*	Moulya *et al.*	Berry *et al.*	Zindrick *et al.*	McLain *et al.*	Datir *et al.*	Lien *et al.*	Pai *et al.*
N		14	110	200	144	220	200	120	156 n_{TH}=103	100 n_{TH} =50	100	150	100	100 set	100 set	100 set	82	240	2,905	18 set	18	T1-L5 (15 set) T11-l5 (6 set)	15 set cadaveric 15 set patients
Level		-	-	-	C2-L5	C3-T12	-	T2-T8	-	-	-	-	-	+	+	+	-	T2, T7,T12	T1-L5	T1-T6	T1-T12		T1-T12
Age, sex		-	-	-	+	+	-	-	-	-	-	-	-	+	-	Age-Sex+	-	-	-	+	+	-	+
Year		2024		2022	1991	2004	2014	2020	2017	2017	2023	2018	2017	2019	2018	2011	2022	1987	1987	2002	2004	2007	2010
Country		Türkiye	UK	India	USA	China	India	India	Türkiye	Türkiye	India	India	India	India	India	India	India	USA	USA	USA	India	Taiwan	India
Material of study		DB		DB	FAWSS	CS	DB	DB	DB	DB	DB	DB	DB	CT-CS	DB	CS	DB	DB**	CT-R	CS	CDR-CT:	CS	CS-R
VBW (mm)		30.81	28.06	44	*	*	-	-	33.31	29.93	25.58	26.97	24.4	-	*	*	28.22	*	-	-			-
VBH (mm)		19.96	18.55	24.6	*	*	-	-	19.29	18.63	16.24	17.06	17.71	-	*	*	18.17	*	-	-			-
VB_{APL} (mm)		26.27	22.67	30.1	*	*	-	-	15.3	24.01	18.53	19.95	21.96	-	*	*	21.77	*	-	-			-
VF_{APD} (mm)		14.86	15.60	14.2	*	*	-	-	7.38	15.54	-	-	-	-	*	*	-	*	-	-			-
VF_{TD} (mm)		15.93	17.40	21.6	*	*	-	-	20.38	18.77	-	-	-	-	*	-	-	*	-	-			-
PH (mm)	R	12.98	11.49	-		*	10.6	10.16	12.67	12.01	9.64	-	-	*	-	*	-	*	*	*	*	*	*
	L	13.01	11.14	-	*	*	10.54	10.38		11.9	9.68	-	-		-							*	
PW (mm)	R	6.03	5.76	-	*	*	4.29	5.18	27.17	5.98	3.75	-	-	*	-	*	-	*	*	*	*	*	*
	L	6.07	5.89	-		*	4.33	5.71		5.83	3.74	-	-		-							*	
IPD (mm)		22.94	23.02		*	*	-	-	-	28	-	-	-	*	-	*	-	*	*	-	*	*	-
CL (mm)	R	40.30	31.69	-	-	-	35.83	-	-	-	-	-	-	*	-	*	-	*	*	*	*		*
	L	40.4	33.17	-	-		35.94	-		-	-	-	-		-			*				*	
PTA (°)	R	9	10	-	*	*	14.52	-	-	-	-	-	-	*	-	*	-	*	*	*	*	*	*
	L	8.5	11	-		*	14.37	-		-	-	-	-		-							*	
PSA (°)	R	9	9	-	*	*	13.82	-	-	-	-	-	-	*	-	*	-	*	*	*	*	*	-
	L	8.5	10	-		*	13.81	-		-	-	-	-		-			*				*	-

DB: Dry Bones; **FAWSS:** Fresh Autopsy Whole Spine Specimens; **CS**: Cadaveric Specimens; **CT-CS:** CT-Cadaveric Specimens; **CT-R:** CT -Radiographs; **CDR-CT:** Cadavers By Direct Radiography-CT; **CS-R**: Cadaveric specimens-Radiographs **DB****: dry bones with autopsy report

A consistent balance of vertebral morphometry was observed, with positive correlations between the overall vertebral body dimensions in both populations. However, the correlations between vertebral body and foramen dimensions were stronger in the BP, likely due to the larger sample size, which made these correlations more reliable. In contrast, the smaller sample size in the AP may have reduced statistical power, making variations less apparent.

Desicioglu *et al*., reported a mean R-PW of 5.98 mm and a mean L-PW of 5.83 mm (Desdicioglu *et al*., 2017). The results of this study with AP were consistent with the results of our study. Nevertheless, it was observed that the PW values reported in studies conducted in the Indian population were lower than both Anatolian and British populations (Patil & Bhuiyan, 2014; Garg *et al*., 2020; Yadav *et al*., 2023). The same was found for the PH values (Table VII). These results suggest that the higher pedicle measurements in the AP and BP reflect a larger pedicle structure that contributes to spinal stability. This is because wider and higher pedicles increase the strength of the spinal structure and protect against injuries (Lehman *et al*., 2003; Smorgick *et al*., 2005). This shows that ethnic and geographical differences have an effect on morphometric characteristics. In addition, the type of work may also play an important role in determining morphometric values, such as PW and PH of the vertebrae. In particular, the physical activity of individuals may cause these values to vary. For example, in people who carry heavy loads, the spine structure can be expected to develop wider and higher pedicles due to the continuous loading. This may be considered as an evolutionary adaptation to increase the stability of the spine. In addition, the load distribution on the spine may differ in seated individuals. Prolonged sitting may lead to a weakening of the lumbar and back muscles and therefore less support for the vertebral structures (Makhsous *et al*., 2009; Cho *et al*., 2023). This may lead to lower pedicle measurements.

While CL was determined as 40.30 mm on the right and 40.40 mm on the left in the AP, it was measured as 31.69 mm on the right and 33.17 mm on the left in the BP. In the Indian population, Patil & Bhuiyan (2014) reported as 35.83 mm on the right and 35.94 mm on the left and the results were consistent with the BP. Pedicle angles were found to be compatible between the Anatolian and the British population, while these angles were found to be larger in the Indian population (Table VII) (Patil & Bhuiyan, 2014). In another aspect, when the pedicle structure was analysed in the correlation analyses performed in our study, it was found that the transverse and sagittal angles of the pedicle showed more variation in the BP. This finding may be explained by the fact that individual differences are more apparent due to the different distribution between the sample groups. In the AP the symmetry between the pedicles was more pronounced. Population differences may result from work style, physical activity, and geographical factors, explaining how genetic and environmental factors influence vertebral structures. Additionally, the longer screwing paths in the AP align with its larger vertebrae. Since screw length and angle affect pedicle stability longer screws in the AP may offer greater stability (Shetty *et al*., 2019).

Limitations. The study could not explore differences based on age, gender and thoracic level. When we searched the literature, we found studies that evaluated all morphometric parameters of the thoracic vertebrae separately according to the vertebral levels, but as can be seen in Table VII, these studies were mostly performed with radiographs, cadaver specimens or autopsy report available dry bones (Berry *et al*., 1987; Zindrick *et al*., 1987; Panjabi *et al*., 1991; McLain *et al*., 2002; Datir & Mitra, 2004; Tan *et al*., 2004; Lien *et al*., 2007; Pai *et al*., 2010; Singh *et al*., 2011; Shetty *et al*., 2019). In our study using dry bones, a morphometric evaluation of the vertebrae with uncertain level was performed, so data comparison with these studies in the literature could not be made. The fact that the sample numbers of the populations in our study were not balanced is also one of the limitations of our study.

CONCLUSION

This study shows significant differences in vertebral morphometry between Anatolian and British populations, with genetic variations and environmental adaptations likely influencing these differences. The AP generally has wider and higher vertebral structures than the BP. These findings highlight the need to consider population-specific reference values in pedicle screw placement and spinal deformity surgeries. Similar studies in the literature support these results and emphasize the importance of further research in this area. Our point of view, the dry bone material used in our study is important in terms of providing reference values free from the effect of tissue integrity. In addition, this study evaluates all the parameters of thoracic vertebral morphometry together and reveals the differences between populations in more detail. The demonstration of normal morphometry may have a significant potential for better understanding of anatomical structures and their interrelationships in the clinic, as well as for diagnosis and personalised treatment approaches.

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KARACA BOZDAG, Z.; CANDIR GÜRSES, B.N.; SOAMES, R.W. & ALASHKHAM, A. Morfometría de vértebras torácicas utilizando especímenes secos. *Int. J. Morphol., 43(6)*:xxxx-xxxx, 2025.

RESUMEN: El estudio tuvo como objetivo analizar las características morfométricas de las vértebras torácicas secas de las poblaciones anatolia (AP) y británica (BP) para evaluar las diferencias entre estas poblaciones y proporcionar una base de datos para los profesionales clínicos en la práctica clínica, especialmente durante los procedimientos quirúrgicos. El estudio examinó 183 vértebras torácicas secas (edad, sexo y nivel desconocidos). Se excluyeron 59 (deformidades morfológicas o puntos de referencia) y se analizaron 124 (anatolia: 14; británica: 110). Todas las mediciones se tomaron con calibradores digitales (0,01 mm) y un goniómetro. Se utilizó plastilina para elevar y posicionar cada vértebra según su posición anatómica. La precisión de la postura se verificó utilizando un nivel de burbuja. El análisis estadístico se realizó utilizando SPSS (IBM SPSS Statistics para Windows, versión 28.0), y un valor $p < 0,05$ se consideró significativo. El ancho del cuerpo vertebral, la distancia anteroposterior, la distancia transversal del foramen, la altura del pedículo izquierdo, la longitud de la trayectoria del tornillo pedicular y el ángulo transversal fueron significativamente diferentes entre las poblaciones. Mientras que el ancho del cuerpo vertebral, la distancia anteroposterior, la altura del pedículo izquierdo, la longitud de la trayectoria del tornillo y el ángulo transversal del pedículo izquierdo fueron mayores en la población anatolia (p < 0,05), se encontraron correlaciones positivas significativas entre la longitud de la trayectoria del tornillo pedicular izquierdo y los ángulos pediculares en la población británica (r = 0,21, p = 0,027). Este estudio mostró que había diferencias significativas en las propiedades morfométricas de las vértebras torácicas entre las poblaciones anatolias y británicas. Estos resultados resaltan la importancia de los valores de referencia poblacionales en la cirugía de tornillos pediculares y de deformidades espinales.

PALABRAS CLAVE: Huesos secos; Vértebras torácicas; Morfometría; Diferencias raciales.

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