MULTI-SLICE COMPUTED TOMOGRAPHY OF THE SEVENTH CERVICAL AND FIRST THORACIC VERTEBRAE AS A NEW TOOL FOR SEX IDENTIFICATION AMONG EGYPTIANS

Nazih Ramadan[1], Mervat Hamdy Abd El-Salam[1], Amani Fahmy Hanon[1], Naglaa Farid El-Sayed[1], Ahmed Yosri Al-Amir[2], Rabab Abdulmoez Amin Eltokhy[1]

[1] Department of Forensic Medicine & Clinical Toxicology, Faculty of Medicine, Cairo University

[2] Radiology Department, Faculty of Medicine, Cairo University

Corresponding author: Dr: Rabab Abdulmoez Amin Eltokhy

Email: drrababab dulmoez@gmail.com Mobile: 01100161896

Submit date: 26-06-2024
Revise date: 22-08-2024
Accept date: 8-09-2024

ABSTRACT

Background: The Biological profile (which includes sex, age, race, and stature) of human remains has an important role in forensic medicine and physical anthropology; sex is the most and first important parameter. Vertebrae exhibit morphological characteristics that make them easily identifiable if recovered from a scene. Previous studies proved sexual dimorphism of the seventh cervical and the first thoracic vertebrae, however, never investigated among Egyptians. Hence, the aim of this work is to investigate the role of these vertebrae in Sex identification among the Egyptians.

Materials and Methods: This study was a cross-sectional analytical study. Seven measurements (Maximum sagittal length (XSL), Length of the vertebral foramen (LVF), Maximum width of the vertebral foramen (WVF), Sagittal maximum body diameter (SBD), Maximum transverse diameter of the body (TBD), Maximum height of anterior vertebral body (XHA), Maximum height of posterior vertebral body (XHP)) were taken from computed tomography scans of the seventh cervical (C7) and first thoracic (T1) vertebrae of 112 Egyptians whom age was from 20 to 60 years with no vertebral or bone diseases. The statistical package for social science (SPSS version 21) was used for data analysis.

Results: Males were proved to have statistically significantly larger measurements than females ($p > 0.005$) for all measurements of C7 and T1, and sex could be determined at an accuracy of 84.4% and 89.3% for C7 and T1 respectively.

Conclusion: This study showed a significant difference in measurements of the seventh cervical vertebrae and the first thoracic vertebrae for sex discrimination so this can suggest that these two vertebrae could be added to other sex-identifying tools in crime or death scenes for the Egyptian population**.**

Keywords: Sex; Egyptian; Vertebrae; Cervical

INTRODUCTION

In forensic medicine and physical anthropology, sex identification is important for completing a biological profile (besides age, race, and stature) of human remains **(Torimitsu et al., 2016).** Regarding sex identification, big bones like the pelvis and skull are used with high accuracy 95-100 % **(Badr El Dine and El Shafei, 2016),** though, these bones may be absent or destroyed in a scene **(Marlow and Pastor, 2011).** Therefore, many previous studies have attempted to determine sex by metric analysis of other bones as femur **(Cuzzullin et al., 2022)**, clavicle **(Dehiya et al., 2019),** scapula **(Curate**

et al., 2024), sternum **(Ekizoglu et al., 2014),** patella **(Tomaszewska et al., 2022)**, talus , metatarsals, tarsals **(Abd-elaleem et al., 2012)**, calcaneus **(Ekizoglu et al., 2017)**, metacarpals, and phalanges **(Senol et al., 2023).**

Vertebrae exhibit morphological characteristics that make them easily identifiable if recovered from a scene **(Rozendaal, 2016 & Voisin, 2011).** Marino in 1995, proved that the atlas (first cervical vertebra) can be used as sex discriminator with 60-89% accuracy, while the second vertebra in the cervical region was verified as a sex determinant tool at high accuracy around 90 % **(Torimitsu et al., 2016 &Gama et al., 2015).**

The 7th cervical vertebra (C7) is a transition between vertebrae of cervical region and thoracic region; it is also called as the vertebra prominens because it is characterized by extensive spinous process **(Amores et al., 2014)**.

Dimorphism between males and females regarding the seventh cervical vertebra was approved by various studies **(Amores et al., 2014, Amores and Viciano, 2022, Rohmani et al., 2021, Sharma et al., 2017, Palancar et al., 2021 & Rozendaal et al., 2020).** In addition, the first thoracic vertebra (T1) reported to have high sex identification accuracy rates from 84% **-** 89% **(Unluturk and Iscan, 2014)**.

For Egyptians, vertebral role in sex identification was proved for the first lumbar and last thoracic vertebrae **(Badr El Dine and El Shafei, 2016, Ramadan et al., 2017 & Ramadan et al., 2017**), however to our knowledge, there are no published articles considered the importance of the 7th cervical or the first thoracic vertebra in sex identification. In addition, it is important to assess ethnic variations either in clinical or forensic studies that include bones as there are differences in fracture risk and other risks between ethnic groups in both men and in women across the globe **(Zengin et al., 2015 & Zengin et al., 2016).**

Our study aimed to assess the role of seventh cervical and first thoracic vertebrae in sex identification for an Egyptian population

METHODOLOGY:

Subjects:

112 patients were included in our study and two equal groups of males and females were done, each group were 56 subjects. Computed tomography (CT) of the neck was done for every patient after giving informed consent. Those patients were patient seeking medical advice in kasralainy hospital and CT neck was done for medical different reasons not affecting bone.

Ethical approvals:

The ethical and scientific Committees of forensic medicine and clinical toxicology department as well as that of faculty of medicine, in Cairo University approved this study.

Inclusion criteria:

Age of patient from 20- 60 with no history of bone disease.

Exclusion criteria:

Bone diseases as congenital diseases, fracture, osteoarthritis, tumors, surgery or metabolic bone diseases were excluded.

Multi-slice computed tomography scans:

Machine: helical CT scanner imaging machine (SOMATOM emotion 16 slice 78830, Siemens, Germany).

Principle: The participant body was exposed to direct X-rays through a spinning tube. The orientation of the sensors along the length (*z*-axis) of the body allows the scanners to acquire 4, 8, 16, 64, or more segments with each spin of the x-ray duct. The gained scans can be remodulated into two- and three-dimensional planes.

Procedure: The scanning process was conducted to get 1.5 mm sections thickness; bone window and clarity B70 for maximum image vision using the software program analyze (Syngo VB 42). photos that didn’t show clear borders were adjusted as maximum intensity projection (MIP) images.

Evaluated Measurements:

Seven measurements [Maximum sagittal length (XSL), vertebral foramen length (LVF), Maximum width of the vertebral foramen (WVF), Sagittal maximum body diameter (SBD), Maximum transverse diameter of the body (TBD), the Maximum height of anterior vertebral body (XHA), Maximum height of posterior vertebral body (XHP)] were measured for C7 and T1 as shown in **figure 1**, **table 1** **(Amores et al., 2014, Albright, 2007).** The Calibrated ruler of the system was used for measurements; approximation to the nearest 0.1 millimeter was done.

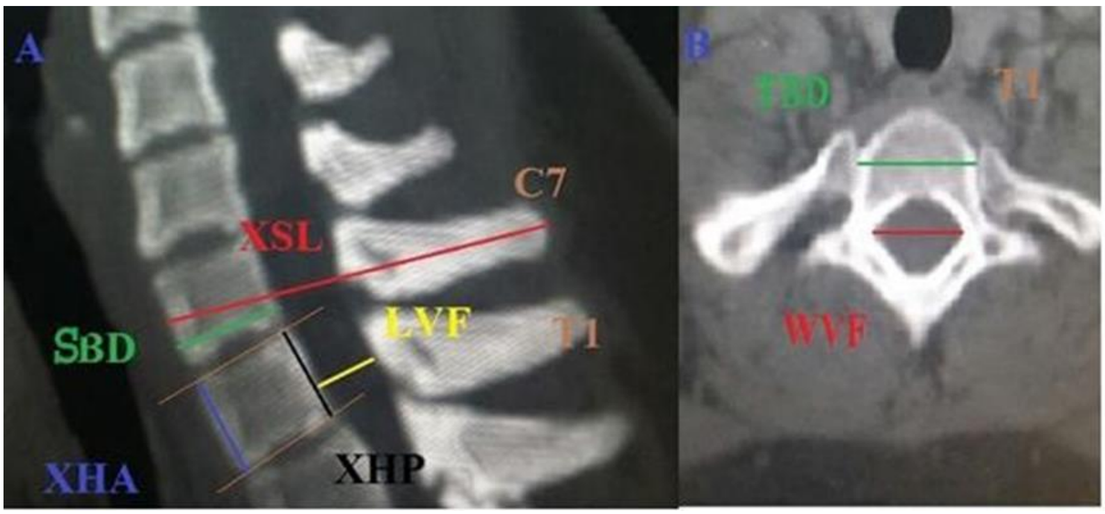

Figure (1): Measurements of the seventh cervical and the first thoracic vertebrae from multi-slice computed tomography of our study. (A) in sagittal plane, (B) in axial plane. Each line takes the same color of its written measurement name abbreviation

Maximum sagittal length (XSL), Length of the vertebral foramen (LVF), Maximum width of the vertebral foramen (WVF), Sagittal maximum body diameter (SBD), Maximum transverse diameter of the body (TBD), Maximum height of anterior vertebral body (XHA), Maximum height of posterior vertebral body (XHP) **(Amores et al.,2014, Albright, 2007).**

Table (1): measurements of the seventh cervical and the first thoracic vertebrae **(Amores et al., 2014, Albright, 2007).**

Measurement	**Description**	**Image**
Maximum sagittal length (XSL)*****	From the most anterior point of the body to the most posterior point of the spinous process	Sagittal MIP
Length of the vertebral foramen (LVF)*****	The sagittal internal length of vertebral foramen from posterior aspect of the vertebral body to the anterior aspect of the spinous process	Sagittal MIP
Maximum width of the vertebral foramen (WVF)**	The maximum internal side to side width of the vertebral foramen	Axial
Sagittal maximum the vertebral body diameter (SBD)*****	Measured from the most anterior point on the body to the most posterior point	Sagittal MIP
Maximum transverse diameter of the vertebral body (TBD)**	Maximum transverse diameter of the body measured between the most lateral edges of the body	Axial
Maximum height of anterior vertebral body (XHA)*****	Maximum height from the most superior edge to the most inferior edge of the anterior border of the vertebral body	Sagittal MIP
Maximum height of posterior vertebral body (XHP)*****	Maximum height from the most superior edge to the most inferior edge of the posterior border of the vertebral body	Sagittal MIP

* Measurements taken from sagittal MIP images, after central adjustment of C7 and T1 using axial and coronal images

** Measurements taken from axial images after central adjustment of C7 and T1 using axial and coronal image

Statistical analysis

The data was analyzed using SPSS (statistical package for social science) version 21. We used Independent T-test for comparing qualitative data, when variables were proved to have significant association ($p < 0.05$) with sex we then tested it in stepwise discriminant function analysis. In this study: twenty randomly selected cases of each sample were repeated one weak apart by the same forensic pathologist to evaluate intra-observer errors. Another randomly selected twenty cases were repeated by the consultant radiologist to evaluate inter-observer errors.

RESULTS

Table (2) shows relative technical error of measurement (rTEMs) and the coefficient of reliability (R) values for the consideration of intra- and inter-observer errors; they were <1.5% for rTEMs; R values were >0.75.

Males were proved to have statistically significant larger measurements than females (p < 0.005) for all measurements of C7 and T1 **(table 3 &4).**

Table (2): Inter-observer and intra-observer error rates for the seventh cervical and first thoracic vertebrae.

Vertebrae	Measurement	Inter-Observer		Intra-Observer	
		rTEM*	R**	rTEM	R
C7	XSL	1.45%	0.97	1.5%	**0.98**
	SBD	1.27%	0.97	1.38%	**0.93**
	XHA	0.66%	0.97	0.97%	**0.92**
	XHP	0.84%	0.97	1.05%	**0.98**
	LVF	1.38%	0.97	1.38%	**0.86**
	WVF	0.93%	0.73	1.05%	**0.75**
	TBD	1.49%	0.85	0.92%	**0.82**
T1	XSL	0.67%	0.98	0.86%	**0.99**
	SBD	1.46%	0.95	0.79%	**0.94**
	XHA	1.16%	0.97	1.13%	**0.90**
	XHP	0.99%	0.97	0.92%	**0.88**
	LVF	0.95%	0.92	1.47%	**0.88**
	WVF	1.11%	0.94	1.21%	**0.79**
	TBD	**0.75%**	**0.95**	**0.60%**	**0.91**

*(rTEM) is the relative technical error of measurement.

**(R) the coefficient of reliability

In addition, Stepwise discriminant function analysis showed that **Maximum width of the vertebral foramen (WVF),** and also, **Maximum sagittal length (XSL)** were the most accurate sex identifying measurements of C7 **(table 3)**, while for T1 **Maximum height of posterior vertebral body (XHP), Maximum sagittal length (XSL), and Maximum width of the vertebral foramen (WVF)** were the most accurate measurements **(table 4)**

Table (3): Difference between males and females in measurements of seventh cervical vertebrae among a sample of Egyptian population (n=112)

	Males					Females					
	N	Min.	Max.	Mean	S.D.	N	Min.	Max.	Mean	S.D.	p. value
AGE	56	20	60	39.65	16.1	56	21	60	37.47	14.8	0.438
XSL	56	50	73.7	62.2	5.5	56	42.7	60	55.0	2.9	0.000**
SBD	56	12	25	18.4	2.5	56	11.9	19	16.4	1.5	0.000**
XHA	56	8.6	18	15.5	1.8	56	8.3	17	14.45	1.6	0.000**
XHP	56	9.5	19.5	15.9	1.9	56	8.3	18.5	14.8	1.7	0.000**
LVF	56	9	21	12.9	1.8	56	8.4	18	12.2	1.7	0.030*
WVF	56	21	30	25.9	2.0	56	15	28.8	24.4	2.2	0.000**
TBD	56	19.2	36.1	29.6	3.2	56	20.4	32.7	27.3	2.7	0.000**

(p<0.05*) significant, (p<0.001**) highly significant

For the seventh cervical vertebrae (C7), sex can be determined at an accuracy rate 84.4% **(table 3)** using the following equation;

S = 0.207*XSL + 0.143*WVF – 15.713

For S >0, the individual is assigned as male and as female if otherwise. While for the first thoracic vertebrae (T1), sex can be determined at accuracy rate 89.3% **(table 4)** using this equation

S = 0.187*XSL + 0.088* XHP + 0.140*WVF– 16.077

For S >0, the individual is assigned as male and as female if otherwise.

Table (4): The difference between males and females in measurements of the first thoracic vertebrae among a sample of Egyptian population (n=112)

	Males					**Females**					**p. value**
	N	**Min.**	**Max.**	**Mean**	**S.D.**	**N**	**Min.**	**Max.**	**Mean**	**S.D.**	
AGE	56	20	60	39.65	16.1	56	21	60	37.47	14.8	0.438
XSL	56	51	74.5	64.3	5.4	56	44	65	56.9	3.5	0.000**
SBD	56	13	24.6	19.4	2.2	56	12.2	21.3	17.4	1.8	0.000**
XHA	56	9.7	23	17.4	2.3	56	8.5	19	15.8	1.6	0.000**
XHP	56	9.7	25	18.2	2	56	9.4	19.6	16.2	1.6	0.000**
LVF	56	10	16.9	12.3	1.6	56	7.6	17.6	11.5	1.7	0.014*
WVF	56	19.4	28.8	23.6	2.1	56	15.5	26.1	22.0	2.2	0.000**
TBD	56	26	40	32.7	2.8	56	22.6	34	29.8	1.8	0.000**

(p<0.05*) significant, (p<0.001**) highly significant

DISCUSSION

The current work was able to prove that all measurements taken both from the 7th cervical vertebra and also, the 1st thoracic vertebra exhibited statistical significance between different sexes. Furthermore, the current study revealed that sex could be determined from C7 and T1 at high accuracy 84.4 % and 89.3% respectively.

This proved sexual dimorphism of these vertebrae thought to be explained by greater growth in transverse diameter and growth spurt in height of vertebra in males (**Marlow and Pastor, 2011**), or may be due to other factors as, genetic, physical activity, socioeconomic status, dietary intake (calories, protein, vitamin D, and calcium), and hormonal levels (**Rozendaal, 2016**).

Amores et al. (2014) conducted a study in Spain and, reached to nearly similar results for C7; they showed that males were significantly larger than females. However, they reached that LVF of C7 was the most accurate for sex determination with accuracy rate 65.5% - 80.2% **(table 5)**. Also **Unluturk and Iscan (2014)** by studying a Turkish sample, were able to identify sex from measurements of T1 at accuracy rates ranging from 84% to 89%.

In addition, **Kibii et al, (2010)**, by studying a South African sample proved Sexual dimorphism in vertebral body and foramen dimensions with more accurate body dimensions.

Table (5); Stepwise discriminant function analysis of measurements of seventh cervical and first thoracic vertebrae among a sample of Egyptian population (n=112)

vertebra	Step *	measurements	Unstandardized coefficient	Wilks' Lambda	Correct prediction rate (%)		
					male	**female**	overall
C7	2	XSL	0.207	0.883			
		WVF	0.143	0.596	78.70 %	90.20 %	84.40 %
		constant	-15.713				
T1	3	XSL	0.187	0.792			
		XPH	0.088	0.58			
		WVF	0.14	0.551	83.60 %	95.10 %	89.30 %
		constant	**-16.077**				

*step number is the number of last step of the DFA for each vertebra

In addition, it was reported in a study by **Knapik et al., (2018)**, in which they considered a sample of African Americans, that foramen dimensions of C7 were significantly different between males and females. However, **Rozendaal, (2016)** reported that on a study carried out on white European populations, WVF was only significant to differentiate between males and females besides vertebral body heights (XH) while LVF wasn't significant.

The study of **Palancar et al., (2021)** which was carried out on a sample of Europeans, Africans, and Greenland Inuit, proved that the differences in sagittal diameter of body and foramen of C7 between males and females were statistically significant, despite that they took measurements on lateral radiographs. Also **Rohmani et al., (2021)** on their study on lateral radiographs of C7 of French sample proved sexual dimorphism in LMA and SBD which is similar to this study.

In addition, **Sharma et al., (2017)** on their study which was conducted in India, reported significant sexual dimorphism in the vertebral bodies of cervical vertebrae (from third to seventh) with the sagittal diameter more significant than transverse diameter. **Hora and Sládek, (2018)** also observed that vertebral body diameters were larger in males with accuracy of 95%.

Amores and Viciano, (2022) showed significant sexual dimorphism in a sample collected from Portugal when comparing cervical vertebrae, from the second to the seventh vertebrae with accuracy ranging from 80.0% to 92.5%.

In contrast to the current findings, **Ruhli et al, (2006)** revealed a slight greater vertebral foramen diameter (LVF) of C7 and T1 in Swiss females than in males.

CONCLUSION&RECOMMENDATIONS

This study showed significant difference in measurements of the 7th cervical and the 1st thoracic vertebrae for sex discrimination so this can recommend that theses vertebrae can be added to other sex identifying tools in crime or death scene for Egyptian population.

CONFLICTS OF INTEREST STATEMENT AND FUNDING

No conflict of interest, no funding

ABBREVIATIONS

Maximum sagittal length (XSL),

Length of the vertebral foramen (LVF),

Maximum width of the vertebral foramen (WVF),

Sagittal maximum body diameter (SBD),

Maximum transverse diameter of the body (TBD),

Maximum height of anterior vertebral body (XHA),

Maximum height of posterior vertebral body (XHP))

the seventh cervical vertebra (C7)

first thoracic vertebra (T1)

Computed tomography (CT)

maximum intensity projection (MIP)

The relative technical error of measurement (rTEMs)

the coefficient of reliability (R)

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الملخص العربي

الاشعة المقطعية للفقرات العنقية السابعة والصدرية الأولى كأداة جديدة لتحديد الجنس بين المصريين

نزيه رمضان[١]، ميرفت حمدي عبدالسلام[١]، أماني فهمي هنون[١]، نجلاء فريد السيد[١]، أحمد يسري الأمير[٢]، رباب عبدالمعز أمين الطوخي[١]

1 قسم الطب الشرعي والسموم الإكلينيكية، كلية الطب، جامعة القاهرة

2 قسم الأشعة بكلية الطب جامعة القاهرة

المقدمه: يلعب الملف البيولوجي (الذي يتضمن الجنس والعمر والعرق والطول) للبقايا البشرية دورًا مهمًا في الطب الشرعي والأنثروبولوجيا الفيزيائية؛ الجنس هو المعلمة الأكثر أهمية والأولى. تظهر الفقرات خصائص مورفولوجية تجعل من السهل التعرف عليها إذا تم استعادتها من مسرح الجريمه. أثبتت الدراسات السابقة ازدواج الشكل الجنسي للفقرة العنقية السابعة والفقرة الصدرية الأولى، ولكن لم يتم بحثها مطلقًا بين المصريين.

المواد والطرق: سبعة قياسات (الطول السهمي الأقصى (XSL)، طول الثقبة الفقرية (LVF)، الحد الأقصى لعرض الثقبة الفقرية (WVF)، الحد الأقصى لقطر الجسم السهمي (SBD)، الحد الأقصى للقطر العرضي للجسم (TBD) تم أخذ الحد الأقصى لارتفاع الجسم الفقري الأمامي (XHA) والحد الأقصى لارتفاع الجسم الفقري الخلفي (XHP)) من فحوصات التصوير المقطعي للفقرة العنقية السابعة (C7) والفقرة الصدرية الأولى (T1) لـ ١١٢ مصريًا تتراوح أعمارهم بين ٢٠ إلى ٦٠ سنة بدون أمراض في العمود الفقري أو العظام. تم استخدام الحزمة الإحصائية للعلوم الاجتماعية (SPSS الإصدار ٢١) لتحليل البيانات.

النتائج: ثبت أن الذكور لديهم قياسات أكبر ذات دلالة إحصائية من الإناث ($p > 0.005$) لجميع قياسات الفقرة العنقية السابعة و الفقرة الصدرية الأولى ، ويمكن تحديد الجنس بدقة ٨٤,٤% و٨٩,٣% للفقرة العنقية السابعة و الفقرة الصدرية الأولى على التوالي.

الاستنتاج: أظهرت هذه الدراسة اختلافًا كبيرًا في قياسات الفقرة العنقية السابعة والفقرة الصدرية الأولى في التمييز بين الجنسين،

التوصيات : توصي هذه الدراسه الي إمكانية إضافة الفقرة العنقية السابعة و الفقرة الصدرية الأولى إلى أدوات تحديد الجنس الأخرى في مسرح الجريمة أو الموت للسكان المصريين.