2ND AND 7TH CERVICAL VERTEBRAE INDICES USING MULTISLICE COMPUTED TOMOGRAPHY AS A DIAGNOSTIC TOOL IN DIFFERENTIATION OF SEX AND AGE IN EGYPTIAN SAMPLE, MENOUFIA GOVERNORATE

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ABSTRACT

Introduction: Age and sex estimations play a vital role in establishing an individual's identity. Identification depending on Computed Topographies (CT) of vertebrae have become increasingly important in the forensic field, as vertebrae are most commonly present at a death scene. The second (C2) and seven (C7) cervical vertebrae have a unique morphology making them easily identifiable in a disarticulated skeleton.

Aim of the study: The study aims to investigate the role of both C2 and C7 vertebrae as a diagnostic tool in the estimation of age and sex among Menoufia population.

Methodology: The study was carried out on 102 cases from Menoufia population; 51 males and 51 females, with age ranging from 12- 70 years. Patients were divided into 3 groups according to WHO age classification with some modifications. The persons included in this study were patients who came for Computed Tomography (CT) scan of the neck for any medical reason in the Radiology Department of Menoufia University and the CT was done for them after giving written informed consent. The cases with pathological conditions and/or with prominent degenerative changes were excluded from this study. The multi -slice computed tomography (MSCT) measurements of the different indices of C2 (15 indices) and C7 (11 indices) in the studied participants were taken.

Results: Males were higher C2 and C7 vertebrae measurements than females in all measurements. This difference was statistically significant in 13 indices of C2 and 9 indices of C7 vertebrae. Density indices of both C2 and C7 vertebrae were independent predictors for sex with accuracy rate 83% and 88% respectively. Also, there was significant positive relation between age and almost all the metric indices of C2 and C7 vertebrae.

Conclusion: MSCT of C2 and C7 vertebrae measurements can be used to identify both the sex and age of unknown individuals; however, further studies with larger sample of population from different Egyptian districts are recommended.C2 and C7 vertebrae measurements

Keywords Computed tomography; Menoufia; C2; C7; vertebrae; Age; Sex.

INTRODUCTION

Identification of a person is a crucial task in forensics. Estimations of age, sex, stature, and ancestry, which is referred to as biological profile, minimize the possible matches of a victim and consequently give beneficial clues in personal identification **(Ramadan et al., 2017)**

Forensic anthropologists face a great challenge regarding the identification of unknown skeletal remains, precisely in corpses with advanced state of decomposition and mass disaster **(Klales et al., 2020)**

Estimating sex via skeletal examination is an important first step in developing a reliable biological profile because it reduces the number of possible victim matches by 50%.**(Langley and MariaTeresa, 2017).**

Also, age estimation has a fundamental role in both forensic practice and anthropology **(Jagannathan et al., 2011).** It has increasing importance in criminal cases. Sometimes there may be a controversy about the age of an assailant, and so the need to ascertain whether he has reached the age of full criminal responsibility or not **(Shaaban and El-Shall, 2017).**

Various indicators can assess individual growth statuses, such as chronological age, teeth eruption, peak height velocity, secondary sexual characteristics, and maturation of the skeleton **(Chandrasekar et al., 2020).** In addition, it was shown that vertebral morphological changes can help in understanding and evaluation of the developmental status of a growing person **(Kacar et al., 2017).**

The Pelvis and skull show the highest dimorphism and are traditionally used bones for differentiation of sex. However, in certain situations (severe mutilation, advanced state of decomposition or skeletonization), they may be subjected to fragmentation and/ or bad preservation or even may not be present. For this reason, it is mandatory to find new methods for gender differentiation depending on less dimorphic bones such as vertebrae, and investigations have shown that acceptable rates of accuracy could be achieved by using them **(Gama et al., 2015; Rozendaal et al., 2020; Ekizoglu et al., 2021).**

Forensic investigators have used the vertebral column because of its relative thickness, compact structure, and ability to resist crushing with mechanical forces in harsh conditions such as a mass disaster or bushfire. It was identified as a well-preserved bone structure in several situations **(Blau and Briggs, 2011; Hora and Sládek, 2018; Padovan et al., 2019).**

The C2 can be easily identified in a disarticulated skeleton, as it has unique morphological characteristics, such as the dens, which allow forensic anthropologists to identify the bone immediately **(Zanutto et al., 2021).**

The vertebral bodies of C2, C3, and C7 have more variable features according to the age**(Liguoro et al., 1994).** Vertebrae may show high rates of accuracy regarding sex differentiation, especially when used in combination. **(Rohmani et al., 2021).**

Different bone indices could be measured by radiological technique or metric measurements by calipers on dry bones, but the latter requires huge effort and financial resources to have access to biological samples, which is usually done in the anthropological museum or laboratories. Radiological techniques are less invasive, more effective, and could be done on living individuals. **(Rohmani et al., 2021).**

Postmortem computed topographies (PMCT) have grown in importance and value in the forensic field. Its efficacy in the visualization of bone structures can help collect data for biological profile estimation using the skeleton **(Torimitsu et al., 2016).**

According to our knowledge, only few investigations had studied the role of C2 and C7 vertebrae using MSCT in differentiation of both sex and age, and this study is the first to be done in Menoufia, Egypt. For this reason, this work aimed to study the role of both C2 and C7 vertebrae as a diagnostic tool in estimation of age and sex among Menoufia population.

MATERIALS & METHODS:

We conducted this comparative cross-sectional study from October 1st 2021 to May 31st 2022 in Menoufia governorate, Egypt. The study was done after approval of Ethics Committee, Faculty of Medicine; Menoufia University number (6/2022FORE16). A written informed consent was obtained from each participant or his/ her guardian after explaining to him/ her aim and methodology of the study. We enrolled 102 cases (51 males and 51 females) with age ranged from 12-70 years, scheduled for imaging due to other reasons in Menoufia University Hospital. Patients were divided into 3 groups according to WHO age classification with some modifications: group 1 (< 18 years), group 2 (18- 60 years) and group 3 (> 60 years) **(Dyussenbayev, 2017).**

Inclusion Criteria:

All patients who needed CT scan of the cervical spines at Menoufia University's Radiology Departments for a variety of medical conditions served as the study's participants.

Exclusion Criteria

All cases with moderate to severe degenerative alterations, post-operative and /or metallic devices, and any pathological conditions, were excluded from the study. Also, patients who refused to participate in the study or to sign the consent were excluded.

Sample size estimation: The sample size calculation was performed using G. power (Universitat Kiel, Germany) 3.1.9.2. 35 depending on previous study (**Mostafavi et al., 2020).** At power 80% and confidence level 95%. Sample size was calculated to be 102 subjects, 51 males and 51 females with ratio (1:1). All participants were selected by cluster random sampling.

Data analysis: We analyzed the collected data using SPSS Version 23 (IBM Corp., Armonk, N.Y., USA). We presented

Quantitative data as mean and standard deviation and tested differences observed by using Student's t and ANOVA test for comparison between two and more than two normally distributed variables respectively. We calculated the strength of association between independent indices of C2 and C7 vertebrae and the dependent outcome (sex) using Odds ratio (OR) and 95% confidence interval (95% CI). We generated the Receiver operator characteristic (ROC) curve for unit of density for C2 (HU2) and unit of density for C7 (HU7). The accuracy of the indicator was measured by Area under the curve. Perfect area was 1 and the worthless result was an area of 0.5. A two tailed P value < 0.05 was considered statistically significant

Data collection:

Cervical vertebra CT was done on Multidetector CT scan for all patients using CT equipment (TOSHIBA, ALISON,16 detectors). Workstation (VITREAI 7) was used for imaging information preparing to get multiplanar reproduction pictures and volume-rendered pictures.

CT protocol:

Scout was performed from above the level of temporal bone to the level of manubrium sterni to include base of the skull and the first thoracic vertebra so that both C2 and C7 cervical vertebrae were visualized. Field of view (FOV) was ranging from 120-200 mm with slice thickness 1 mm, interval < 0.5 mm.

Fifteen measures were taken for C2 vertebra as follow:

1. Max height of cervical vertebra 2 (AMA), max length of the superior facet (CMFS), maximum sagittal body diameter (DSMC) and maximum length of the inferior Facet (CMFI) were measured in sagittal reformate **(fig 1 A and B).**
2. Odontoid process midsagittal maximum diameter (DSD), odontoid process maximum transverse diameter (DTD), vertebral foramen length (CMFV) and vertebral foramen maximum width (LMFV) were measured in axial view **(fig 1 C and D).**
3. the superior facets maximum distance (DMFS), Maximum width of superior facet (LMFS), odontoid process maximum height (AMD), cervical 2 maximum transverse diameter (DTMC), maximum axis width (LMA) and inferior facet maximum width (LMFI) were measured in coronal reconstruction images **(fig 2).**
4. Vertebral body density (HU2): Bone density was measured in Hounsfield unite (HU)

Eleven measures were taken for C7 vertebra as follow:

1. Superior facet length (LSF), inferior facet length (LIF), inferior surface of the vertebral body maximum length (LVB) and height of spinous process (HSP) were measured in sagittal reformate **(fig 3).**
2. Superior facet width (WSF), inferior facet width (WIF) and inferior surface of the vertebral body maximum width (WVB) were measured in coronal reconstruction images **(fig 3).**
3. Vertebral foramen width (WVF), length of spinous process (LSP) and length of the vertebral foramen (LVF) were measured in axial view **(fig 4).**
4. Vertebral body density (HU7): bone density was measured in Hounsfield unite (HU).

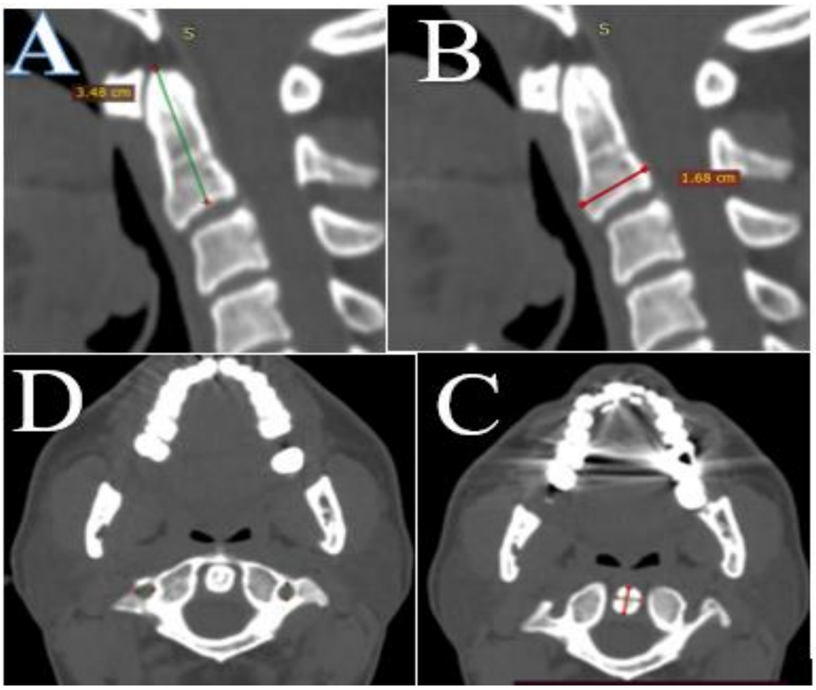

Figure (1): A :(AMA), B:(DSMC), C:(DSD) and (DTD), D: (CMFV)and (LMFV)

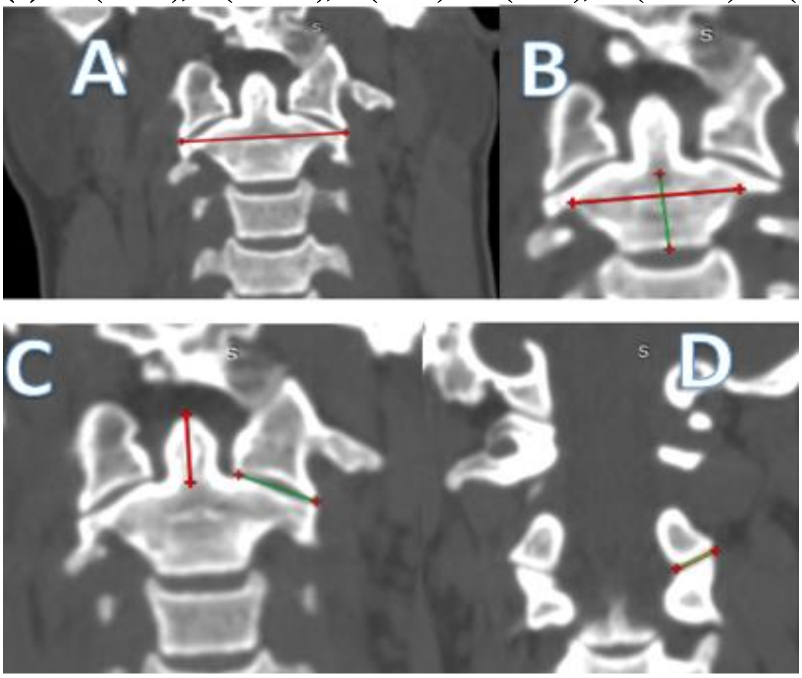

Figure (2): A:(DMFS), B:(DTMC) and (LMA), C:(AMD) and (LMFS), D: (LMFI)

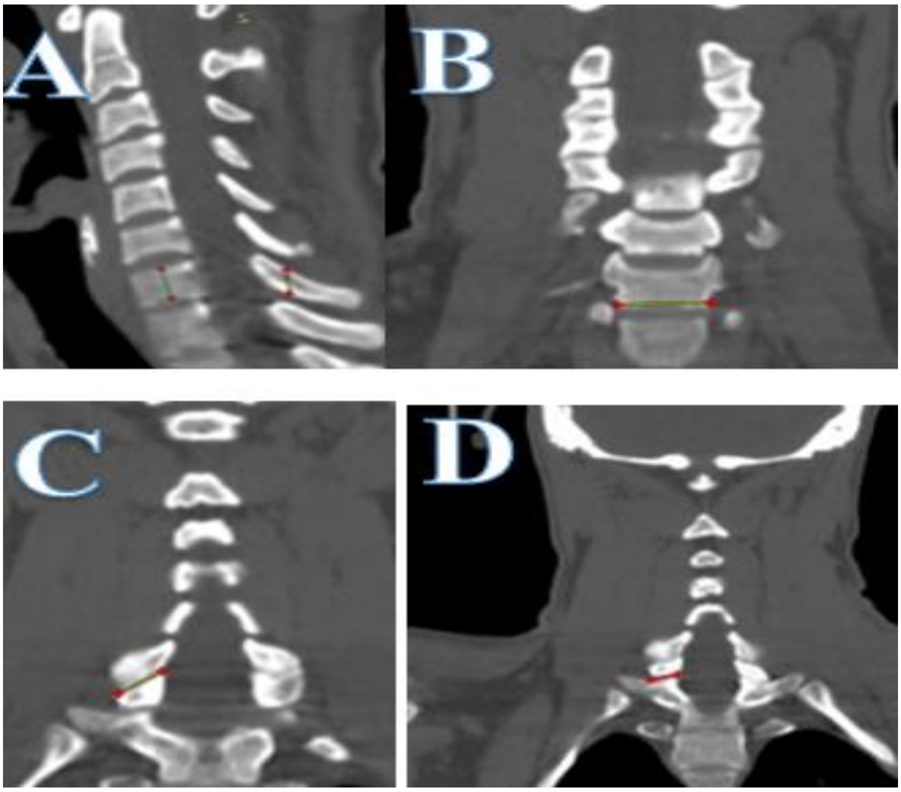

Figure (3): A:(LVB), (HSP) B:(WVB), C: (WSF), D: (WIF)

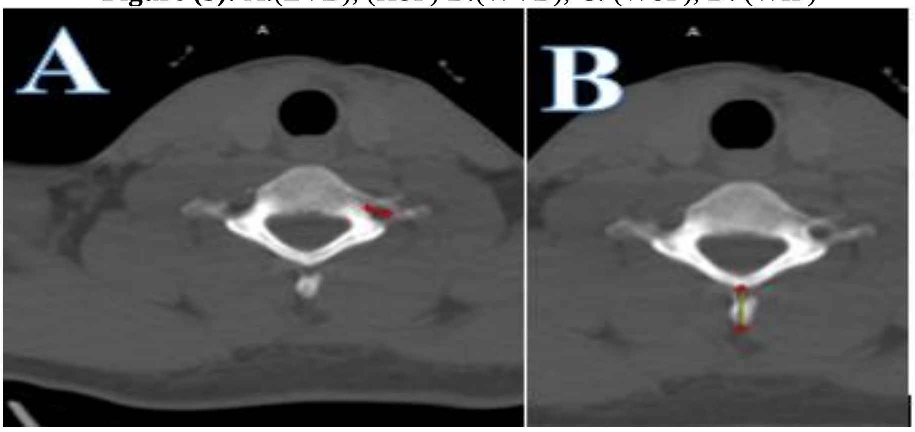

Figure 4: A:(WVF), B:(LSP)

RESULTS

The mean age of the studied participants was 43.02 ranging from (< 12 - 70 years). They were 102 cases (51 males and 51 females). The measurements for the different indices of C2 (15 indices) and C7 cervical vertebrae (11 indices) in the studied participants are described in **(Table 1).**

13 indices in C2 vertebrae (AMA, DSD, DMFS, CMFS, LMFS, CMFV, DSMC, LMFV, AMD, DTMC, LMA, LMFI and HU2) were significantly higher in males than females (p value <0.05). Also, 9 indices in C7 vertebrae (LSF, WSF, LIF, WIF, WVF, LVB, WVB, LSP and HU7) were significantly higher in males than females (p value <0.05) **(Table 2).**

The HU2 and HU7 indices in C2 and C7 vertebrae were the independent predictors for sex (p value were 0.02 and 0.01 respectively) **(Table 3 and 4).**

The area under the curve in the ROC curve for HU2 and HU7 indices in C2 and C7 vertebrae in differentiation between sex were 0.907 and 0.857 respectively. The accuracy for HU2 and HU7 indices in the second and seventh cervical vertebrae in differentiation between sex were (83% and 88%) respectively **(Table 5).**

All measured indices in C2 vertebra were significantly different between different studied age group (AMA, DSD, DTD, DMFS, CMFS, LMFS, CMFV, AMD, DTMC, LMA, LMFI and HU2) (P value < 0.05) except DSMC **(Table 6).** Also, all measured indices in C7 vertebra were significantly different between different studied age group (P value < 0.05) **(Table 7).**

Table (1): Measures of the indices of C2 and C7 vertebrae among the studied groups

	Studied groups(N=102)				
	Mean ± SD	**Range**		**Mean ± SD**	**Range**
Age (years)	43.02±**17.59**	12 – 70	**Age (years)**	43.02±**17.59**	12 – 70
15 indices of C2 vertebra			**11 indices of C7 vertebra**		
AMA	40.34±**6.22**	24.20 – 48.20	**LSF**	9.92±**1.49**	5.00 – 12.60
DSD	11.98±**1.54**	8.00 – 15.20	**WSF**	14.44±**2.19**	9.00 – 18.00
DTD	9.68±**0.89**	7.00 – 11.20	**LIF**	11.99±**1.77**	7.00 – 14.50
DMFS	47.51±**3.05**	35.20 – 50.78	**WIF**	13.15±**1.72**	6.00 – 15.00
CMFS	14.39±**1.57**	8.00 – 16.10	**IVF**	22.78±**2.12**	16.00 – 27.00
LMFS	13.81±**1.70**	9.30 – 16.00	**WVF**	25.70±**2.27**	20.00 – 29.00
CMFV	24.36±**2.86**	16.00 – 28.20	**LVB**	19.62±**2.56**	10.00 – 25.00
DSMC	16.29±**1.82**	10.20 – 18.70	**WVB**	31.86±**2.44**	22.00 – 35.00
LMFV	26.06±**1.79**	20.00 – 29.10	**LSP**	29.37±**2.78**	18.00 – 33.00
AMD	16.26±**2.09**	9.00 – 18.80	**HSP**	9.82±**1.81**	5.00 – 12.60
DTMC	23.59±**1.75**	16.00 - 26.00	**HU7**	323.99±**52.98**	210– 495
LMA	66.51±**4.56**	50.00 – 72.00			
CMFI	9.85±**1.39**	5.50 – 11.90			
LMFI	10.75±**1.67**	6.00 –13.00			
HU2	407.01±**119.25**	200 – 655			
HSP	9.82±**1.81**	5.00 – 12.60			
HU7	323.99±**52.98**	210– 495			

N=number **SD= standard deviation**

Table (2): Statistical comparison between male and female regarding the different indices of C2 and C7 vertebrae:

	Studied groups(N=102)					
	Male (n=51)		Female(n=51)		t- test	P value
	Mean ± SD	Range	Mean ± SD	Range		
15 indices of C2 vertebra						
AMA	44.09±**4.24**	31.40 – 48.20	36.59±**5.61**	24.20 – 46.25	7.61	<0.001**
DSD	12.76±**1.54**	9.50 – 15.20	11.21±**1.08**	8.00 – 13.50	5.88	<0.001**
DTD	9.96±**0.85**	8.20 – 11.20	9.85±**0.83**	7.00 - 10.30	0.66	0.51
DMFS	48.64±**2.41**	42.70 – 50.78	46.39±**3.23**	35.20 – 50.40	4.00	<0.001**
CMFS	14.76±**1.28**	12.00 – 16.10	14.03±**1.75**	8.00 – 15.80	2.41	0.01*
LMFS	14.41±**1.38**	11.70±**16.00**	13.22±**1.79**	9.30 – 15.80	3.73	<0.001**
CMFV	25.56±**2.44**	19.60 – 28.20	23.16±**2.76**	16.00 – 26.70	4.66	<0.001**
DSMC	17.35±**1.23**	14.50 – 18.70	15.24±**1.71**	10.20 – 18.50	7.15	<0.001**
LMFV	26.76±**1.58**	23.20 – 29.10	25.98±**1.72**	20.00 – 28.00	2.39	0.02*
AMD	17.28±**1.37**	14.10 – 18.80	15.24±**2.19**	9.00 – 18.70	5.61	<0.001**
DTMC	24.09±**1.25**	21.30 – 26.00	23.09±**2.03**	16.00 – 25.30	2.99	0.004*
LMA	67.78±**3.58**	59.00 – 72.00	65.23±**5.08**	50.00 – 72.00	2.93	0.004*
CMFI	10.41±**1.05**	8.20 – 11.80	10.12±**1.11**	5.50 – 11.90	1.36	0.18
LMFI	11.57±**1.31**	8.80 – 13.00	9.92±**1.59**	6.00 - 12.50	5.75	<0.001**
HU2	496.65±**99.15**	300 – 655	317.37±**50.03**	200 – 397	11.53	<0.001**
11 indices of C7 vertebra						
LSF	10.65±**1.09**	8.20 – 12.60	9.20±**1.49**	5.00 – 12.00	5.58	<0.001**
WSF	15.65±**1.99**	11.70 – 18.00	14.76±**1.64**	9.00 – 16.50	2.46	0.02*
LIF	13.10±**1.29**	10.00 – 14.50	10.88±**1.47**	7.00 – 14.00	8.11	<0.001**
WIF	14.11±**0.89**	12.00 – 15.00	12.18±**1.80**	6.00- -14.80	6.87	<0.001**
LVF	21.98±**1.80**	21.00 – 27.00	21.57±**1.71**	16.00 – 24.20	1.18	0.24
WVF	25.03±**1.69**	23.00 – 29.00	24.16±**1.71**	20.00 – 27.60	2.58	0.01*
LVB	20.64±**1.63**	17.60 – 23.00	18.61±**2.91**	10.00 – 25.00	4.36	<0.001**
WVB	33.06±**1.59**	30.00 - 35.00	30.66±**2.57**	22.00 – 35.00	5.68	<0.001**
ISP	30.66±**1.68**	26.90 – 33.00	28.08±**3.06**	18.00 – 33.00	5.27	<0.001**
HSP	9.01±**1.58**	7.50 – 12.60	8.84±**1.47**	5.00 – 12.00	0.56	0.57
HU7	356.92±37.29	257 – 390	291.06±45.46	210 – 495	8.00	<0.001**

Data are presented as mean ±SD*significant **highly significant.

Table (3): Logistic regression analysis for independent predictors' indices of sex in C2 vertebrae

Indices of C2 vertebrae	P-value	OR	CI (95%)
AMA	0.06	3.81	1.03-14.09
DSD	0.21	0.04	0.001-1.57
DMFS	0.32	0.72	0.38-1.38
CMFS	0.76	0.79	0.18-3.56
LMFS	0.62	1.49	0.31-7.13
CMFV	0.87	0.89	0.23-3.47
DSMC	0.12	2.12	0.97-4.66
LMFV	0.09	2.71	0.58-12.62
AMD	0.66	1.63	0.19-13.94
DTMC	0.50	2.47	0.95-6.42
LMA	0.26	0.41	0.09-1.93
LMFI	0.26	1.06	1.008-1.11
HU2	0.02*	5.13	1.98-13.29

OR= odds ratio **CI= confidence interval** *significant

Table (4): Logistic regression analysis for independent predictors' indices of sex in C7 vertebrae

Indices of C7 vertebrae	P-value	OR	CI (95%)
LSF	0.89	0.90	0.19-4.20
WSF	0.84	0.89	0.30-2.62
LIF	0.06	1.59	0.31-8.26
WIF	0.58	0.45	0.17-1.21
WVF	0.36	1.46	0.65-3.27
LVB	0.11	1.03	1.01-1.05
WVB	0.66	1.17	0.59-2.32
LSP	0.73	0.86	0.36-2.05
HU7	0.01*	2.76	0.94-8.07

OR= odds ratio **CI= confidence interval** *significant

Table (5): Diagnostic validity of HU2 and HU7 in differentiation between sex by roc curve

	HU2		HU7	
Cut off point	347.5		350.0	
Sensitivity	0.902		0.784	
Specificity	0.765		0.98	
Positive predictive value	0.886		0.819	
Negative predictive value	0.793		0.976	
Accuracy	0.833		0.882	
Area under the curve	0.907		0.857	
P value	**<0.001**		**<0.001**	
95% confidence interval	Upper limit	Lower limit	Upper limit	Lower limit
	0.845	0.969	0.778	0.935

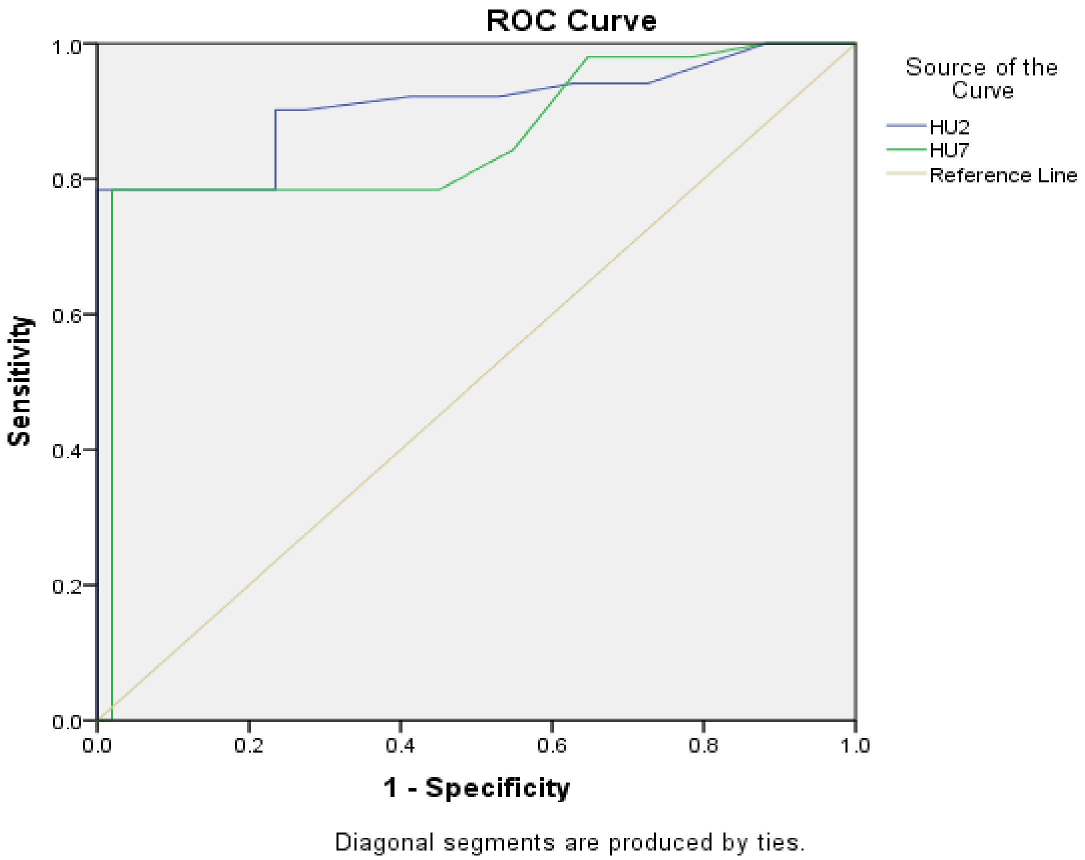

Figure 5: ROC curve for HU2 and HU7 indices in C2 and C7 vertebrae for differentiation between sex

Table (6): Statistical comparison between different studied age groups regarding the different indices of the second cervical vertebrae

15 indices of C2 vertebra	Studied different age groups (N=102)							
	Group 1(<18 years old) (n=19)		Group2 (18-60 years old) (n=66)		Group 3(>60 years old) (n=17)		ANOVA test	P value
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range		
AMA	33.61±**6.07**	24.2 – 44.3	41.87±**5.08**	30.5-48.2	41.94±**5.67**	33.6 – 48.0	18.37	<0.001**
DSD	10.22±**1.26**	8.0 – 12.0	12.48±**1.27**	10.5 – 15.2	12.04±**1.34**	10.6 – 14.8	22.89	<0.001**
DTD	8.5±**0.97**	7.0 – 10.0	9.94±**0.63**	9.0 – 11.2	9.99±**0.52**	9.0-10.5	33.70	<0.001**
DMFS	43.92±**4.34**	35.2 – 50.0	48.45±**2.0**	44.0 – 50.78	47.89±**1.49**	46.7 - 50.4	23.84	<0.001**
CMFS	12.79±**2.44**	8.0 – 15.3	14.66±**1.04**	12.5 – 16.1	15.15±**0.70**	13.5 – 16.0	16.92	<0.001**
LMFS	11.90±**1.76**	9.3 – 14.8	14.17±**1.33**	11.0 – 16.0	14.57±**1.46**	11.7-16.0	20.98	<0.001**
CMFV	20.28±**2.43**	16.0 – 24.2	25.09±**2.16**	21 – 28.2	26.09±**1.01**	24.8 – 27.5	46.79	<0.001**
DSMC	15.65±**1.62**	13.0 – 17.8	16.38±**1.98**	10.2 – 18.7	16.69±**1.18**	15.3 – 18.2	1.69	0.19
LMFV	23.75±**1.89**	20.0 – 25.6	26.53±**1.29**	24.5 - 29.1	26.82±**1.26**	25.3 – 29.1	31.70	<0.001**
AMD	13.81±**2.45**	9.0 – 17.3	16.76±**1.57**	14.2 – 18.7	17.07±**1.41**	15.2 - 18.8	23.48	<0.001**
DTMC	21.34±**2.54**	16.0 – 24.3	24.11±**0.87**	22.0 – 25.3	24.08±1.28	22.5 – 26.0	30.49	<0.001**
LMA	59.85±**5.37**	50.0-67.0	68.19±**2.61**	63.0 – 72.0	67.38±**2.38**	65 – 70.5	49.05	<0.001**
CMFI	8.81±**1.99**	5.5 – 11.3	10.14±**1.12**	8.2 – 11.9	9.87±**0.97**	8.2 – 11.2	7.79	0.001*
LMFI	8.85±**1.66**	6.0 – 12.3	11.26±**1.24**	9.2 – 13.0	10.88±**1.68**	9.0 – 12.7	21.74	<0.001
HU2	344.95±**113.29**	200 – 520	422.92±**115.14**	200 - 655	414.59±**125.64**	300 – 590	3.34	0.04*

Table (7): Statistical comparison between different studied age groups regarding the different indices of the seven cervical vertebrae

11 indices of C7 vertebra	Studied different age groups (N=102) Group 1(<18 years old) (n=19) Mean ± SD	Range	Group2 (18-60 years old) (n=66) Mean ± SD	Range	Group 3(>60 years old) (n=17) Mean ± SD	Range	ANOVA test	P value
LSF	8.38±**1.82**	5.0 – 11.6	10.25±**1.05**	8.6 – 12.0	10.38±**1.52**	8.7 – 12.6	16.50	<0.001**
WSF	12.33±**2.18**	9.0 – 17.3	14.89±**1.80**	11.6 – 18.0	15.05±**2.27**	12.5 – 18	13.61	<0.001**
LIF	10.0±**1.65**	7.0 – 13.0	12.45±**1.47**	10.0 – 14.5	12.44±**1.46**	11 – 14.5	20.56	<0.001**
WIF	11.87±**2.87**	6.0 – 14.9	13.45±**1.19**	11.5 – 15.0	13.38±**1.09**	12.2 – 15.0	7.22	0.001*
LVF	21.19±**2.62**	16 – 24	23.01±**1.66**	20.6 – 27.0	23.65±**2.35**	21.3 – 27.0	8.15	0.001*
WVF	24.26±**2.71**	20.0 – 27.8	26.0±**1.98**	23.0 – 28.7	26.15±**2.33**	23.5 – 29.0	5.11	0.008*
LVB	17.49±**3.69**	10.0 – 21.3	20.35±**1.95**	17.2 – 25.0	19.19±**1.67**	17.6 – 22.0	11.45	<0.001**
WVB	29.88±**3.79**	22.0 – 35.0	32.23±**1.74**	29.3 – 35	32.64±**1.84**	30.0 – 34.8	9.05	<0.001**
LSP	27.06±**4.49**	18.0 – 33.0	30.04±**1.88**	26.9 – 33.0	29.36±**1.84**	27.0 – 32.2	10.04	<0.001**
HSP	8.04±**1.90**	5.0 – 11.5	10.25±**1.44**	7.9 – 12.6	10.15±**1.87**	7.8 – 12.4	14.27	<0.001**
HU7	297.37±**62.17**	210-380	325.17±**48.44**	210-395	343.29±**32.85**	311 - 390	4.09	0.02*

*significant **highly significant

DISCUSSION

The ability of cervical vertebral measurements and morphology to contribute to forensic age and gender determination is currently being extensively researched. Vertebrae have physical traits that distinguish them from other bones in the human body and enable rapid identification if needed **(Charles and Okongo, 2009).** The cervical vertebrae are easily distinguished from the thoracic and lumbar vertebrae due to their unique attributes: the cervical bones are the smallest vertebrae; all of them show transverse foramina in the lateral vertebral arches; and horizontally oriented spinous processes that have a bifurcated tip **(White et al., 2012).** The transition from a trapezoid to a rectangular shape, a rise in the height-width ratio, and the development of a concavity at the inferior margin characterise cervical vertebrae development. Several staging systems make use of these properties**(San Román et al., 2002).**

The current study focused on studying metric indices of the C2 and C7 cervical vertebrae as a diagnostic tool in the identification of sex and age. C2 and C7 vertebrae have morphological criteria that are not present in C3-C6, such as an odontoid process in C2 and a flat transitional inferior vertebral body surface in C7. Rapid anatomical sequencing of the cervical vertebrae is made possible by these distinctive skeletal characteristics**(White et al., 2012).**

The present study was carried out on 102 participants (51 males and 51 females), whose mean age was 43.02 years, ranging from 12 to 70 years. The current results revealed that males had higher means for all measurements of C2 and C7 than females. The difference was significant in 13 out of 15 indices in C2 and 9 out of 11 in C7. Vertebral density demonstrated far greater sexual dimorphism (83% for C2 and 88% for C7) and was also the only measurement with significant discriminative value in the logistic regression model.

These findings agreed with **Mostafavi et**

al., 2020, who concluded that nearly all measurements were larger in males, but the difference was statistically significant in nine indices out of 15. thus proving the presence of sexual dimorphism in the vertebral measurements. **Mostafavi et al., 2020** found that LMSF and AMA were considered as the independent predictive of sex with diagnostic accuracy of 81.4%.

Our results also coincided with **Ekizoglu et al., 2021** in turkey who found significant differences between females and males regarding three vertebral measurements (CHT, CTR, and CAP); with the maximum body height (CHT) being the sexual dimorphism indicator (SDI)**.**

Our results were nearly the same as those of **Padovan et al., 2020** who measured four variables of the atlas vertebrae and all were higher in males than females, with the observation that maximum transverse diameter of the atlas vertebra obtained the major discrepancy between both sexes. Similar findings were also found in **Gama et al., 2015, Marlow and Pastor, 2011, and Torimitsu et al., 2016.**

As regard measured vertebral indices in different age groups, our results revealed that measured indices were significantly different between different studied age group except for DSMC in C2. This can be explained by that most of our bodies systems – including the skeleton - undergo changes in response to an individual's growth and development by getting older. Density was among the significant measurements regarding age differentiation; however, all other measured indices except DSMC were highly significant than density.

Using different cervical vertebral indices measured by different radiological methods to estimate cervical vertebrae maturation (CVM) is abundant in the literature. They were introduced by **(Lamparski, 1972),** studied by **Hassel and Farman, 1995** ; **Baccetti et al., 2005** and **Caldas et al., 2007.** Some modifications of the original Lamparski’s method were also introduced by **Mito et al., 2002** and by **San Román et al., 2002**.

To the best of our knowledge, there are currently in Egypt no comparative studies of different age groups based on the analysis of numerous metric indices of C2 and C7 using multi-slice CT.

Our results are agreed with **Rühli et al., 2005** who examined C7 in males of both modern Swiss and historic European real bone samples. Their results revealed significant moderate positive correlation between age and sagittal body diameter**.** Also; **Choi et al., 2016** proved strong positive correlation between age and vertebral volume measured by CT of C2, C3 and C4 cervical vertebrae.

Shaaban and El-Shall., 2017 evaluated skeletal maturation in a sample of Egyptian children and concluded that the cervical vertebral bone age is accurate in determining age of the skeleton as the other well-established hand wrist techniques. They found that vertebral body parameters of C3 and C4 (anterior vertebral body height (AH), vertebral body height (H), posterior vertebral body height (PH), and anteroposterior vertebral body length (AP)) increased significantly in an accelerated manner in both sexes. But their study was different from ours as they used digital measurements of C3 and C4 in cephalometric radiographs, while our study utilized CT metric indices of C2 and C7.

In disagreement with our results; **Gelbrich et al., 2017** stated the limited usefulness of cervical vertebrae in age estimation when compared to other methods as hand bones and teeth. They justified the fact that adult cervical vertebrae have a wide biological variance of shapes in contrast to teeth and hand bones that have definite appearances in the end stage of development. They also stated that measurements of cervical vertebrae do not sharply separate adults from children, where the ranges of metric measurements in adults and pre-pubertal children overlap significantly. The difference between our results and **Gelbrich et al., 2017** may be explained by methodological differences, where we used MSCT which allows for a better exploration of cervical vertebrae compared to lateral cephalograms.

CONCLUSION

The results of the current study indicate that MSCT density measurements of C2 and C7 are sexually dimorphic and can be used as a diagnostic tool for sex estimation from human skeletal remains in Egyptian population especially in situations like mass disasters where other bones are absent or destroyed. Also, it illustrated significant relationship between age and the metric indices of C2 and C7 vertebrae.

CONFLICT OF INTEREST: All authors declare that there are no competing interests.

LIMITATION OF THE STUDY:

The study is better to be performed with larger sample of population from different Egyptian districts.

STRENGTH OF THE STUDY:

According to our knowledge, this research represents the first trial to estimate both sex and age through MSCT images of C2 and C7 vertebrae in Menoufia population and may be in Egypt. Density indices were tested and it was the most sexually dimorphic among other measurements that were analyzed in this study. Also, different age groups were used to investigate the role of C2 and C7 metric measurements in age differentiation.

RECOMMENDATIONS:

Further studies are recommended to be done on larger population samples from different Egyptian districts to investigate the effects of nutritional and environmental factors on sexual dimorphism and skeletal maturation of C2 and C7 vertebrae.

Since density indices were analyzed in this study and it showed considerable accuracy in sex differentiation, it is preferable to be added in future investigations.

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الملخص العربى

قياسات الفقرة العنقية الثانية والسابعة بالاشعة المقطعية متعددة الشرائح كأداة تشخيصية للتعرف على الجنس والعمر فى عينة من المصريين، محافظة المنوفية

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المقدمة: يلعب التعرف على العمر والجنس دورًا حيويًا للغاية في تحديد هوية الفرد. أصبح التعرف اعتمادًا على التصوير المقطعي للفقرات ذات أهمية متزايدة في مجال الطب الشرعي. وتمتلك كلا من الفقرة العنقية الثانية و السابعة شكلا فريدا من نوعه يجعل من السهل التعرف عليهما، ويعد تحديد الجنس من خلال فحص الهيكل العظمى خطوة أولية فى تطوير ملف بيولوجى موثوق لأنه يقلل من عدد المطابقات المحتملة بنسبة 50%.

الهدف من البحث: هدفت هذه الدراسة إلى معرفة دور كل من الفقرة العنقية الثانية و السابعة كأداة تشخيصية في تقدير العمر والجنس بين سكان المنوفية.

طرق البحث : أجريت الدراسة على 102 حالة من سكان محافظة المنوفية. 51 ذكرا و 51 أنثى تتراوح أعمارهم بين 12 و 70 عامًا. كان الأشخاص المشمولين في هذه الدراسة مرضى أتوا لإجراء فحص التصوير المقطعي لمنطقة الرقبة لاسباب طبية في قسم الأشعة بجامعة المنوفية . تم استبعاد الحالات المرضية و الحالات ذات التغيرات التنكسية البارزة من هذه الدراسة. تم عمل التصوير المقطعي متعدد الشرائح للقياسات المختلفة لـلفقرة العنقية الثانية (15 قياسا) و السابعة (11 قياسا) لكل الحالات المشاركة فى هذه الدراسة .

النتائج: كانت نسبة الذكور أعلى من الإناث في جميع قياسات الفقرة العنقية الثانية و السابعة . وكان هذا الاختلاف ذا دلالة إحصائية في 13 قياسا للفقرة العنقية الثانية و 9 قياسات للسابعة. كان مؤشر الكثافة لكلا من الفقرتين العنقيتين الثانية و السابعة هو المتنبىء المستقل للجنس بمعدل دقة 83٪ و 88٪ على التوالي. كما كان هناك أيضا ارتباط إيجابي ذا دلالة إحصائية بين العمر و تقريبا جميع القياسات لكلا من الفقرتين.

الخلاصة والتوصيات: يمكن استخدام التصوير المقطعي متعدد الشرائح لقياسات الفقرة العنقية الثانية و السابعة كأداة لتحديد كلا من الجنس والعمر للأفراد مجهولى الهوية .و يوصى بإجراء مزيد من الدراسات على عنية سكانية أكبر من مناطق مصرية مختلفة لدراسة آثار العوامل الغذائية والبيئية على نضج الهيكل العظمي للفقرة العنقية الثانية و السابعة.