

# Comparison of Morphological Features of Second Cervical Vertebra between Genders Using Computed Tomography

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## Abstract

**Introduction:** Gender determination has been the emphasis of many forensic studies and have significance in mass fatality cases where bodies are damaged beyond recognition, as these factors are essential and various method are developed that allows gender determination. Second Cervical vertebra due to its ample degree of sexual dimorphism in its dimension allows sex determination. Forensic investigators can identify the bone by its morphological characteristics, such as the dens, short spinous process and cervical vertebra is known to be the best preserved of all the vertebra in cadavers.

**Aim:** To compare the morphological features of second cervical vertebra between genders using Computed Tomography.

**Materials and Method:** This was a retrospective study which included subjects visiting for CT (Computerized Tomography) of cervical spine in Department of Radio-diagnosis and Imaging, Kasturba Medical College, Manipal, Karnataka, India. Sample size was calculated using the formula for estimation of population mean which gave a total sample of 160. A total of 160 patients underwent computed tomography of cervical spine on MDCT Brilliance 64 slice Philips with routine protocol and later post-processed into Multiplanar imaging. In present study nine measurements of the second cervical vertebra were taken. Anthropometric measurements were performed which was calculated using the measurement tools. The data was analyzed using SPSS (V.20.0).

**Results:** Discriminant function analysis was performed to calculate the mean and standard deviation. Standardized canonical discriminant function was performed to find out the variable dependency and was found that maximum distance measured from the most lateral edges of the superior articular facets (DMFS) contributed much of the separation between genders. Step wise discriminant function test was performed to predict the categorical dependent variable a multivariable model was generated which showed that maximum distance measured from the most lateral edges of the superior articular facets (DMFS) and Maximum sagittal length (AS) reached the accuracy of 77.5% in gender discrimination. The most discriminant variable for the C2 was DMFS followed by AS, with expected accuracies of 73.8% and 71.9%. Among nine variables seven variables (AS, LMA, DMFS, DSD, DTD, WVF and DTMC) showed correct prediction rates approximately 78.8% and two variables (DA, DSMC) yielded no result.

**Conclusion:** DMFS contributed much separation with high accuracy in comparison to others, affirming that there is considerable sexual dimorphism with respect to the second cervical vertebra which could determine the gender of human based on CT measurements of second cervical vertebra.

**Keywords:** Anthropometry, Cervical spine, Gender determination, Sexual dimorphism.

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## Introduction

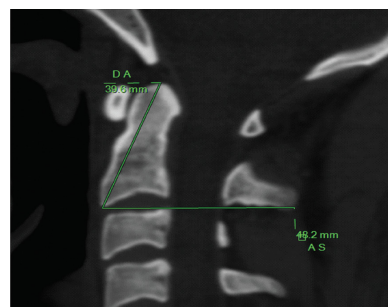
Gender determination has been the emphasis of many forensic studies and have significance in mass fatality cases where bodies are damaged beyond recognition, as these factors are essential and various method are developed that allows gender determination<sup>[1-3]</sup>.

DNA technologies are rational, narrowed down due to the accessibility of forensic legal laboratories and the cost effectiveness. For gender determination the most reliable parts are skull and pelvis which exhibits sexual dimorphism [2,4]. However, some human skeletal parts are found to be damaged due to decomposition and carnivore modification, other parts that are less dimorphic such as tibia, humerus, hyoid bone, foramen magnum should be considered for gender determination, and thus new techniques that deal with such parts should be considered. Second cervical vertebra due to its ample degree of sexual dimorphism in its dimension allows sex determination. Forensic investigators can identify the bone by its morphological characteristics, such as the dens, short spinous process and cervical vertebra is known to be the best preserved of all the vertebra in cadavers [3,5]. Therefore, the aim of the present study was to assess the sexual dimorphism from the 12<sup>th</sup> thoracic and the first lumbar vertebra measurements and data was obtained from reformatted images of multi-slice computed tomography (MSCT).

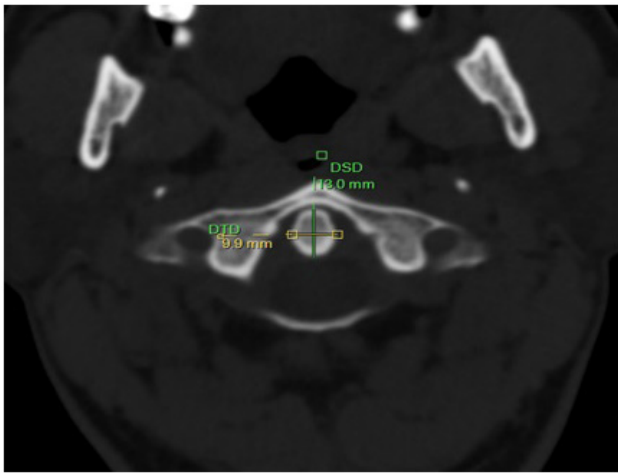
### Materials and Method

A retrospective observational study was carried out at Department of Radio-Diagnosis and Imaging, Kasturba Hospital, Manipal, Karnataka, India, using Phillips Brilliance 64-SLICE CT. Approval was acquired from institution research committee, School of Allied Health Sciences and ethical committee, Kasturba hospital. Sample size was calculated using the formula for estimation of population mean which gave a total sample of 160. Data from 160 samples (80 males and 80 females) were obtained, who were referred to the Radio-diagnosis department by the treating physician for CT cervical spine over the period of 12 months. Patients with trauma, major injuries and fractures of cervical spine were excluded from the study. CT of cervical spine was performed with patients positioned on the CT couch in supine head first position, with area coverage from tip of mastoid to sternal notch. Scan of the required area of interest was performed on acquired scanogram keeping in mind that the scan is performed with no loss of anatomical structure, axial sections of cervical spine was obtained with 0.9 mm slice thickness and slice increment of 0.45 mm with detail D filter producing standard bone resolution images. Informed consent was obtained from the patient before the start of examination. The original series of cervical spine with slice thickness of 0.9 mm and slice interval of 0.45 mm were selected for the study, Axial images per patient data

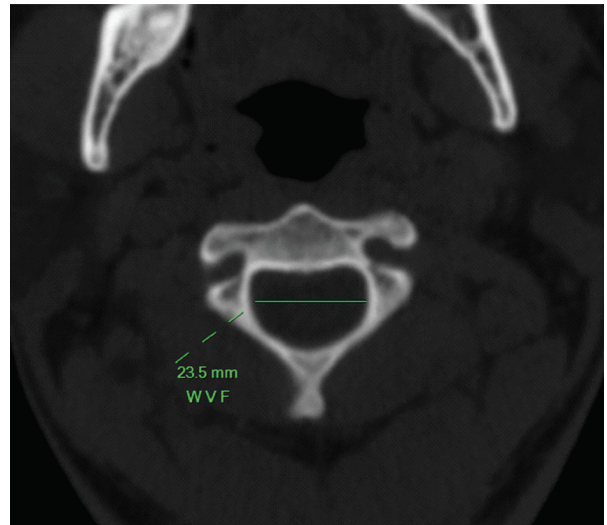
set which were included in the study were sent to Phillips Extended Brilliance workstation and the acquired axial sections were reformatted into coronal and sagittal sections using MPR (Multi-Planar Reconstruction) technique [6]. Anthropometric measurements were performed on the following section; the maximum length of the parameter was measured on axial and sagittal sections. The Maximum height of the Dens (DA) and Maximum sagittal length (AS) was measured from the sagittal section where tilts can be checked. The axial and coronal planes were used to correct the image to get the orientation of the second cervical vertebra. The other measurements were taken from the axial sections which were checked for tilts and corrected using sagittal and coronal images to acquire the center of the second cervical vertebra. Maximum height of dens (DA) is defined as length from the superior point on the dens to the anterior-inferior point on the vertebral body and Maximum sagittal length (AS) i.e., Length from the anterior-inferior point on the vertebral body to the posterior point on spinous process [Fig-1]. Dens Sagittal Diameter (DSD), (Maximum sagittal diameter measured between the anterior and posterior points on dens). Dens Transverse Diameter (DTD), (Maximum transverse diameter of dens measured between most lateral edges of the dens) [Fig-2]. (Maximum distance measured from the most lateral edges of the superior articular facets) (DMFS) [Fig-3]. Maximum width of the axis (LMA) shown in [Fig-4], Width of Vertebral Foramen (WVF) (Maximum internal width of the vertebral foramen) [Fig-5]. Maximum sagittal diameter of the body (DSMC) (The maximum sagittal diameter of the body measured from the anterior-inferior point on the board to posterior-inferior point). Maximum transverse diameter of the body (DTMC). (The maximum transverse diameter of the body measured between the most lateral edges of the body) [Fig-6], were measured using the measurement tools provided by the Phillips extended brilliance work station.



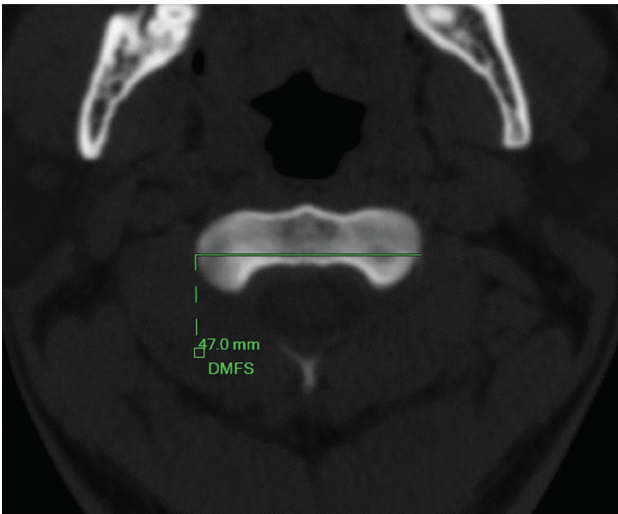
**[Fig-1]: Figure showing maximum height of the dens (DA) and maximum sagittal length (AS).**



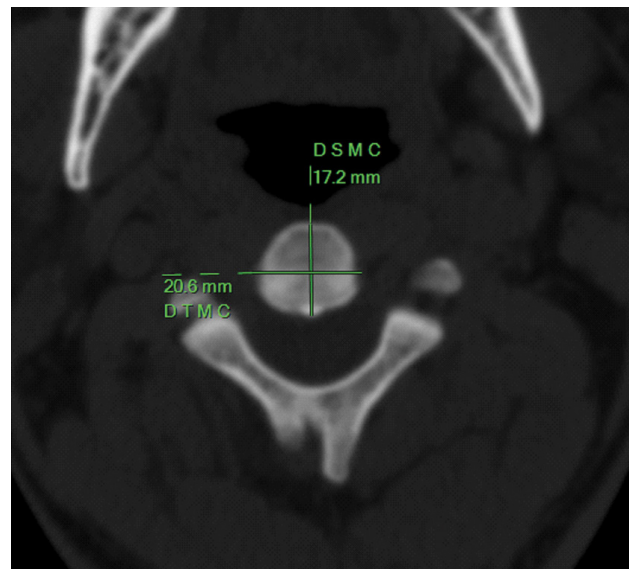
[Fig-2]: Figure showing Dens Sagittal Diameter (DSD) and Dens Transverse Diameter (DTD).



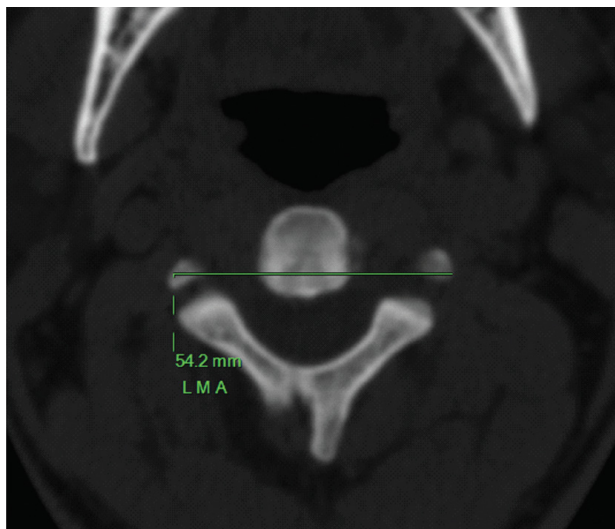
[Fig-5]: Figure showing Width of Vertebral Foramen (WVF).



[Fig-3]: Figure showing maximum distance between superior facets (DMFS).



[Fig-6]: Figure showing maximum sagittal diameter of the body (DSMC) and maximum transverse diameter of the body (DTMC).



[Fig-4]: Figure showing maximum width of the axis (LMA).

**Statistical Analysis:** The metric data obtained were analyzed by using SPSS Version 20.0 and statistical difference in the cervical vertebra measurements of males and females were assessed using discriminant function analysis to predict the categorical dependent variable and to compare the canonical discriminant function coefficients to recognize which independent variable was more segregating than alternate variables. Discriminant function analysis test was used to evaluate the mean and standard deviation for the anthropometric parameters of both male and female. Standardized and unstandardized canonical discriminant function was determined to assess the variable dependency.

### Results

The Mean and standard deviation of both sexes for all the nine variables are reported using descriptive statistics as shown in [Table-1].

**[Table 1]: Descriptive statistics for the nine variables are reported which shows mean and standard deviation of both sexes.**

Variable	Sex	Mean	Standard Deviation
DA	Male (80)	85.18	421.27
	Female (80)	82.33	421.48
AS	Male (80)	46.35	5.009
	Female (80)	43.18	2.727
LMA	Male (80)	54.54	5.202
	Female (80)	54.83	44.98
DMFS	Male (80)	45.33	2.515
	Female (80)	42.05	2.267
DSD	Male (80)	12.39	10.703
	Female (80)	10.17	1.248
DTD	Male (80)	9.841	1.092
	Female (80)	9.616	3.629
WVF	Male (80)	22.77	1.567
	Female (80)	21.95	1.364
DSMC	Male (80)	17.02	1.399
	Female (80)	32.88	159.2
DTMC	Male (80)	21.24	2.630
	Female (80)	19.81	2.450

**[Table-2]: Canonical discriminant function coefficients.**

	Function 1
DA	.000
AS	.082
LMA	-.002
DMFS	.321
DSD	.024

**[Table-3]: Stepwise discriminant function analysis.**

Variable	Unstandardized Coefficient	Group Centroids		Prediction Accuracy	
		Male	Female	Male	Female
AS	0.082	0.723	-0.723	76.3	23.8
Constant	-19.453				
DMFS	0.361	0.723	-0.723	21.3	78.8
Constant	-19.453				

	Function 1
DTD	-.044
WVF	.125
DSMC	.000
DTMC	.034
(Constant)	-20.946

Discriminant function analysis was used to predict a categorical dependent variable (called a grouping variable) by one or more continuous or binary independent variables (called predictor variables). On comparing canonical discriminant function coefficients, it was conceivable to recognize that DMFS showed much differentiation followed by WVF, AS, DTMC, DSD, DTD and LMA as shown in [Table/Fig-8].

The most discriminant variable for the C2 is DMFS followed by AS, with expected accuracies of 73.8% and 71.9%. Among nine variables seven variables (AS, LMA, DMFS, DSD, DTD, WVF andDTMC) showed correct prediction rates approximately 78.8% and two variables (DA, DSMC) yielded no result. The equation for sex estimation using the seven variables is as follows:

$Z = -0.20946 + 0.082 (AS) + (-0.002) (LMA) + 0.321 (DMFS) + 0.024 (DSD) + (-0.044) (DTD) + 0.125 (WVF) + 0.034 (DTMC)$ . The values ranging from -0.758 to 0 is assigned as Female and 0 to 0.758 is assigned as Male.

Stepwise discriminant function analysis was performed which resulted in multivariable model. Two variable models reached the accuracy of 77.5%. The equation for gender estimation using two variables is as follows.

$Z = -19.453 + 0.082 (AS) + 0.361 (DMFS)$  The values ranging from -0.723 to 0 is assigned as Female and 0 to 0.723 is assigned as Male as shown in [Table/Fig-9].

**Discussion**

In present study 160 patients (80 males and 80 females) were included who were referred for the CT scans of the neck and cervical spine where the C2 vertebra is seen, in which the measurements can be taken.

In the present study the overall mean value of the males is larger than the females; this shows the existence of sexual dimorphism. Torimitsu S et al., conducted a study on sexual determination based on multidetector computed tomographic measurements of the second cervical vertebra in a contemporary Japanese population. Multiple DFA with stepwise variable selection resulted in multi variable models a five-variable model reached an accuracy rate of 92.9% [5]. In the present study, descriptive statistics for nine variables were included and all the nine variables demonstrated significant sexual dimorphism. In the present study, descriptive statistics for nine variables were included where only seven variables (AS, LMA, DMFS, DSD, DTD, WVF, and DTMC) demonstrated significant sexual dimorphism and two variables (DA, DSMC) yielded no result.

Stepwise variable selection resulted in a multivariable model a two variable model reached an accuracy rate of 77.5%. Torimitsu S et al., reported in his study the most discriminant variable for the C2 was DMFS followed by LMA with an accuracy of 83.5% and 83.1% respectively [5]. In the present study, the most discriminant variable for the C2 is DMFS followed by AS with an accuracy of 73.8% and 71.9% respectively.

Gama I et al., performed a study in documented Portuguese skeletal sample at University of Coimbra. In present study, investigator performed t-test analysis to identify differences among sexes and found that out of 13 dimensions one measurement was not showing significant differences and reported that LMA-followed by DSMC are the most dimorphic dimensions of the second vertebra with the level of dimorphism of 11.18% and 10.6% respectively [7]. In the present study the most discriminant variable for the C2 is DMFS followed by AS with an accuracy of 73.8% and 71.9% respectively. Gama I et al., performed logistic regression analysis with stepwise variable selection to develop a model and reported a multivariate model with four variables reached an accuracy of 89.7% as shown in [Table/Fig-10] [5,7].

[Table-4]: Table showing previous studies percentage accuracy.

Study	No of Patients	Result Accuracy
Sugur Torimitsu, et al	224(112 males & 112 females)	92.9%.
Ines Gama, et al	1 <sup>st</sup> Sample 190(99 males & 91 females) 2 <sup>nd</sup> Sample 47(24 males & 23 females)	89.7%
Current study	160(80 males & 80 females)	78.8%

Stepwise variable selection resulted in a multivariable model a two variable model reached an accuracy rate of 77.5%. In the present study DMFS showed significant variability among males and females which suggests that measurements of DMFS can be obtained and used to differentiate between the genders.

**Limitations:** The study has certain limitations such as all the parameters measured did not show significant values and were not efficient discriminators among the gender group. Further studies can be carried out using larger sample size which may lead to better accuracy and reveal a stronger conclusion.

**Conclusion**

In the present study nine measurements of the

second cervical vertebra were taken out of which seven variables were good discriminators where DMFS contributed much separation with high accuracy in comparison to others. The results allow affirmation that there is considerable sexual dimorphism with respect to the second cervical vertebra which could determine the gender of human based on computed tomographic measurements of second cervical vertebra.

**Conflict of Interest:** Nil

**Funding:** Nil

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