Scholars Journal of Applied Medical Sciences
Abbreviated Key Title: Sch J App Med Sci
ISSN 2347-954X (Print) | ISSN 2320-6691 (Online)
Journal homepage: https://saspublisher.com/sjams/

OPEN ACCESS

Anatomy

Sex Discriminatory Characteristics of the First Lumbar (L1) Vertebra of Adult Nigerians: A Radiologic Study Using CT Scan

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| **Received:** 20.04.2019 | **Accepted:** 27.04.2019 | **Published:** 30.04.2019
DOI: 10.21276/sjams.2019.7.4.47

Abstract **Original Research Article**

Introduction: Small irregular bony structures of the human body hold a wealth of information that can be used to establish and complete the biological profile of an individual; hence solve sex identification puzzles especially in cases of fragmented bone. ***Aim and Objectives:*** This study was therefore carried out to investigate the reliability of the use of the CT image of the first lumbar vertebra (L1) in estimating the sex of adult Nigerians. ***Methods:*** One hundred (100) CT scan images (60 males [M] and 40 females [F]) of the first lumbar (L1) vertebrae of adult Nigerians within the age range 20-40 years were used for the study. The CT-Scans of the subjects were measured using the View Tec MedView 1.0.0.2 software program with an accuracy of 0.01mm. Seven (7) vertebral parameters were measured: Canal anteroposterior diameter (CAP-D), canal transverse diameter (CT-D), vertebra anteroposterior diameter (VAP-D), right and left pedicle width (RT & LT PH), right and left pedicle height (RT & LT PH). XLSTAT (version 2015.4.01) discriminant function analysis was used to evaluate the sex discriminatory characteristics of the L1 vertebra, while SPSS version 23 (IBM® Armork, USA) ROC Curve was used to compare predictability of the variables independently. The confidence level was set at 95% and P<0.05 was taken to be significant. ***Results:*** The mean (±S.D) values of measured dimensions of L1 vertebrae were significantly higher in males (P<0.01) except for the CAP-D, which was significantly higher in females (P<0.01), while the CT-D was not statistically different in both sexes (P=0.533). The variables entered into the DFA produced a prediction model that was significant (Lamba=0.138, P<0.01) and accurate (R_c^2=86.2%), which produced a 99.0% accurate sex categorisation; with the VAP-D (ROC=0.998) as the better predictor. ***Conclusion:*** So far in the forensic studies, any human part that produces an accuracy of 99% in sex determination can be regarded as the anatomical structure of choice for establishing sex.
Keywords: Discriminant Function Analysis, L1 vertebra, Sex discrimination, Nigerians.

INTRODUCTION

As long as forensic studies remain practical and disaster continually exist, the need to establish sex remains a fundamental requirement for the completion of the biological profile of the dead. Though this process has remained challenging especially when it requires on-the-field intervention [1-3] the need to locate any available and reliable anatomical structure whole or fragmented that can significantly reduce the investigation time as well as assure accurate results are the desires of the field forensic anthropometrist.

Small irregular bony structures of the human body hold a wealth of information that can be used to establish and complete the biological profile of an individual [1, 4]. The most often used anatomical structures in estimating sex are the skull, pelvis, and long bones[5, 6]; however, other irregular bones such as scapula, clavicle, fingers and toes, patella, vertebrae, ribs, and dentition and palates have also been used with varying accuracies[1,7-10].

Studies have shown that vertebrae exhibit an array of sex-specific attributes in both dimensions and orientation [11-13], which allows for accurate sex estimation by morphometric analysis[12,13]. Researchers have reported high accuracy in discriminating sex using vertebrae; Amores *et al.* [14] studied the C7 and T12 vertebrae of 121 individuals of known sex, age, and cause of death from San Jose cemetery in Granada (Spain) and obtained a sex discriminatory accuracy of 80% from eight dimensions, while 24 linear dimensions form 120 adult Egyptian patients (54 males and 66 females) produced an accuracy of 93.1% for T12 and 63.1% for L1 and an increased accuracy of 96.5% when dimensions of both vertebrae were combined (T12 and L1) [15]. Zheng *et al.* [16] reported accuracy of between (57.1–86.6%)

using single and grouped linear dimensions of the L1 vertebra. Ostrofsky & Churchill [17] measured 11 dimensions of the lumbar vertebrae from the Raymond A. Dart Collection (47 males, 51 females) of South African blacks and reported accuracies ranging from 75.9% to 88.7%.

In the bid to achieve sex estimation, multivariate regression [14] as well as discriminant functions analysis [16, 17] are very reliable statistical tools. However, the most widely applied statistical model in sex determination is the discriminant function analysis (DFA) [18-19], which allows for extensive assessment of anthropometric data[1,20,21] This study, therefore, investigated the sex-discriminatory characteristics of the 1st lumbar vertebra obtained from CT scan.

Materials and Methods

Measurements were taken on the CT-scans for the lumbar (L1) vertebrae using the ViewTec. MedView 1.0.0.2 software program, which has an accuracy of 0.01mm. The landmark for the measurements was the superior surface of the pedicles; where both the anterior and posterior aspect of the canal, pedicles, as well as the corresponding interlaminar line, is visible and measurable. The software was programmed to produce accurate measurements and calculate angles.

After selecting the slide of interest, the distance between the various points was measured by selecting the "*Measure distance between two points*" button and then clicking with the mouse pointer on the first point, then taking the line the second point and clicking. The distance is automatically displayed; the same process is used to determine angular dimensions. Axial images reformatted perpendicular to the pedicle axis through the pedicle isthmus was used for measurements of the pedicle width and height.

Data analysis

The statistical analysis was performed using SPSS software (IBM ® Version 23.0; SPSS, Inc., Chicago, IL) and XLSTAT (version 2015.4.01). The descriptive statistics and ROC Curve (used to compare predictability of the variables) were carried out using SPSS version 23 (IBM® Armork, USA), while XLSTAT (version 2015.4.01) discriminant function analysis was used to estimate sex; achieved by accurate categorisation. The confidence level was set at 95% and P<0.05 was taken to be significant.

Results and Discussion

The descriptive characteristics of the measured vertebrae dimensions for males and females and the Wilki-Lambda test of mean difference were presented in Table 1. From the results, it was observed that all male values were significantly greater than female values (P<0.01) except for CAP-D, which was significantly greater in females (P<0.01) and CT-D, which was statistically not significant (P=0.533). The CAP-D of adult Egyptians [15] and Nigerians [22] were reported to be smaller in females than males [22], while Elhassan *et al*.[23] reported larger values for females, with no significant difference.

Table-1: Descriptive characteristics of the measured parameters of L1 vertebrae and Wilki-Lambda unidimensional test for equality of mean

Variable	Male (N=60)	Female (N=40)	Total (N=100)	test of equality of the means*		
	Mean±S.D (mm)	Mean±S.D (mm)	Mean±S.D (mm)	Lambda (Λ)	F-value	p-value
CAP-D	15.95±0.18	16.14±0.63	16.02±0.28	0.8952	11.4776	0.001
CT-D	22.07±1.44	21.87±1.72	21.99±1.56	0.996	0.3918	0.533
VAP-D	29.41±0.63	27.30±0.39	28.57±1.17	0.2163	355.1267	<0.001
RT PW	8.29±0.46	7.34±0.74	7.91±0.75	0.6093	62.8371	<0.001
LT PW	8.29±0.45	7.27±0.76	7.88±0.77	0.5802	70.9183	<0.001
RT PH	15.28±0.73	13.12±0.50	14.42±1.25	0.267	269.1093	<0.001
LT PH	15.25±0.71	13.08±0.47	14.38±1.24	0.2546	286.925	<0.001

Note: CAP-D=Canal antero-posterior diameter, CT-D=Canal transverse diameter, VAP-D=Vertebra antero-posterior diameter, RT PW=Right Pedicle width, LT PW=Left Pedicle width, RT PH=Right Pedicle height, LT PH=Left Pedicle height.

S.D=Std. Error of Mean, N=Number of observation, Λ=Wilki-Lambda value

* Box's M within-class covariant matrices (P<0.01)

The Wilks' Lambda test for predictability into group membership in Table 2 showed that the variables will make a statistically significant prediction ($\Lambda=0.138$, $\chi^2_{(df=7)}=187.210$, $P<0.001$). The canonical correlations analysis (CCA) for the vertebrae dimensions in Table 2 indicated that the variables in the model produced very high correlations (CCA=0.929); suggesting that the proportion of variance explained (R^2) by the model variables was significantly high at 86.2%. The variables that seemed to produce the highest predictions were VAP-D (0.761), LT PH (0.684) and RT PH (0.663), while LT PW, RT PW, CAP-D, and CT-D individually produced less than an average prediction (Table 3).

Table-2: Wilks' Lambda test for predictability into group membership and Canonical correlation analysis

Willki-Lamda		Canonical correlation analysis			
		Lambda (Λ)	Eigenvalue[a]	r_c	R_c^2
Lambda (Λ)	0.138	F1	6.251	0.9285	86.20%
Chi-square	187.21				
DF	7				
p-value	< 0.0001				

Note: a. First 1 canonical discriminant functions were used in the analysis.
r_c Canonical correlation
R_c^2 Prediction model accuracy

Table-3: Variable prediction and discriminant function coefficients

Variables	F1	F2	F3
VAP-D	0.761	0.645	1.175
LT PH	0.684	0.440	0.702
RT PH	0.663	0.108	0.167
LT PW	0.340	0.725	1.224
RT PW	0.320	-0.386	-0.658
CAP-D	-0.137	-0.079	-0.299
CT-D	0.025	0.098	0.063
Intercept/constant	-	-	-47.136

Note: F1 Factors correlations
F2 Standardized canonical discriminant function coefficients
F3 Unstandardized canonical discriminant function coefficients

The DFA results of both groups can additionally be defined by the group means of the predictor variables using the unstandardized canonical discriminant function coefficients in Table 3. The outcome of the mathematical evaluation produces group means, which are called the centroids (Table 4). In this study, using the L1 dimensions, the males had a centroid value of 2.021 while female had a centroid value of -3.031. After executing the regression analysis using the function coefficients [FC] in Table 3, values that are found to fall within a particular centroid are predicted as belonging to that group. However, it should be noted that more accurate prediction is achieved when the difference between the canonical group means (centroids) is larger [1, 10].

Table-4: Class prediction using centroids

Class	Functions at the centroids
Female	2.021
Male	-3.031

In Table 5, the coefficients of linear discriminant function are the classification functions [CFC] using the measured dimensions of L1. The original and the cross-validation classification in Table 6 showed that the L1 vertebra can achieve an accurate classification of 99% for the Nigerian Population.

The discriminant model for sex categorization was obtained as follows;

- **Male** = -3716.010 + 246.087 (CAP-D) + 0.832 (CT-D) + 93.365 (VAP-D) + 82.289 (RT PW) - 62.168 (LT PW) + 22.150 (RT PH) - 15.475 (LT PH).
- **Female** = -3480.824 + 247.597 (CAP-D) + 0.513 (CT-D) + 87.426 (VAP-D) + 85.611 (RT PW) - 68.354 (LT PW) + 21.309 (RT PH) + 11.927 (LT PH).

Table-5: Classification function coefficients (CFC) in the model

Variable	Female	Male
Intercept	-3716.01	-3480.82
CAP-D	246.09	247.597
CT-D	0.83	0.513
VAP-D	93.37	87.426
RT PW	82.29	85.611
LT PW	-62.17	-68.354
RT PH	22.15	21.309
LT PH	15.48	11.927

Table-6: Initial classification and classification after cross-validation

Classification	Predicted Group Membership [a,c]			% Correct classification
	Sex	Male	Female	
Original	Male (%)	59 (98.33)	1 (1.67)	99.0%
	Female (%)	0 (0)	40 (100)	
Cross-validated[b]	Male (%)	59 (98.33)	1 (1.67)	99.0%
	Female (%)	0 (0)	40 (100)	

Note: a. 99.0% of original grouped cases correctly classified.
b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
c. 99.0% of cross-validated grouped cases correctly classified.

Using a comparative scale range for AUC, we can state that VAP-D RT PH, LT PH are variables that will produce an excellent (AUC > 0.90) discrimination, while RT PW and LT PW are good (AUC = 0.80 - 0.90; P<0.001) discrimination and CT-D will not produce a significant discrimination (AUC = 0.54; P=0.059). On the other hand, CAP-D produced an AUC value below the reference line which was because the positive direction was male whereas the result found an inverted course; thus the predictability of CAP-D can be evaluated by using (1-$Area_{[CAP-D]}$ = 1 - 0.267 = 0.733) (Table 7, Fig. 1). Therefore, CAP-D was 0.7333 accurate in predictions.

Table-7: Summary statistics for Area under the ROC curve (AUC)

Test Result Variable(s)	Area	Std. error	P-value	95% Confidence Interval	
				Lower Bound	Upper Bound
CAP-D	0.267	0.056	<0.001	0.158	0.376
CT-D	0.544	0.059	0.460	0.428	0.659
VAP-D	0.998	0.002	<0.001	0.993	1.000
RT PW	0.851	0.041	<0.001	0.771	0.931
LT PW	0.865	0.038	<0.001	0.790	0.940
RT PH	0.987	0.008	<0.001	0.971	1.000
LT PH	0.988	0.009	<0.001	0.970	1.000

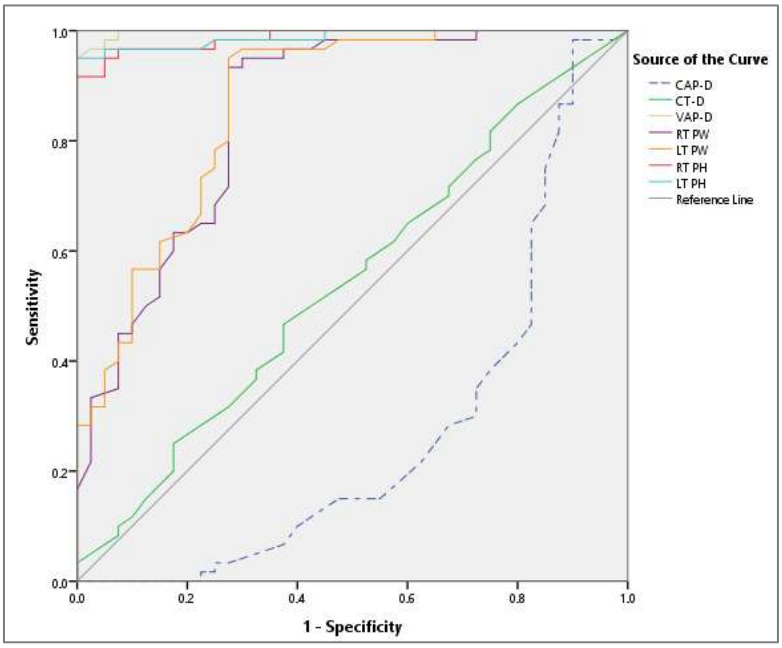

Fig-1: ROC Curve for evaluating the predictive abilities (male over female) of the L1 vertebrae dimension (Canal antero-posterior diameter [CAP-D], Canal transverse diameter [CT-D], Vertebra antero-posterior diameter [VAP-D], Right Pedicle width [RT PW], Left Pedicle width [LT PW], Right Pedicle height [RT PH], Left Pedicle height [LT PH])

Comparing values obtained by other researchers; Amores *et al*.[14] (80%), Badr El Dine & El Shafeib[15] (93.1% for T12, 63.1% for L1 and 96.5% for both T12 and L1), Zheng *et al*. [16] (between

57.1 to 86.6% using single and grouped linear dimensions of L1), Ostrofsky & Churchill[17] (75.9% to 88.7% for different lumbar vertebrae), this study, with a 99% accuracy seemed to be among the highest accuracy achieved.

Unarguably, previous studies have reported that the most accurate (with nearly 100% accuracy) way of establishing sex is in the presence of complete skeleton [15, 25]; with 98% for the pelvis and the skull together and 95% for the pelvis only [25]. Contrary to the assumption that the most accurate bones for estimating sex are the skull, pelvis, and long bones [5, 6]; however, the L1 vertebra has achieved sex estimation with an accuracy of 99%.

Acknowledgements

The authors acknowledge the contributions of Prof. B.C Didia, Assoc. Prof. G.S Oladipo, who assisted in proof-reading the work. The authors are also grateful to the Directors of Intercontinental, Transview and Union Diagnostic Centers, Port Harcourt, Rivers State; for providing us with unlimited access to their facilities for the data collection.

Conclusion

This study has shown that the first lumbar (L1) vertebrae can excellently discriminate sex. Therefore, it can now be regarded as an anatomical structure of choice for the anthropometric estimation of sex among the Nigerian population.

References

1. Alabi SA, Didia BC, Oladipo GS, Aigbogun Jr EO. Evaluation of sexual dimorphism by discriminant function analysis of toe length (1T–5T) of adult Igbo populace in Nigeria. Nigerian medical journal: journal of the Nigeria Medical Association. 2016 Jul;57(4):226.
2. Bilge Y, Kedici PS, Alakoç YD, Ülküer KÜ, İlkyaz YY. The identification of a dismembered human body: a multidisciplinary approach. Forensic Science International. 2003 Nov 26;137(2-3):141-6.
3. Vanrell JP. Conceitos e Nocoes Historicas em Odontologia legal. In Vanrell. Odontologia Legal e Antropologia Forense. 1st ed. Rio de Janeiro: Guanabara Koogan SA. 2002.
4. Kanchan T, Krishan K. Anthropometry of hand in sex determination of dismembered remains. J Forensic Leg Med. 2011; 18(1): 14-7.
5. Iscan MY, Miller‑Shaivitz P. Determination of sex from the tibia. Am J Phys Anthropol. 1984; 64: 53-57.
6. Iscan MY, Shihai D. Sexual dimorphism in the Chinese femur. Forensic Sci Int. 1995; 74: 79‑87.
7. Bainbridge D, Santiago GT. A study of the sex differences in the scapula. J R Anthropol Inst. 1956; 86:109‑34.
8. Di Vella G, Campobasso CP, Dragone M, Introna F. Jr. Skeletal sex determination by scapular measurements. Boll Soc Ital Biol Sper. 1994; 70: 299‑305.
9. Kanchan T, Krishan K. Anthropometry of hand in sex determination of dismembered remains – A review of literature. J Forensic Leg Med. 2011; 18:14‑7.
10. Ibeachu PC, Aigbogun (Jr) EO. Palatal rugoscopic estimation of sex among Igbo students in the University of Port Harcourt. European J Biomed Pharm Sci (EJBPS). 2017; 4(9): 58-64.
11. Taylor JR, Twomey LT. Sexual dimorphism in human vertebral body shape. J Anat. 1984; 138(2): 281-6.
12. Ferreira MT. *Para lá da morte: estudo tafonómico de decomposição cadavérica e da degradação óssea e implicações na estimativa do intervalo pós-morte* (Doctoral dissertation).
13. Gama I, Navega D, Cunha E. Sex estimation using the second cervical vertebra: a morphometric analysis in a documented Portuguese skeletal sample. Int J Legal Med. 2015; 129(2): 365-372.
14. Amores A, Botella MC, Alemán I. Sexual dimorphism in the 7th cervical and 12th thoracic vertebrae from a Mediterranean population. Journal of forensic sciences. 2014 Mar;59(2):301-5.
15. El Dine FM, El Shafei MM. Sex determination using anthropometric measurements from multi-slice computed tomography of the 12th thoracic and the first lumbar vertebrae among adult Egyptians. Egyptian Journal of Forensic Sciences. 2015 Sep 1;5(3):82-9.
16. Zheng WX, Cheng FB, Cheng KL, Tian Y, Lai Y, Zhang WS, Zheng YJ, Li YQ. Sex assessment using measurements of the first lumbar vertebra. Forensic science international. 2012 Jun 10;219(1-3):285-e1.
17. Ostrofsky KR, Churchill SE. Sex determination by discriminant function analysis of lumbar vertebrae. J Forensic Sci. 2015; 60(1): 21-28.
18. Fisher RA. The statistical utilization of multiple measurements. Annals of eugenics. 1938 Aug;8(4):376-86.
19. Fisher RA. The precision of discriminant functions. Annals of Eugenics. 1940 Jan;10(1):422-9.
20. İşcan MY. Forensic anthropology of sex and body size. Forensic Science International. 2005 Jan 29;147(2-3):107-12.
21. Ibeachu PC, E Jr A, Didia BC, Fawehinmi HB. Determination of sexual dimorphism by odontometric study using discriminant function analysis of adult Ikwerre dental cast. population. 2015;6:7.
22. Amonoo-Kuofi HS. The sagittal diameter of the lumbar vertebral canal in normal adult Nigerians. J Anat. 1985; 140(1): 69-78.
23. Elhassan YA, Ali QM, Ahmed AO. Sagittal diameter of the lumbosacral spinal canal in normal

(asymptomatic) adult Sudanese population 2014. Sudan Medical Monitor. 2014 Oct 1;9(4):153.
24. Krogman WM, Iscan MY. The Human Skeleton in Forensic Medicine. 2nd ed. Charles C. Thomas, Springfield, Illinois. 1986.