Sexual dimorphism through the study of atlas vertebra in the Brazilian population

Larissa Padovan[1], Viviane Ulbricht[1], Francisco Carlos Groppo[2], João Sarmento Pereira Neto[3], Vanessa Moreira Andrade[1,4], Luiz Francesquini Júnior[1]

[1]Department of Health Sciences and Social Odontology, Area of Legal Odontology, Piracicaba Dental School, University of Campinas, [2]Department of Farmacology, Area of Farmacology and Therapeutics, Piracicaba Dental School, University of Campinas, [3]Department of Health Sciences and Social Odontology, Area of Orthodontics, Piracicaba Dental School, University of Campinas, Sao Paulo, [4]Department of Civil Police State, Afrânio Peixoto Legal Medicine Institute, Forensic Odontology Service, Rio de Janeiro, Brazil

Address for correspondence:
Dr. Luiz Francesquini Júnior, Department of Health Sciences and Social Odontology, Area of Legal Odontology, Piracicaba Dental School, University of Campinas, Av. Limeira, 901, Piracicaba, Sao Paulo, Brazil.
E-mail: francesq@unicamp.br

Abstract

Background: Sex determination by linear measurements of the bones is widely used because of the several kinds of death in which the corpses can be damaged. **Aim:** The aim of this study was to establish a logit for sexual dimorphism through measurements of the atlas vertebra. **Settings and Design:** The principle sample was composed of 191 skeletons belonging to the Forensic Physical Anthropology Laboratory Prof. Eduardo Daruge. However, first, a calibration with other 25 skeletons was carried out. **Materials and Methods:** Using a digital caliper, linear measurements were made of the anteroposterior diameter of the atlas vertebra (variable A), anteroposterior diameter of the rachidian canal (variable B), transverse diameter of the rachidian canal (variable C), and maximum transverse diameter of the atlas vertebra (variable D). **Statistical Analysis Used:** The data were analyzed using IBM® SPSS® 25 Statistics program. **Results:** The mean measurements of all four variables for men were higher than that for women, being observed that variable D obtained the major discrepancy between the sexes. Considering both sexes, the variable C obtained the best results of standard deviation, while the variable D achieved the worse results. The *t*-test observed acceptance about hypothesis that exists differences between the gender and all four measures assessed. The logit developed is sex = −24.970 + 0.183 × A + 0.230 × D, in which "A" represents anteroposterior diameter of the atlas and "D" represents the maximum transverse diameter of the atlas. **Conclusion:** This model results in 81.2% accuracy, 85.5% sensitivity, and 75.3% specificity.

Key words: Anthropometry, forensic dentistry, sex characteristics, spine

Introduction

The fingerprint analysis is commonly used for forensic human identification; however, in situations with soft tissue destruction as carbonization or decomposition, the forensic anthropology plays an important role since it interprets qualitative or quantitative information of the skeleton.[1]

Access this article online	
	Quick Response Code
Website: www.jfds.org	
DOI: 10.4103/jfo.jfds_85_19	

The great extension of Brazil and its ancestral diversity cause no prevalence of specific phenotypic traits on the Brazilian bone structures, but miscellanea among leucodermas,

Submitted: 30-Oct-19 **Accepted:** 07-Mar-20
Published: 03-Jun-20

How to cite this article: Padovan L, Ulbricht V, Groppo FC, Neto JS, Andrade VM, Júnior LF. Sexual dimorphism through the study of atlas vertebra in the Brazilian population. J Forensic Dent Sci 2019;11:158-62.

melanodermas, and xanthodermas characteristics. This context can generate a situation which a melanoderma woman can be bigger than a xanthoderma man, which may complicate the gender determination by simple qualitative examination. Such matter becomes more complicated since the possibility of existence of undifferentiated individuals which male and female characteristics are mixed.

The sex determination is considered the main part of the anthropometric study, being highly important, as example, in a disaster situation, allowing separation of male from female bones, which speeds up the whole process of identification,[2] since the anthropometry is considered a secondary method of identification, helping the primary methods according to the International Criminal Police Organization (Interpol).[3]

The DNA examination also lets with high precision of the gender determination but may not determinate with precision of the ancestry due to the high degree of miscegenation among Brazilians.[4-6] In addition, it must be noted that some factors such as immersion in chemical products, or even sea water and natural degradation of the necrotic tissues, can make the gene study not viable in 73.68%.[7]

The human skeletons present differential characteristics such as prominences, rugosity, crests, apophysis, and lengths, which characterize the sexual dimorphism.[8,9] The morphological analysis of the bony pelvis represents the most credible technique for sex estimation;[10,11] however, the skeleton may be incomplete; missing the pelvis, or the bony pelvis, may be not well preserved preventing its analysis.[11] Hence, it is essential to develop methods which permit sex estimation using other bones from the skeletal.[10,12]

At crime scenes, the most found bones are the skull, the femur, and the jaw,[13] but there is a huge possibility to find the atlas vertebra in these cases. The vertebrae are considered the best preserved skeletal bones in many cases,[11] such as mass disasters.

The first cervical vertebra named atlas is articulated with the occipital bone, in the occipitoatloid joint, allowing the head movements. It has a particular shape and is easily distinguished from the other vertebrae. Measurements of the vertebral dimensions are considered the best predictors of sex after the pelvic elements.[11] The closing age at atlas' anterior synchondroses also has distinct differences between sexes.[14]

In Brazil, the sex determination by linear measurements of the bones is widely used because of the several kinds of death in which the corpses are damaged. Thus, from the possibility to determine sex through the analysis of atlas vertebra, this study becomes important to develop a mathematical model for this purpose to be used in the Brazilian population.

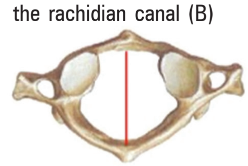
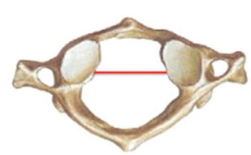
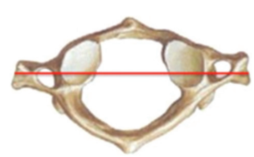
Materials and Methods

This project was approved by the local research ethics committee (CAAE 38522714.6.0000.5418).

A total of 191 atlas vertebrae selected from the osteological collection of the Forensic Physical Anthropology Laboratory Prof. Eduardo Daruge of the Piracicaba Dental School, placed at the Southeast region of the country, were analyzed. The selected bones, legally donated for the laboratory, belonged to the individuals whose families were no longer alive or did not request the corpse remains for socioeconomic reasons, during a period of 3–5 years.

Linear measurements were obtained using a digital caliper (Stainless-Hardened®-150 mm, Mauá, São Paulo, Brazil). Four measurements were made in each atlas vertebrae: anteroposterior diameter of the atlas (variable A), anteroposterior diameter of the rachidian canal (variable B), transverse diameter of the rachidian canal (variable C), and maximum transverse diameter of the atlas (variable D) [Table 1].

Table 1: Classification and identification of variables of the study

Type	Variables	Classification	Category
Dependents	Sex	Qualitative	M=Male F=Female
Independents	Anteroposterior diameter of the atlas (A) 	Quantitative	Continuous
	Anteroposterior diameter of the rachidian canal (B) 	Quantitative	Continuous
	Transverse diameter of the rachidian canal (C) 	Quantitative	Continuous
	Maximum transverse diameter of the atlas (D) 	Quantitative	Continuous

Inter- and intra-examiner tests were carried out to verify the researcher's calibration. For this calibration, 25 skeletons with discriminated gender, ancestry and age, had they atlas vertebrae measured by two examiners in three different occasions, to obtain the percentage of inter- and intra-examiner agreement. Moreover, once calibrated with the standard of excellence, the principle sample composed of 191 atlas vertebra was finally measured by one examiner.

The data were analyzed using IBM® SPSS® 25 USA statistics program. Then, we used the Kolmogorov–Smirnov test to check the normality of the data and also used an unpaired *t*-test to test the hypothesis if exists a sexual dimorphism between the measurements. Using the stepwise-forward Wald method was obtained a logistic regression. By the way, was determined the Pearson's correlation for all variables on the selected model.

Results

The intraclass correlation (ICC) coefficient for both inter- and intra-examiner agreements was excellent for the four studied measurements (ICC ≥0.75), indicating that all the measurements made in this study can be reproduced. The gender distribution of the principle sample was made accordingly to the frequency [Table 2] and percentage [Figure 1].

Since the sample was composed of 191 atlas vertebra, the data were collected and were made a Kolmogorov–Smirnov test to check this normality, and the variables which presented statistical significance were A, C, and D (significance >0.05) [Table 3]. Therefore, these variables can be submitted to parametric tests. On the other hand, the variable B did not obtain statistical significance, and for this reason, it was not submitted to parametric tests.

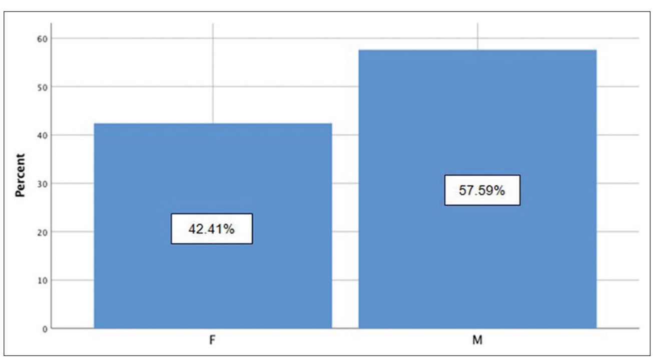


Figure 1: Gender distribution of the principle sample (%)

Table 2: Gender distribution of the principle sample

	Frequency
Male	110
Female	81
Total	191

Then, a descriptive analysis was made, using as mean the measurements of central tendency, and as standard deviation the measures of dispersion, specified regarding sex [Table 4].

The mean measurements of all four variables for male were higher than for female, and a major discrepancy between the sexes was observed for the maximum transverse diameter of the atlas (variable D). Considering both sexes, the transverse diameter of the rachidian canal (variable C) obtained the best results of standard deviation that is the lower values (±2.65 for females and ± 2.11 for males). The maximum transverse diameter of the atlas (variable D) achieved the worse results for standard deviation (±5.58 for female and ± 5.11 for male).

An unpaired *t*-test was performed for the independent samples regarding sex [Table 5], and applying this test was observed acceptance about hypothesis that exists significant sex differences for all four measures assessed, since the significance was <0.05.

All four variables were tested and were applied the logistic regression for sex determination by the stepwise-forward Wald method. The variables A and D were selected by established the best model [Table 6].

$$\text{Logit} = -24.970 + 0.183 \times A + 0.230 \times D.$$

Finally, a Pearson's test was realized only with the selected variables of the model, and this way, all the correlations were significant in the level of 0.01, with a strong correlation [Table 7].

The developed logit results in 81.2% accuracy, 85.5% sensitivity, and 75.3% specificity, therefore, being more effective in sex determination than a mere random hit, in other words, to be considered as "male" values must be higher than 0.5 and to be considered as "female" values must be lower than 0.5 [Table 8].

Table 3: Normality test

	Kolmogorov-Smirnov		
	Statistic	df	Significant
A	0.043	191	0.200*
B	0.077	191	0.007
C	0.051	191	0.200*
D	0.056	191	0.200*

*This is a lower bound of the true significance

Table 4: Descriptive statistical regarding sex

Variables regarding sex	Mean (mm)±SD			
	F	M	F	M
A	42.28	45.36	±2.85	±2.90
B	30.08	31.33	±2.16	±3.01
C	28.11	29.00	±2.65	±2.11
D	70.87	78.83	±5.58	±5.11

SD: Standard deviation

Table 5: Unpaired *t*-test for the independent samples regarding sex

	Levene's test for equality of variances		*T*-test for equality of means						
	F	Significant	*t*	Degrees of freedom	Significant (two-tailed)	Mean difference	SE difference	95% CI	
								Lower	Upper
A	0.255	0.614	7.309	189	0	3.083	0.421	2.2515996	3.916
B	0.439	0.508	3.186	189	0.002	1.253	0.393	0.4772881	2.028
C	2.163	0.143	2.575	189	0.011	0.889	0.345	0.2080703	1.570
D	0.022	0.883	10.23	189	0	7.967	0.778	6.4308775	9.503

SE: Standard error, CI: Confidence interval

Table 6: Stepwise-forward Wald logistic regression analysis for sex determination - variables in model

	B	SE	Wald	Degrees of freedom	Significant	Exp (B)	95% CI	
							Lower	Upper
A	0.183	0.073	6.351	11	0.012	1.201	1.041	1.384
D	0.230	0.043	29.318	11	0.000	1.259	1.158	1.369
Constant	−24.970	3.709	45.318	11	0.000	0.000		

SE: Standard error, CI: Confidence interval

Table 7: Pearson's correlation test between the model variables

	Pearson's correlation	A	D
A	Pearson correlation	1	0.553**
	Significant (two-tailed)		0.000
	n	191	191
D	Pearson correlation	0.553**	1
	Significant (two-tailed)	0.000	
	n	191	191

**Correlation is significant

Table 8: Frequency distribution of correct percentages of sex determination

	Predicted		
	Sex		Correct percentage
	Female	Male	
Female	61	20	75.3
Male	16	94	85.5
Overall (%)			81.2

Discussion

For results be more reliable, the choice of a method for sex estimation must be based on the reference population used for it creation; in other words, this population must have proportions as similar as possible with the population being investigated,[10] and it explains the importance of this study. In addition, in most forensic cases with fragmentary skeletons, the professional responsible for the identification process did not know the race of the unidentified victim.[12]

The results obtained in this study indicate that the mean measurements of all four variables for men were higher than for women. Such situation is according to another international researchers which assessed linear measurements of the first cervical vertebra[15] and the 12th thoracic vertebra.[16]

An accuracy of at least 80% makes a method of sex estimation to be considered useful.[10] In the present study, for pooled sample our logit reached 81.2% of correct sex determination, which confirmed to be possible determine gender by the Atlas. This results in agreement with other studies that analyzed the atlas vertebra, in which they found 80%–87% of correct sex attribution,[15] trust levels between 75% and 85%,[17] and 82% of confidence of sex estimation.[18]

Considering the second cervical vertebra, it is possible to cite two studies, which the percent of males and females properly classified was, respectively, 79.2% and 83.3%[10] and ranging from 81.7% to 83.4%.[12]

Marlow and Pastor[10] reported the functional relationship between the cranial base and the atlas and axis vertebrae, and the sex differences analyzing size and weight of skulls can explain the sexual dimorphism.

The mathematical logistic regression model built (logit): sex = −24.970 + 0.183 × A + 0.230 × D, where "A" represents anteroposterior diameter of the atlas and "D" represents the maximum transverse diameter of the atlas, results in 81.2% accuracy, 85.5% sensitivity, and 75.3% specificity.

Conclusion

Although sex determination through the atlas first cervical vertebra is not commonly used, unlike what happens to several other osseous structures of the body, it is shown in this study the value of this particular bone for the sex estimation in forensic cases, since our results indicated 81.2% of correct percentage of sex determination.

Acknowledgments
We would like to thank the Student Support Service (SAE), the Institutional Scientific Initiation Scholarship Program,

and the National Council for Scientific and Technological Development (CNPq) for the funding to carry out the study.

Financial support and sponsorship

The study was financially supported by Student Support Service (SAE), the Institutional Scientific Initiation Scholarship Program, and the National Council for Scientific and Technological Development (CNPq).

Conflicts of interest

There are no conflicts of interest.

References

1. Oliviera OF, Tinoco RL, Júnior ED, Araujo LG, Silva RH, Paranhos LR. Sex determination from occipital condylar measurements by baudoin index in forensic purposes. Int J Morphol 2013;31:1297-300.
2. Francesquini Júnior L, Francesquini MA, de La Cruz BM, Pereira SD, Ambrosano GM, Barbosa CM, *et al*. Identification of sex using cranial base measurements. J Forensic Odontostomatol 2007;25:7-11.
3. INTERPOL Disaster Victim Identification Guide: INTERPOL 2014. Proposed Amendments; March, 2014.
4. Alves-Silva J, da Silva Santos M, Guimarães PE, Ferreira AC, Bandelt HJ, Pena SD, *et al*. The ancestry of Brazilian mtDNA lineages. Am J Hum Genet 2000;67:444-61.
5. Carvalho-Silva DR, Santos FR, Rocha J, Pena SD. The phylogeography of Brazilian Y-chromosome lineages. Am J Hum Genet 2001;68:281-6.
6. Parra FC, Amado RC, Lambertucci JR, Rocha J, Antunes CM, Pena SD. Color and genomic ancestry in Brazilians. Proc Natl Acad Sci U S A 2003;100:177-82.
7. Rosa MA, Gonzáles E, Fregel R, Velasco J, Delgado T, Gonzáles AM, *et al*. Canary Islands aborigin sex determination based on mandible parameters contrasted by amelogenin analysis. J Archaeol Sci 2007;34:1515-22.
8. Smith SL. Attribution of foot bones to sex and population groups. J Forensic Sci 1997;42:186-95.
9. Saini V, Srivastava R, Shamal SN, Singh TB, Kumar V, Kumar P, *et al*. Temporal variations in basicranium dimorphism of North Indians. Int J Legal Med 2014;128:699-707.
10. Marlow EJ, Pastor RF. Sex determination using the second cervical vertebra: A test of the method. J Forensic Sci 2011;56:165-9.
11. Hora M, Sládek V. Population specificity of sex estimation from vertebrae. Forensic Sci Int 2018;291:279.e1-12.
12. Wescott DJ. Sex variation in the second cervical vertebra. J Forensic Sci 2000;45:462-6.
13. Bass WM, Driscoll PA. Summary of skeletal identification in Tennessee: 1971-1981. J Forensic Sci 1983;28:159-68.
14. Asukai M, Fujita T, Suzuki D, Nishida T, Ohishi T, Matsuyama Y. Sex-related differences in the developmental morphology of the atlas: A computed tomography study. Spine (Phila Pa 1976) 2018;43:699-704.
15. Medina CS, Polo LC, Botella MC. Dimorfismo sexual en primera vértebra cervical en una muestra de población colombiana. Rev Esp Med Legal 2011;37:140-5.
16. Yu SB, Lee UY, Kwak DS, Ahn YW, Jin CZ, Zhao J, *et al*. Determination of sex for the 12th thoracic vertebra by morphometry of three-dimensional reconstructed vertebral models. J Forensic Sci 2008;53:620-5.
17. Marino EA. Sex estimation using the first cervical vertebra. Am J Phys Anthropol 1995;97:127-33.
18. Del Río MP, Sánchez SJ, Prieto CJ. Determinación del sexo mediante el análisis de imagen en el atlas.Cuad Med Forense 2000;22:45-52.