JOURNAL of FORENSIC ODONTO-STOMATOLOGY

VOLUME 30 Number 2 December 2012

SECTION IDENTIFICATION

Sexual Dimorphism in Brazilian Human Skulls: Discriminant Function Analysis

Osvaldo, Fortes de Oliveira[1]; Rachel, Lima Ribeiro Tinoco[1]; Eduardo, Daruge Júnior[1]; Andrea Sayuri, Silveira Dias Terada[2]; Ricardo Henrique, Alves da Silva[2]; Luiz Renato, Paranhos[3]

[1]. *Department of Forensic Dentistry, State University of Campinas, Brazil*

[2]. *Department of Stomatology, Public Health and Forensic Dentistry, Ribeirão Preto Dental School, University of São Paulo, Brazil*

[3] *Department of Oral Biology, Sagrado Coração University, Bauru, Brazil*

Corresponding author: paranhos@ortodontista.com.br

The authors declare that they have no conflict of interest.

ABSTRACT

Many anthropological studies have shown that sex can be determined using the human skeleton, especially by examining the pelvis and skull. The aim of this study was to verify the presence of sexual dimorphism in the Brazilian population by craniometric analysis; to identify the most reliable measurements and to propose a discriminant function for sex determination. The selected sample was composed of 100 adult skulls, 50 male and 50 female, from Cuiabá city, Mato Grosso State, Brazil. Of all the measurements taken, only the difference between the bi-euryon distances has proven insignificant, while themost dimorphic measure was the bi-zygomatic diameter. A discriminant function was obtained by applying the bi-zygomatic and the basion-lambda measurements, with a confidence level of 72%. The authors concluded that most of the traits analyzed are sexually dimorphic and the discriminant function elaborated is reliable for sex determination in human identification for forensic purposes.

KEYWORDS: *Forensic anthropology, Sexual dimorphism, Craniometry, Forensic Dentistry.*

JFOS. December 2012, Vol.30, No.2 Pag 26-33

ISSN :2219-6749

INTRODUCTION

Human identification is one of the major and most important tasks of Forensic Medicine and Dentistry. The identification of a deceased individual holds social, economic and legal repercussions. Soft tissues are commonly no longer present, due to carbonization, trauma or advanced decomposition. In those cases, forensic anthropology serves an important role in human identification.[1,2]

One of the main features considered in anthropological analysis for identification purposes is the sex. The most reliable bone structures for sex determination are the pelvis and the skull.[1,3,4] Studies based on metric features of teh pelvis and skull have been considered most reliable, given their objectivity, reproducibility and statistical value.[5, 6]

Anthropological features vary from one population to another. Therefore, human identification methods within this science must be validated before they can be used in each geographical group[5]. Sex determination by metric traits of cranial structures has been tested by many authors around the world.[1-3, 6-13]

The aim of this study was to evaluate the sexual dimorphism in metric relations between anatomical points of the skull, as well as to compile an effective mathematical function for sex determination in a Brazilian population, located in Central-Western region of the country.

MATERIAL AND METHODS

A sample composed of 100 human skulls with known sex and age at death, with equal number of each of the sexes. After cleaning the material, each skull received a code number to minimize operator bias. The damaged skulls were excluded, as well as those with signs of gross asymmetry, trauma, or that belonged to individuals under the age of 22 years at death.

Craniometric landmarks were located according to standard textbooks of anthropology.[14-5] described on Table 1, shown on Figure 1

.

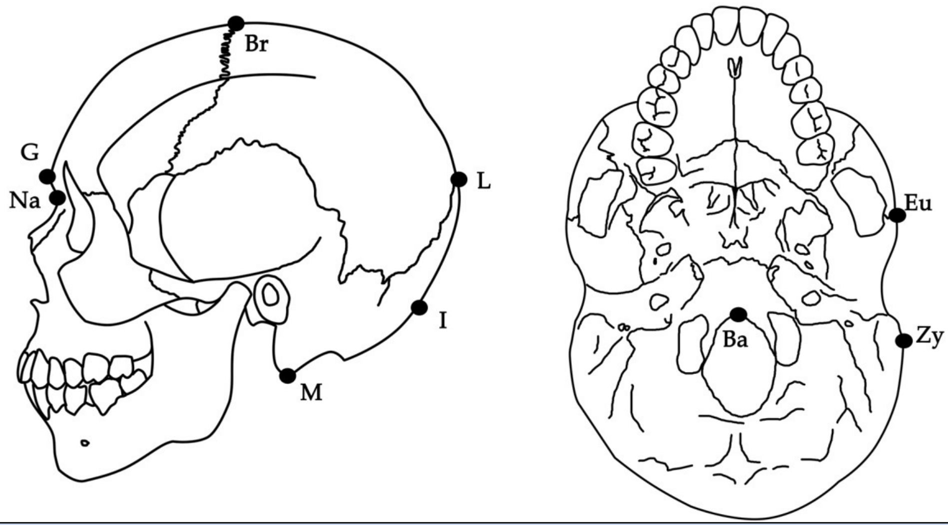

Figure 1: Craniometric landmarks locations – Ba (basion), Eu (euryon), Zy (zygion), Na (nasion), G (glabella), Br (bregma), L (lambda), I (inion), M (mastoid).[14-15]

Table 1: Definition of craniometric landmarks.[14-5]

Basion	The most inferior point on the anterior border of the foramen magnum
Bregma	The point where the sagittal suture ends anteriorly at the coronal suture in the sagittal plane
Euryon	The lateral point on the parietal bone that marks the greater transverse diameter of the skull
Glabella	The most anterior point on the frontal midline, between the supraorbital tori
Inion	The most prominent projection of the occipital bone at the most superior point of the external occipital protuberance
Lambda	The midline point where the sagittal suture meets the lambdoid suture
Mastoid	The most proeminent and inferior point of the mastoid process
Nasion	The point where the internasal suture meets the nasofrontal suture in the midsagittal plane
Zygion	The lateral point on the zygomatic bone that marks the greatest bizygomatic diameter

Table 2: Mean, standard deviation, Student´s t-test for paired samples, and Dahlberg´s test for random and casual error.

Measure	1st exam		2nd exam		t	*p*	Error
	mean	SD	mean	SD			
Na-L	171.64	7.09	171.48	7.15	1.398	0.175	0.41
Na-Ba	97.54	5.28	97.02	5.16	2.865	0.009*	0.73
G-L	171.84	7.48	171.70	7.59	1.319	0.200	0.38
G-I	172.60	10.57	172.10	10.54	2.182	0.039*	0.87
G-Br	102.82	6.19	102.34	5.88	1.949	0.063	0.91
Ba-L	111.46	6.19	110.98	6.20	1.193	0.244	1.43
Ba-Br	127.90	8.91	127.96	8.73	0.398	0.694	0.52
Zy-Zy	108.09	8.53	107.04	8.51	3.244	0.003*	1.34
Eu-Eu	140.20	8.74	140.46	8.47	1.162	0.257	0.80
M-M	106.06	6.27	105.82	6.17	2.073	0.049*	0.45

The measurements were taken with a digital caliper (Digimess™, Sao Paulo, Brazil), and outside spring caliper for regions where the digital caliper could not be used. All the exams were performed by a single observer. The measures taken were the following: Nasion-Lambda (Na-L); Nasion-Basion (Na-Ba); Glabella-Lambda (G-L); Glabella-Inion (G-I); Glabella-Bregma (G-Br); Basion-Lambda (Ba-L); Basion-Bregma (Ba-Br); Zygion-Zygion (Zy-Zy); Euryon-Euryon (Eu-Eu); Mastoid-Mastoid (M-M).

Twenty-five skulls were re-examined after a two weeks interval, to evaluate the intra-examiner reliability, by Student´s t-test for paired samples. The random error was assessed by the formula proposed by Dahlberg: error = $\sqrt{\Sigma d^2/2n}$, where d = difference between 1st and 2nd measurements, and n = number of repetitions.

Discriminant analysis stepwise model was used to verify the best mathematical model to discriminate sexes and determine which measure is more relevant. Results with p <0.05 were considered statiscally significant. All statistical procedures were performed using Statistical Package for the Social Sciences – SPSS™, version 13.

RESULTS

The data for the systematic and casual error are presented in Table 2, and four of nine measures of paired samples showed statistically significant results.

The Kolmogorov-Smirnov test was used to check the data distribution, by which one can note that the variations within the measurements were statistically insignificant, as seen in Table 3.

Table 3: Kolmogorov-Smirnov test.

Sex	Measure	Mean	SD	*P*
Female	Na-L	169.47	7.24	0.216
	Na-Ba	96.03	4.83	0.903
	G-L	169.62	7.45	0.335
	G-I	169.07	8.28	0.878
	G-Br	102.36	6.14	0.890
	Ba-L	110.29	7.68	0.943
	Ba-Br	127.28	7.24	0.472
	Zy-Zy	103.29	5.99	0.745
	Eu-Eu	139.42	7.05	0.202
	M-M	103.75	5.05	0.853
Male	Na-L	174.15	5.53	0.915
	Na-Ba	99.72	4.97	0.545
	G-L	175.16	6.34	0.195
	G-I	176.45	7.30	0.620
	G-Br	106.06	5.96	0.934
	Ba-L	114.28	6.27	0.948
	Ba-Br	131.24	8.34	0.824
	Zy-Zy	110.88	7.06	0.746
	Eu-Eu	140.49	7.68	0.859
	M-M	107.05	5.95	0.353

Table 4: Variation of means between sexes analyzed by Student's t-test.

Measure	Female		Male		*p*
	Mean	SD	Mean	SD	
Na-L	169.47	7.24	174.15	5.53	<0.001 *
Na-Ba	96.03	4.83	99.72	4.97	<0.001 *
G-L	169.62	7.45	175.16	6.34	<0.001 *
G-I	169.07	8.28	176.45	7.30	<0.001 *
G-Br	102.36	6.14	106.06	5.96	0.003 *
Ba-L	110.29	7.68	114.28	6.27	0.005 *
Ba-Br	127.28	7.24	131.24	8.34	0.013 *
Zy-Zy	103.29	5.99	110.88	7.06	<0.001 *
Eu-Eu	139.42	7.05	140.49	7.68	0.470
M-M	103.75	5.05	107.05	5.95	0.004 *

With respect to differences between sexes, according to Student´s t-test, all the measures had statistically significant results, with exception of the bieuryon width, as shown in Table 4.

Discriminant analysis stepwise model, considering the nine variables studied Table 5, showed that the best variable to separate the groups is the bizygomatic width (p <0.001) followed by the basion-lambda length (p<0.001). Applying other variables did not improve the discrimination obtained with these two variables.

The function obtained by discriminant analysis was: sex= (0.1373 x Zy-Zy)+ (0.0639 x [Ba-L-21.8876]) with a zero result pointing to females, and any greater result pointing to males, with success rates presented in Table 6.

DISCUSSION

Forensic anthropology is a branch of the Forensic Sciences concerned with the application of general anthropological knowledge and methods to the process of law.[16] The results obtained in this study show that for all the measures taken male subjects presented an average higher than for females, indicating that sex determination may be made by cranial measurements, as described by Günay &

Altinkök[7] and Kemkes & Gobel.[5] The accuracy of sex determination methods in highly interbred populations is usually lower than in areas with ethnic predominance of a single group, like in Central Europe.[5,13-4] In Brazil, the population is very miscegenated, due to the mixture between European, African and Asiatic immigrants and the indigenous population who already lived in the country. The population of the analyzed region was made up by the miscegenation of indians, whites and blacks, and the majority is comprised by *caboclos*, result of the miscegenation between whites and Indians, increasing the chances of great part of the sample belongs to this ethnical group.[17]

Table 5: Section points that optimize the success rates for the nine variables that show statistically significant difference between sexes.

Measure	Section point	Success rate		
		Total (%)	Female (%)	Male (%)
Na-L	166.50	65	36	94
Na-Ba	99.50	68	80	56
G-L	166.25	65	34	96
G-I	167.50	67	42	92
G-Br	101.28	63	46	80
Ba-L	114.50	64	76	52
Ba-Br	131.50	65	78	52
Zy-Zy	106.86	75	80	70
M-M	105.59	63	70	56

When determining the sex of a human skull, the randomly guessing would present an average accuracy of 50%, since theoretically the guess would be right in half of the cases.[18] And according to Sweet,[18] every human being has an identity in life and there is a basic societal need for this identity to be recognized after death, both for family consolation and for juridical purposes.

The sex estimation by analysis of the skull can be made by two methods available: the qualitative or quantitative method. The qualitative variables, used glabella features, thick bones and superciliary arches, form of treatment, bone surface appearance due to the action of the muscles, mastoid processes, the parietal eminences, alveolar arch, and coronoid fronto-nasal articulation.[19] The quantitative variables use measurements between pre-set points for sex identification.[20]

Table 6: Success rate of the discriminant function analysis with the measures Zy-Zy, and Ba-L

		Sex	Result		Total
			F	M	
Sample	n	F	38	12	50
		M	16	34	50
	%	F	76	24	100
		M	32	68	100
Total success rate					72

Suazo et al.[21] examined 284 adult skulls from São Paulo State, of which 187 were male and 97 female, and verified through quantitative methods that the best indicators were found in traits whose formation is related to the insertion and action of major muscle groups, such as mastoid process, zygomatic bone, mandible, and roughness of the occipital bone.

According to Vanrell,[22] the differential diagnosis of the sex by the analysis of the morphological characteristics of the skull and mandible has 77% success rate, while the analysis on metric traits of the skull in distinguishing the sex exceed 90% accuracy. In this, research the authors chose to take measurements of the skull with subsequent statistical analysis by discriminant function, which represents an objective method for sex determination, as suggested by Steyn & Iscan[6] and Patil & Mody.[1] According to these authors, a discriminant analysis overcomes subjective methods, providing a more reliable result, reason why it has been increasingly used in sex determination.

Amongst all the measurements performed in this study it was observed, according to discriminant analysis, that the bizygomatic distance presented the greatestsexual dimorphism, corroborating the results of other researchers, such as Krogman & Iscan,[23] Steyn & Iscan,[6] Monticelli & Graw,[8] Kranioti *et al.*[10] and Naikmasur *et al.*[12]

The bieuryon width showed no significant dimorphism in this sample, unlike the data presented by Franklin et al, [24] who analyzed eight measures in skulls of South African indians, and the measures with greatest dimorphism were bizygomatic distance, length and height of the skull.

Skulls from the sample were not distinguished by ethnic traits, and the fact that the regional population is marked for its high level of miscegenation, may have influenced the results obtained. It seems fair to conclude that, as defended by Iscan,[25] cranial patterns are population-specific features, affected by environmental factors such as diet, climate, and culture. Yet, it should be noted that the bizygomatic width represents an important feature in evaluating the sexual dimorphism in several populations, and should always be considered in sex determination for human identification.

CONCLUSION

From the analysis of the results, the authors conclude that all cranial measurements performed showed significant values for sex determination, except for the cranial width (bieuryon width). Among all the measurements taken in this research, the greatest sexual dimorphism was shown by the bizygomatic width. Through discriminant analysis, a mathematical model for sex determination was developed applying the bizygomatic width and the basion-lambda length, with a cofidence level of 72%.

.

REFERENCES

1. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: a lateral cephalometric study. Forensic Sci Int 2005; 147:175-80.
2. Graw M, Wahl J, Ahlbrecht M. Course of the meatus acusticus internus as criterion for sex differentiation. Forensic Sci Int 2005; 147:113-7.
3. Duric M, Rakocevic Z, Donic D. The reability of sex determination of skeletons from forensic context in the Balkans. Forensic Sci Int 2005; 147:159-64.
4. Iscan MY. Forensic anthropology of sex and body size. Forensic Sci Int 2005; 147:107-12.
5. Kemkes A, Gobel T. Metric assessment of the “mastoid triangle” for sex determination: a validation study. J Forensic Sci 2006; 51:985-9.
6. Steyn M, Iscan MY. Sexual dimorphism in the crania and mandibles of South Africa whites. Forensic Sci Int 1998; 98:9-16.
7. Günay Y, Altinkök M. The value of the size of foramen magnum in sex determination. J Clin Forensic Med 2000; 7:147-9.
8. Monticelli F, Graw M. Investigation on the reliability of determining sex from the human zygomaticum. Forensic Med Sci Pathol 2008; 4:181-6.
9. Suazo GIC, Zavando MDA, Smith RL. Sex determination using mastoid process measurements in Brazilian skulls. Int J Morphol 2008; 26:941-4.
10. Kranioti EF, Iscan MY, Michalodimitrakis M. Craniometric analysis of the modern Cretan population. Forensic Sci Int 2008; 180:110.e1-110.e5.
11. Gapert R, Black S, Last J. Sex determination from the foramen magnum: Discriminant function analysis in an eighteenth and nineteenth century British sample. Int J Legal Med 2009; 123:25-33.
12. Naikmasur VG, Shrivastava R, Mutalik S. Determination of sex in South Indians and immigrant Tibetans from cephalometric analysis and discriminant functions. Forensic Sci Int 2010; 197:122.e1-122.e6.
13. Bigoni L, Veleminska J, Bruzek J. Three dimensional geometric morphometric analysis of cranio-facial sexual dimorphism in a Central European sample of known sex. Homo 2010; 61:16-32.
14. Byers SN. Introduction to forensic anthropology. 4th ed. Boston: Pearson, 2010.
15. White TD, Black MT, Folkens PA. Human osteology. 3rd ed. Boston: Academic Press, 2011.
16. Silva RHA, Oliveria RN. Forensic anthropology and molecular biology: independent or complementary sciences in forensic dentistry? An overview. Braz J Oral Sci. 2008; 7(25):1575-9.
17. Zorzetto R. A África nos genes do povo brasileiro. Pesquisa Fapesp. Abril/2007.
18. Sweet D. Why a dentist for identification? Dent Clin North Am. 2001; 45: 237-51.
19. Rogers TL. Determing the sex of human remains through cranial morphology. J. Forensic Sci. 2005; 50:493-500.
20. 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
21. Suazo GIC, Zavando MDA, Smith RL. Performance Evaluation as a Diagnostic Test for Traditional Methods for Forensic Identification of Sex. Int. J. Morphol. 2009; 27:381-6.
22. Vanrell JP. Odontologia Legal e Antropologia Forense. 2. ed. Rio de Janeiro: Guanabara Koogan; 2009.
23. Krogman WM, Iscan MY. The human skeleton in forensic medicine. 2nd ed. Illinois: CC Thomas Publisher; 1986.
24. Franklin D, Freedman L, Milne N. Sexual dimorphism and discriminant function sexing in indigenous South African crania. Homo. 2005; 55(3):213-28.
25. Iscan MY. Age markers in the human skeleton. Springfield: Charles C. Thomas; 1989.

****