ORIGINAL ARTICLE

Radiographic anthropometric study of frontal sinus for sex determination in Benin city, South-South Nigeria

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Abstract

Context: The frontal sinuses are situated in the frontal bone between the outer and inner plates of the bone. A good knowledge on dimensions is relevant for successful surgery. **Aim:** This study was carried out to determine the dimorphic potential of the frontal sinuses and to ascertain the accuracy in sex determination using the logistic regression model among Edo people of Nigeria. **Materials and Methods:** It was a 7 years retrospective study on the Edo, utilizing posterior-anterior radiographs of frontal sinuses in University of Benin Teaching Hospital. The right and left frontal sinus heights and widths were measured in centimeter. **Statistical Analysis:** The data were analyzed using independent samples *t*-test and logistic regression with the aid of Statistical Package for the Social Sciences version 20. $P \leq 0.05$ was considered statistically significant. **Results:** All dimensions were higher in males than in females, wherein the the left side height and width were statistically significant (P < 0.05). Left side frontal sinus width gave the highest accuracy of 60% in sex determination using logit regression. **Conclusion:** The dimorphic nature of the left dimensions has implications for human identification.

Key words: Forensic anthropology, frontal sinus, logistic regression, radiographs, sex determination

Introduction

Sexual dimorphism is the observable differences in morphology or definite structural features exhibited between males and females of the same species.^[1] Sex determination plays a central role in solving medico-legal puzzle and in anthropology. The frontal sinuses are visible on the radiograph by the 6th year;^[2,3] hence, it is possible for individual identification for forensic reasons,^[4] A good

Access this article online					
	Quick Response Code				
Website: www.jfds.org					
DOI: 10.4103/jfo.jfds_40_16					

knowledge of dimensions of the frontal sinuses is relevant for a successful surgery,^[5,6] and in anthropology. Various studies on the frontal sinuses have been conducted across the globe.^[2-21] The purpose of this study was to determine the dimorphic potential of the frontal sinus and to ascertain its accuracy in sex determination from logistic regression analysis among the Edo people of Nigeria.

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How to cite this article: Eboh DE, Ogbeide OU, Ivwighren T. Radiographic anthropometric study of frontal sinus for sex determination in Benin city, South-South Nigeria. J Forensic Dent Sci 2017;9:31-5.

Materials and Methods

This was a retrospective study and all patients of Edo ethnic group, who attended the radiological services of the University of Benin Teaching Hospital, for plain X-ray of the frontal sinus, between January 2005 and August 2012, formed the study population. The study comprised 216 X-ray films of subjects aged 20–91 years and selected through the simple random sampling technique. All films were those taken by the Caldwell method. Biodata of each subject was obtained from the records in the hospital. X-ray films that showed normal anatomical features were included; those with evidence of pathology were excluded from the study. The research Ethics Committee of the Institution approved the research method.

The following parameters were measured: right frontal sinus height (Hr); right frontal sinus width (Wr); left frontal sinus height (HI); and left frontal sinus width (WI).^[7,9] The frontal sinus septum is the partition between the left and right sinuses, and it determines the extent of the width on both sides. The frontal sinus height on each side (Hr and HI) was measured as the maximum distance between the lowest and highest extents of the frontal sinus, whereas the width (Wr and WI) of the frontal sinus was measured as the distance between the medial and lateral most extents of the right and left sides of the frontal sinus [Figure 1]. All measurements were taken in centimeter (cm) using the inelastic plastic ruler. The radiograph without a well-defined septum was excluded from the study.

Statistical analysis

The data were analyzed with Statistical Package for the Social Sciences (SPSS) version 20 (IBM, Armonk, New York). The independent samples *t*-test was used to compare the difference in the means of the dimensions measured between males and females. Thereafter, a logistic regression model was developed using SPSS version 20, based on the logit link function and male sex, whereby parameters of

Wr Hr M

Figure 1: Measurement of height and width of frontal sinuses

the model were determined that allowed the prediction of the probability of relevance of the cranium to the male sex.

Results

Demographic data of study subjects revealed 52.8% were males, while 47.8% were females [Figure 2]. The mean age of subjects was 39.53 (SD 15.27) years.

The total means of all parameters measured are shown in [Table 1]. Mean height is greater than the respective width. The mean dimensions on the left side were significantly higher in males than in females (P < 0.05) [Table 1], while on the right side, there were no significant sex differences in the mean dimensions (P > 0.05) [Table 1]. There were no significant differences in the mean dimensions of parameters measured between the right and the left sides (P > 0.05) [Table 2]. There were significant correlations between the respective parameters measured on both sides (P < 0.05), with very high correlation coefficients [Table 3].

Independent samples *t*-tests showed that the height (Hr) and width (Wr) of the right frontal sinus did not exhibit significant sex differences (P > 0.05). Only the height (Hl) and width (Wl) on the left side showed significant sex differences (P < 0.05); hence, they were further used to develop a logistic regression model based on logit link function and the male sex.

Overall, 4% of the variation in the dependent variable (sex) can be explained by the model (based on Nagelkerke R^2); –2log likelihood for Hl was 292.284. In addition, 5% of the variation in the dependent variable (gender) can be explained by the model (based on Nagelkerke R^2); –2log likelihood for Wl was 290.536.

Results showed that 51 (50%) females and 78 (68.4%) males were classified correctly by the model developed. This



Figure 2: Percentage distribution of study subjects according to gender

Parameter (cm)	Data	Minimum	Maximum	Mean	SD	t	df	Р
Right side height	Male	2.00	7.60	3.86	1.05	1.567	214	0.119**
	Female	1.60	8.00	3.63	1.13			
	Combined	1.60	8.00	3.75	1.09	-	-	-
Right side width	Male	1.30	6.40	3.41	0.10	0.361	214	0.719**
	Female	1.10	6.40	3.36	0.11			
	Combined	1.10	6.40	3.39	1.07	-	-	-
Left side height	Male	1.70	7.60	3.97	0.10	2.542	214	0.012*
	Female	2.00	7.50	3.59	0.11			
	Combined	1.70	7.60	3.79	1.11	-	-	-
Left side width	Male	1.20	6.50	3.65	0.10	2.887	214	0.004*
	Female	1.00	6.20	3.21	0.11			
	Combined	1.00	6.50	3.44	1.13	-	-	-

Table 1	l: D	escriptive	statistics	and	independent	samples	t-test of	parameters	studied
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*Significant at 0.05, **Not significant at 0.055. SD: Standard deviation

Table 2: Paired samples t-test of parameters studied

Parameter (cm)	п	Mean	SD	t	df	Р
Pair 1						
Right side height (cm)	216	3.7519	1.08974	-0.912	215	0.363**
Left side height (cm)	216	3.7889	1.10587			
Pair 2						
Right side width (cm)	216	3.3866	1.06795	-0.977	215	0.330**
Left side width (cm)	216	3.4435	1.13492			
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**Not significant at 0.05. SD: Standard deviation

 Table 3: Paired samples correlations of parameters studied

Parameter (cm)	п	Correlation	Р
Pair 1			
Right side height (cm) and left side height (cm)	216	0.852	0.001*
Pair 2			
Right side width (cm) and left side width (cm)	216	0.699	0.001*
*Significant at 0.05			

*Significant at 0.05

gave overall correct classifications of 59.7% when the HI was the independent variable [Table 4]. When WI was the independent variable, 49 (48.0%) females and 70 (61.4%) males were classified correctly by the model developed, giving overall correct classifications of 55.1% [Table 4].

Omnibus tests of model coefficients indicated Chi-square value of 6.49 with the significance of 0.01 in the case of left frontal sinus height. In the case of left frontal sinus width, tests of model coefficients gave Chi-square value of 8.24 at a significance of 0.004. These outcomes indicated that the models were fair predictors of the sex of an individual [Table 3].

The coefficient and odds ratio for the left side height (LH) is 0.33 and 1.38, respectively, while it was 0.35 and 1.43, respectively, in the case of the left sinus width (Wl). Therefore, for a "1" unit increase in the LH and LW, there is 1.4 times more likelihood to be a male than female.

The parameters presented earlier enabled the formulation of the functions by which the logit values were obtained which were used in the calculation of the probability of relevance to measuring the skull. Predictive probability was for the male sex, with cut-off value as 0.5. This indicated that when the probability of a skull being classified into a male was ≥ 0.5 , the skull was a male; otherwise, it was a female. In all, the *P* values were found to be statistically significant (≤ 0.05).

In each case, the probability was calculated from the logit value from equations in [Table 3] by the expression: P (male) = $e \log t/(1 + e \log t)$. Where P = probability of being a male; e = mathematical exponential.

Nonetheless, about 40% and 45% classification for left sinus height (HI) and width (WI) respectively was incorrect. This outcome was better than for the prediction of gender based on chance with 47% probability of error when only the intercept (constant) was used.

Discussion

Human identification can be achieved using various tools which include body prints such as fingerprints, lip prints, ear prints, teeth, pelvic bones, and long bones. A situation in which unidentified bodies are seriously burned or skeletonized, forensic anthropological assessment becomes the key to the identification process. The unique morphology of the frontal sinus makes it possible for human identification. The areas and dimensions of both sinuses are rarely equal and in some cases may be absent.^[9] The morphology may be visualized on the computed tomography and even posterior-anterior (PA) radiographs from 5 years of age.^[10]

In the present study, mean dimensions of all parameters measured on both sides were greater in males compared with females. This morphological sex differences in sizes of frontal sinus may be ascribed to genetic factors, but

Parameter	Logit model (y=a+bx)	—2log Likelihood	Chi-square for model fit	Р	Overall percentage of correct prediction	
Left side height	y = -1.117 + 0.326 x	292.284	6.49	0.011	59.7	
Left side width	y = -1.104 + 354 x	290.536	8.236	0.004	55.1	

Table 4: Logistic regression results

environmental factors such as nutrition, as well as hormonal and muscular factors, may have a role to play.^[7,11-13] This may explain the reason males have larger frontal sinus than females.^[7,14] Previous studies also reported that frontal sinus dimensions are larger in males compared to females.^[7,8,13,15,16]

The assessment of frontal sinus for side differences revealed left side dimensions were larger than the right; the differences were not significant (*P* > 0.05). This is in agreement with some existing studies,^[7,13,16] but it is in contrast to the study by Belaldavar *et al.*^[8] The reason for the difference in the sizes of frontal sinus on both sides may not be unconnected to their independent development.^[13,17] The septum separating the pair of sinuses is rarely in the midline creating the asymmetry.^[18] The unequal resorption of the diploe during the development of the sinus of both sides may also account for the difference in their sizes.^[8,17] In a situation like this, the larger sinus may cross the midline.^[19] Nonetheless, dominant presence of symmetry between pairs of frontal sinuses has been reported in some study populations.^[9,19]

The size of the frontal sinus in the present study is greater than in some previous studies.^[4,7,8,13] Furthermore, the mean frontal sinus dimensions in the present study are approximately similar to the study by Rubira-Bullen *et al.*^[6] even though they used a different method of measurement and classified subjects into age groups. The differences observed among different studies reviewed may be due to geographic and environmental factors. It has been reported in the literature that "there is a positive correlation between the degree of pneumatization and environmental coldness of the population".^[21,22] In addition, there is a mutual relationship between the extent of pneumatization and individual size as well as the shape of the frontal sinus.^[21]

Correlations between paired dimensions were statistically significant (P < 0.05), strong, and positive. This observation may be due to a reciprocal increase in the sinus dimensions of both sides during development.

Test of significant difference with independent samples *t*-tests indicates only left side sinus height and width gave a significant difference between males and females (P < 0.05). Consequently, only left side height and width were involved in the logistic regression to predict the sex of an individual. In this study, the dependent variable is sex which is dichotomous (male and female), and independent variables are left side height and width. The accuracy of sex determination using left side height and width individually

was approximately 60% and 55%, respectively. Left side height gave a better regression outcome in this case. In a related study in India using PA radiographs, Belaldavar *et al.*^[8] reported that the overall "accuracy was 60.4%, 64.4%, 60.4%, and 59.4% for right sinus height, left sinus height, right sinus width, and left sinus width," respectively. The left sinus height was the most accurate in this study,^[8] and it is higher than in the present study. In South India, Verma *et al.*^[7] also using the Caldwell technique, reported that the frontal sinus height and width on both sides were not used in the logistic regression since they did not exhibit statistically significant sex differences. They only used the respective areas and had an accuracy of 60.9%.

This study focused only on the Edo people who attended the hospital. It is, therefore, recommended that more grandiose study that should include other ethnic groups to address this limitation.

Conclusion

The mean height is greater than the respective width. The mean dimensions on the left side are significantly higher in males than in females while those on the right are not. There are no significant differences in the mean dimensions of parameters measured between the right and the left sides. There are significant correlations between the respective parameters measured on both sides. Left side frontal sinus width gave the highest accuracy of 60% in sex determination using logit regression among Nigerians, which is quite low. Bearing in mind the not too high precision in sex determination using logistic regression, this method may be used as a supplementary tool as it applies to the frontal sinus.

Financial support and sponsorship Nil.

Conflicts of interest

There are no conflicts of interest.

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