

Applicability of the Ricketts' posteroanterior cephalometry for sex determination using logistic regression analysis in Hispano American Peruvians

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Introduction

The posteroanterior (PA) cephalometric norms in a nonadult Peruvian sample were established and significant differences between the sexes were found in

Abstract

Background: The Ricketts' posteroanterior (PA) cephalometry seems to be the most widely used and it has not been tested by multivariate statistics for sex determination. **Objective:** The objective was to determine the applicability of Ricketts' PA cephalometry for sex determination using the logistic regression analysis. **Materials and Methods:** The logistic models were estimated at distinct age cutoffs (all ages, 11 years, 13 years, and 15 years) in a database from 1,296 Hispano American Peruvians between 5 years and 44 years of age. **Results:** The logistic models were composed by six cephalometric measurements; the accuracy achieved by resubstitution varied between 60% and 70% and all the variables, with one exception, exhibited a direct relationship with the probability of being classified as male; the nasal width exhibited an indirect relationship. **Conclusion:** The maxillary and facial widths were present in all models and may represent a sexual dimorphism indicator. The accuracy found was lower than the literature and the Ricketts' PA cephalometry may not be adequate for sex determination. The indirect relationship of the nasal width in models with data from patients of 12 years of age or less may be a trait related to age or a characteristic in the studied population, which could be better studied and confirmed.

Key words: Cephalometry, logistic models, nasal cavity, sex determination, sex dimorphisms


seven cephalometric measurements (intermolar width, right molar to maxillae distance, nasal width, nasal height, maxillary width, mandibular width, and facial width); these measurements could be indicators of sexual dimorphism in the studied population.^[1]

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The sexual dimorphism represents a group of morphologic characteristics that differentiate males from females whether in size, structure, or appearance;^[2] those differences may be influenced by a combination of sexual selection, energy intake, nutrition, body composition, genetics, cultural practices, and human migration.^[3]

When the sexual characteristics of the soft parts are not available, the sex determination can be based only on characteristics displayed by the skeleton and in the case of a defleshed skull the lateral and PA cephalometric radiographies assumes a predominant role as they can provide architectural and morphological details and multiple points for comparison.^[4] The sex can be determined by two field methods, the morphological or qualitative method that comprises the evaluation of descriptive characteristics criteria of the osseous specimen and the anthropometric or quantitative method that comprises taking measurements of the skull or radiography and using it on multivariate statistics such as discriminant function analysis (DFA), Fourier analysis, and logistic regression (LR) analysis.^[5,6] Both the sex determination methods have their disadvantages such as lack of objectivity, reliance on the experience of the operator^[7] and insufficient statistical robustness to satisfy judicial requirements^[8] for the qualitative method and the population/sample specificity^[9] and lack of testing of multivariate functions for the quantitative method.^[10]

The skeletal characteristics, including the levels and the extent^[11] of sexual dimorphism and the intercorrelation between features,^[3,11] vary among a population and across time; hence, it is essential to continually investigate skeletal variation and sexual dimorphism of various populations within and between geographic regions.^[3] Furthermore, it is essential to have sex estimation standards for various skeletal elements because not all elements may be available for examination^[3] and for that reason, a great effort has been made to find the criteria capable of distinguishing male and female skulls, either suggesting new suites of traits or applying different morphometric and statistics approaches to register and analyze the cranial traits with acceptable levels of precision and accuracy.^[9]

The Ricketts' PA cephalometric analysis seems to be the most widely used because it provides normative values for different ages^[1]; it has not been evaluated by multivariate statistics for sex determination, which justifies the objective for the present study to determine the applicability of the Ricketts' PA cephalometric measurements for sex determination by the estimation of logistic regression models in a cephalometric database from Hispano American Peruvians patients, evaluation of the composing variables, and comparison of the accuracy of sex determination with similar studies in the literature.

Materials and Methods

The PA cephalometric radiographs were acquired in an Odontorama Pc-100 (Trophy Radiologie, Croissy-Beaubourg, France) plain film x-ray machine with a standardized technique and teeth in maximum intercuspation. The plain films were processed by conventional means. The PA cephalometric tracing, landmarks, and the measurements used were the same as described in a previously published paper.^[1]

The Ricketts' PA cephalometric measurements from 1,525 patients between 5 years and 44 years of age who attended our radiological center (Dentofacial Disarmonies Research Center - CIDDENT) for radiographic assessment prior to orthodontics between years 2009 and 2012 were retrieved from the archives. The exclusion criteria were: Error in data entry, craniofacial syndromes (any), cleft/lip palate (any type), and any absent data from the cephalometric measurements.

Following the exclusion criteria, the PA cephalometric measurements of 1,296 patients were grouped in a Microsoft Excel database and the LR models were estimated in IBM Statistical Package for the Social Sciences (SPSS®) Statistics version 19.0 (SPSS Inc., Chicago, IL, USA).

A significant level of 5% was considered as a critical value. Each model was estimated with sex as a dependent variable and the cephalometric measurements as an independent variable; the four LR models were estimated in the entire database and in three age cutoff subsamples (≥ 11 , ≥ 13 , and ≥ 15) in order to assess the possible differences related to age between the resulting models. All the logistic models were tested by applying and calculating the correct classification rate of males in the entire database and in the different age cutoff subsamples (resubstitution).

Because the present study represents a thorough evaluation by broadening the database of a previously published work, the intraoperator variability determined still applies.^[1]

Results

The database consisted of 1,296 Ricketts' PA cephalometric analysis from patients between 5 years and 44 years of age, with a median of 11, a mean age of 11.72 ± 3.7 years, and Q1 and Q3 of 9 years and 14 years, respectively. Of the patients, 52.7% were females with a median of 11, a mean age and standard deviation of 11.5 ± 4 years, an age range between 6 years and 42 years, and Q1 and Q3 at 9 years and 13 years of age. Of the patients, 47.3% of them were males with a median of 12, a mean age and standard deviation of 11.8 ± 4 years, an age range between 5 years and 44 years, and Q1 and Q3 of 9 years and 14 years of age [Table 1].

The logistic regression was estimated in four different models arbitrarily determined under the assumption that the lower the age, the lower the difference between the sexes [Table 2]:

- Model 1: Minimum age cutoff at 5 years of age
- Model 2: Minimum age cutoff at 11 years of age
- Model 3: Minimum age cutoff at 13 years of age
- Model 4: Minimum age cutoff at 15 years of age.

Table 1: Distribution based on age and sex in the studied database

Age	Female	Male	Total
5	0	1	1
6	16	17	33
7	50	32	82
8	56	57	113
9	68	65	133
10	96	69	165
11	78	60	138
12	81	72	153
13	81	59	140
14	56	65	121
15	31	35	66
16	28	28	56
17	12	23	35
18	8	10	18
19-44	22	20	42
Total	683	613	1296

The logistic regression models were estimated using the statistically significant variables (Wald's test, 1 degree of freedom, $P < 0.05$); the models, their composing variables, and the B-coefficients are shown in Table 2. Each logistic model was composed of three or more variables, which were (in a nonspecific order of importance) intermolar width, nasal width, nasal height, maxillary width, mandibular width, and facial width. It was found that all the variables in the four logistic models, with the exception of nasal width in models 1 and 2, expressed a direct relationship with the probability of being correctly classified as male. The nasal width expresses an indirect relationship with the probability of being classified as male in models 1 and 2, which includes data of up to 12 years of age.

The four logistic models were tested in the dataset by substitution at the same age cutoff (all ages, cutoff at the age of 11 years, cutoff at the age of 13 years, and cutoff

Table 2: Independent variables of the logistic regression models estimated with four different age cutoffs

	B (logit)	SE	Wald statistic	df	Sign	Exp (B)	95% CI** for Exp (B)	
							Lower	Upper
Model 1*								
Maxillary width	0.065	0.022	8.895	1	0	1.067	1.023	1.114
Facial width	0.066	0.014	21.653	1	0	1.068	1.039	1.098
Intermolar mandibular width	0.099	0.023	19.151	1	0	1.104	1.056	1.153
Nasal width	-0.152	0.028	30.634	1	0	0.859	0.814	0.906
Mandibular width	0.044	0.016	7.384	1	0.01	1.045	1.012	1.079
Constant	-18.09	1.576	131.67	1	0	0		
Model 2†								
Maxillary width	0.071	0.028	6.282	1	0.01	1.074	1.016	1.135
Facial width	0.071	0.019	14.199	1	0	1.073	1.034	1.113
Intermolar mandibular width	0.088	0.029	9.043	1	0	1.092	1.031	1.157
Nasal width	-0.133	0.037	13.099	1	0	0.876	0.815	0.941
Nasal height	0.077	0.028	7.701	1	0.01	1.08	1.023	1.14
Mandibular width	0.076	0.023	11.348	1	0	1.079	1.032	1.128
Constant	-26.153	2.405	118.203	1	0	0		
Model 3‡								
Maxillary width	0.082	0.035	5.434	1	0.02	1.086	1.013	1.163
Facial width	0.08	0.024	10.847	1	0	1.083	1.033	1.136
Nasal height	0.102	0.035	8.489	1	0	1.108	1.034	1.187
Mandibular width	0.064	0.028	5.129	1	0.02	1.067	1.009	1.128
Constant	-27.656	2.969	86.755	1	0	0		
Model 4§								
Maxillary width	0.154	0.051	9.009	1	0	1.167	1.055	1.291
Facial width	0.084	0.032	6.782	1	0.01	1.087	1.021	1.158
Nasal height	0.112	0.05	5.063	1	0.02	1.118	1.015	1.232
Constant	-27.938	4.513	38.324	1	0	0		

*All cases (n=1296), †Cases with 11 years of age or more (n=769), ‡Cases with 13 years of age or more (n=478), §Cases with 15 years of age or more (n=217)

**CI: Confidence interval. df: Degree of freedom, Exp (B): Exponentiation of the B coefficient, SE: Standard error

at the age of 15 years) in order to determine the correct classification rate of males. Additionally, the receiver operating curve (ROC) and the area under curve (AUC) of each model were estimated [Table 3].

Discussion

The craniofacies and the central nervous system develop along a primary female trajectory unless there is a male gonadal hormone secretion after gestational week 10 to initiate sexual dimorphism; hence, the sexes differ in cerebral morphology, facial shape, and cognitive abilities.^[12]

The sex determination by craniometry in lateral and/or PA cephalometric radiography has been studied in different populations, mostly with discriminant function analysis (DFA) than logical regression analysis (LRA). Ceballos and Rentschler^[13] in 1958 utilized means and bar charts analyses for sex determination using four measurements obtained from PA cephalometric radiography of 200 Caucasian adult patients (100 males and 100 females) and achieved 88% accuracy. Townsend, Richards, and Carroll^[7] in 1982 studied the DFA for sex determination in 15 measurements of both PA and lateral cephalometric radiographies of 80 Australian aboriginal adult patients (40 males and 40 females) and achieved 80% accuracy. Gonzales^[5] in 2012 utilized DFA for sex determination using 20 measurements obtained from lateral cephalometric radiography, in a longitudinal way, of 83 individuals (47 males and 36 females) of European descent from 5 years to 16 years of age and found three functions accounting for the 87.3% of the total variance. Inoue^[4] in 1992 utilized Fourier analysis for sex determination using 39 craniometric points in the forehead from lateral cephalometric radiography of 200 Japanese skulls

(100 males and 100 females) and achieved 85% accuracy. Hsiao, Chang, and Liu^[14] in 1996 utilized DFA for sex determination using 18 measurements obtained from lateral cephalometric radiography from a random sample of 100 Taiwanese adults (50 males and 50 females) and achieved 100% accuracy. Hsiao, Tsai, Chou, Pan, Tseng, Chang, and Chen^[15] in 2010 utilized DFA for sex determination using 22 measurements obtained from lateral cephalometric radiography of 100 Taiwanese children (50 males and 50 females) and achieved 92–95% accuracy using seven variables. Patil and Mody^[4] in 2005 utilized DFA for sex determination using 10 measurements obtained from lateral cephalometric radiography of 150 central Indian adults (75 males and 75 females) and achieved 99% accuracy. In our study, the estimated models were composed by three to six significant variables with an accuracy achieved by resubstitution between 63% and 75%, which was lesser than the reviewed studies and was classified as a relatively low accuracy rate;^[16] although differences exist, when comparing with similar studies regarding the number of patients and the statistical technique utilized for sex determination, the low accuracy of the four logistic models is sufficient to conclude that the Ricketts' PA cephalometric measurements are not adequate for sex determination. However, this study represents the first attempt to apply LRA in a Ricketts' PA cephalometric database and although the results were not as expected, the study design can be improved if we increase and equalize the sample size for every year of age for obtaining individual logistic models for every year of age, especially in nonadult patients because the sex differentiation in those patients is difficult in both the field methods.^[5,8]

The accuracy obtained by resubstitution of all the estimated models ranged between 63% and 75%, which is low if we

Table 3: Correct classification rate of sex determination of males (expressed in percentage) and the area under curve (AUC) of the receiver operating curve (ROC) curve resulting from the resubstitution of each estimated model in different age cutoff on the database

Correct classification rate/models	All cases (%)	Cutoff at 11 years subsample (%)	Cutoff at 13 years subsample (%)	Cutoff at 15 years subsample (%)	AUC	
					95% CI** lower bound	95% CI upper bound
Model 1*					0.71	
Maxillary width, facial width, intermolar mandibular width, nasal width, mandibular width	65.4	67.6	68.8	69.6	0.682	0.738
Model 2 [†]					0.7	
Maxillary width, facial width, intermolar mandibular width, nasal width, nasal height, mandibular width	65.4	70.4	71.5	71.4	0.667	0.724
Model 3 [‡]					0.662	
Maxillary width, facial width, nasal height, mandibular width	64	70	73.6	73.7	0.632	0.691
Model 4 [§]					0.664	
Maxillary width, facial width, nasal height	63.6	68.8	72.6	75.6	0.634	0.694

*All cases (n=1296), [†]Cases with 11 years of age or more (n=769), [‡]Cases with 13 years of age or more (n=478), [§]Cases with 15 years of age or more (n=217), P < 0.05 **CI: Confidence interval

bear in mind that the minimum accuracy value found in the literature by the use of craniometric/cephalometric variables is 80%.^[17] Moreover, the AUC found for the logistic models ranges between 0.66 and 0.71 with a 95% confidence interval (CI) range between 0.6 and 0.7, which are not far from the nondiscrimination point (AUC = 0.5) and we can reasonably conclude that the estimated logistic models are able to discriminate between sexes better than chance but their sensibility are not of clinical value for sex determination.

There are significant differences between the sexes; males, on average, are larger and with increased muscle attachment in their skeletons^[8] than females^[3] and furthermore, the degree of sexual dimorphism is inherent in the population from which the individual originates.^[8] The facial and maxillary widths were present in all the four estimated models with a direct relationship with the probability of being classified as a male and could be considered as sexual dimorphism indicators of the population studied (Hispano American Peruvian). The nasal width expressed an indirect relationship with the probability of being classified as male, this is, an unusual, unreported and probably a significant finding that encourages further discussion; its presence in models that include data of up to 12 years of age could be a trait related to age or a characteristic of the studied population; there are no similar studies to compare, and considering that our results come from a transversal study in a database of a nonrandom sample from the Peruvian nonadult population, the statistical inference may not be entirely correct or certain but represents an open question that can be better studied in longitudinal studies on the same population or in other populations for comparison.

The determination of sex from skeletons plays a crucial role in forensic and archaeological cases as it narrows the possibility of identification by 50%.^[18] The two field methods of sex determination (quantitative and qualitative) are obviously imperfect;^[5] however, both of these have proved to be very useful individually and yield a higher accuracy rate when used in combination as they complement one another.^[18] The reported accuracy rate of sex determination is 100% from a complete skeleton, 98% from both the pelvis and the skull, 95% from the pelvis only or the pelvis and the long bones, 90–95% from both the skull and the long bones, and 80–90% from the long bones only.^[16] The accuracy in the present study ranged between 60% and 75%, which is classified as low^[16] but is better than by chance alone.

The advantage of the Ricketts' PA cephalometry lies in its standardization and worldwide use, which would enable us to design studies on large databases from different geographical locations for the purpose of confirming the findings and the applicability of the PA cephalometry in sex determination.

The lateral cephalometric radiography does not give information about width but the PA cephalometric radiography does and so, the indirect relationship found for the nasal width measurement cannot be found or demonstrated in lateral radiography; this finding can be studied only in PA cephalometry of three-dimensional (3D)-computed tomography/cone-beam computed tomography (CT/CBCT) on different population groups and in cohorts if possible, with specifically designed nasal cavity cephalometric measurements. With the increasing implementation of digital maxillofacial radiography in university clinics and private practice centers, the possibility of a longitudinal series of standardized lateral, PA cephalometric radiography and 3D-CT/CBCT should be feasible and the design of large-scale morphometric studies in distinct populations or between populations should be feasible too. There is a lot of possibilities in radiographic-based sex determination studies for researchers.

Conclusions

- The applicability of the Ricketts' PA cephalometric measurements for sex determination by means of LRA was evaluated and the accuracy found in the present study was better than by chance but was classified as low accuracy when compared with similar studies in the literature
- Most of the variables of the estimated models demonstrated a direct relationship with the probability of being classified as a male; the nasal width variable demonstrated an indirect relationship with the probability of being classified as a male in models that included data of up to 12 years of age, which could be a trait related to age or a characteristic of the studied population and it would be advisable to evaluate such indirect relationship in longitudinal studies or in cross-sectional studies with larger samples than the present study.
- The facial and maxillary widths were found in every estimated model and could be considered as sexual dimorphism indicators of the studied population.

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Conflicts of interest

There are no conflicts of interest.

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