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

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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

Introduction

The posteroanterior (PA) cephalometric norms in a nonadult Peruvian sample were established and significant differences between the sexes were found in 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]
The sexual dimorphism represents a group of morphologic characteristics that differentiate males from females whether in size, structure, or appearance; those differences may be influenced by a combination of sexual selection, energy intake, nutrition, body composition, genetics, cultural practices, and human migration.

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. 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 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. Both the sex determination methods have their disadvantages such as lack of objectivity, reliance on the experience of the operator and insufficient statistical robustness to satisfy judicial requirements for the qualitative method and the population/sample specificity and lack of testing of multivariate functions for the quantitative method.

The skeletal characteristics, including the levels and the extent of sexual dimorphism and the intercorrelation between features, 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. Furthermore, it is essential to have sex estimation standards for various skeletal elements because not all elements may be available for examination 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.

The Ricketts’ PA cephalometric analysis seems to be the most widely used because it provides normative values for different ages; 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-Beauborg, 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.

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.

**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.

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, mandibulary 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 resubstitution at the same age cutoff (all ages, cutoff at the age of 11 years, cutoff at the age of 13 years, and cutoff

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

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
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<td>57</td>
<td>113</td>
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<tr>
<td>9</td>
<td>68</td>
<td>65</td>
<td>133</td>
</tr>
<tr>
<td>10</td>
<td>96</td>
<td>69</td>
<td>165</td>
</tr>
<tr>
<td>11</td>
<td>78</td>
<td>60</td>
<td>138</td>
</tr>
<tr>
<td>12</td>
<td>81</td>
<td>72</td>
<td>153</td>
</tr>
<tr>
<td>13</td>
<td>81</td>
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<tr>
<td>14</td>
<td>56</td>
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<td>15</td>
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<td>16</td>
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<tr>
<td>17</td>
<td>12</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>19-44</td>
<td>22</td>
<td>20</td>
<td>42</td>
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<tr>
<td>Total</td>
<td>683</td>
<td>613</td>
<td>1296</td>
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</table>

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

<table>
<thead>
<tr>
<th>Model</th>
<th>B (logit)</th>
<th>SE</th>
<th>Wald statistic</th>
<th>df</th>
<th>Sign</th>
<th>Exp (B)</th>
<th>95% CI** for Exp (B)</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxillary width</td>
<td>0.065</td>
<td>0.022</td>
<td>8.895</td>
<td>1</td>
<td>0</td>
<td>1.067</td>
<td>1.023</td>
<td>1.114</td>
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<tr>
<td>Facial width</td>
<td>0.066</td>
<td>0.014</td>
<td>21.653</td>
<td>1</td>
<td>0</td>
<td>1.068</td>
<td>1.039</td>
<td>1.098</td>
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<tr>
<td>Intermolar mandibulary width</td>
<td>0.099</td>
<td>0.023</td>
<td>19.151</td>
<td>1</td>
<td>0</td>
<td>1.104</td>
<td>1.056</td>
<td>1.153</td>
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<tr>
<td>Nasal width</td>
<td>−0.152</td>
<td>0.028</td>
<td>30.634</td>
<td>1</td>
<td>0</td>
<td>0.859</td>
<td>0.814</td>
<td>0.906</td>
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<tr>
<td>Mandibulary width</td>
<td>0.044</td>
<td>0.016</td>
<td>7.384</td>
<td>1</td>
<td>0.01</td>
<td>1.045</td>
<td>1.012</td>
<td>1.079</td>
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<td>Constant</td>
<td>−18.09</td>
<td>1.576</td>
<td>131.67</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>Model 2†</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Maxillary width</td>
<td>0.071</td>
<td>0.028</td>
<td>6.282</td>
<td>1</td>
<td>0.01</td>
<td>1.074</td>
<td>1.016</td>
<td>1.135</td>
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<tr>
<td>Facial width</td>
<td>0.071</td>
<td>0.019</td>
<td>14.199</td>
<td>1</td>
<td>0</td>
<td>1.073</td>
<td>1.034</td>
<td>1.113</td>
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<tr>
<td>Intermolar mandibulary width</td>
<td>0.088</td>
<td>0.029</td>
<td>9.043</td>
<td>1</td>
<td>0</td>
<td>1.092</td>
<td>1.031</td>
<td>1.157</td>
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<tr>
<td>Nasal width</td>
<td>−0.133</td>
<td>0.037</td>
<td>13.099</td>
<td>1</td>
<td>0</td>
<td>0.876</td>
<td>0.815</td>
<td>0.941</td>
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<tr>
<td>Nasal height</td>
<td>0.077</td>
<td>0.028</td>
<td>7.701</td>
<td>1</td>
<td>0.01</td>
<td>1.08</td>
<td>1.023</td>
<td>1.14</td>
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<tr>
<td>Mandibulary width</td>
<td>0.076</td>
<td>0.023</td>
<td>11.348</td>
<td>1</td>
<td>0</td>
<td>1.079</td>
<td>1.032</td>
<td>1.128</td>
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<tr>
<td>Constant</td>
<td>−26.153</td>
<td>2.405</td>
<td>118.203</td>
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<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Model 3‡</td>
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<tr>
<td>Maxillary width</td>
<td>0.082</td>
<td>0.035</td>
<td>5.434</td>
<td>1</td>
<td>0.02</td>
<td>1.086</td>
<td>1.013</td>
<td>1.163</td>
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<td>Facial width</td>
<td>0.08</td>
<td>0.024</td>
<td>10.947</td>
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<td>0</td>
<td>1.083</td>
<td>1.033</td>
<td>1.136</td>
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<tr>
<td>Nasal height</td>
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<td>0.035</td>
<td>8.489</td>
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<td>0</td>
<td>1.108</td>
<td>1.034</td>
<td>1.187</td>
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</tr>
<tr>
<td>Mandibulary width</td>
<td>0.064</td>
<td>0.028</td>
<td>5.129</td>
<td>1</td>
<td>0.02</td>
<td>1.067</td>
<td>1.009</td>
<td>1.128</td>
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<tr>
<td>Constant</td>
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<td>118.755</td>
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<tr>
<td>Model 4§</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Maxillary width</td>
<td>0.154</td>
<td>0.051</td>
<td>9.099</td>
<td>1</td>
<td>0</td>
<td>1.167</td>
<td>1.055</td>
<td>1.291</td>
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<tr>
<td>Facial width</td>
<td>0.084</td>
<td>0.032</td>
<td>6.782</td>
<td>1</td>
<td>0.01</td>
<td>1.087</td>
<td>1.021</td>
<td>1.158</td>
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</tr>
<tr>
<td>Nasal height</td>
<td>0.112</td>
<td>0.05</td>
<td>5.063</td>
<td>1</td>
<td>0.02</td>
<td>1.118</td>
<td>1.015</td>
<td>1.232</td>
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</tr>
<tr>
<td>Constant</td>
<td>−27.938</td>
<td>4.513</td>
<td>38.324</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*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.

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 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 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 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 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 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 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. 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 lower than the reviewed studies and was classified as a relatively low accuracy rate 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 Rickets’ PA cephalometric measurements are not adequate for sex determination. However, this study represents the first attempt to apply LRA in a Rickets’ 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.

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

<table>
<thead>
<tr>
<th>Correct classification rate/models</th>
<th>All cases (%)</th>
<th>Cutoff at 11 years subsample (%)</th>
<th>Cutoff at 13 years subsample (%)</th>
<th>Cutoff at 15 years subsample (%)</th>
<th>AUC 95% CI**</th>
<th>95% CI **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxillary width, facial width, intermolar mandibulary width, nasal width, mandibulary width</td>
<td>65.4</td>
<td>67.6</td>
<td>68.8</td>
<td>69.6</td>
<td>0.662</td>
<td>0.738</td>
</tr>
<tr>
<td>Model 2*</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Maxillary width, facial width, intermolar mandibulary width, nasal width, nasal height, mandibulary width</td>
<td>65.4</td>
<td>70.4</td>
<td>71.5</td>
<td>71.4</td>
<td>0.667</td>
<td>0.724</td>
</tr>
<tr>
<td>Model 3*</td>
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<td></td>
</tr>
<tr>
<td>Maxillary width, facial width, nasal height, mandibulary width</td>
<td>64</td>
<td>70</td>
<td>73.6</td>
<td>73.7</td>
<td>0.632</td>
<td>0.691</td>
</tr>
<tr>
<td>Model 4*</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Maxillary width, facial width, nasal height</td>
<td>63.6</td>
<td>68.8</td>
<td>72.6</td>
<td>75.6</td>
<td>0.634</td>
<td>0.694</td>
</tr>
</tbody>
</table>

*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.[9] 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.

References

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