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Reliability of Cephalogram in Determining Skull Gender Dimorphism

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Abstract

Background: The forensic anthropologists have been vastly studied the dimorphism in teeth, hair, pelvis, skull and in bone sizes.
Objectives: To investigate the gender dimorphic potential of cephalometric parameters.
Materials and Methods: Thirteen angular and twenty-one linear lateral cephalometric measurements were analyzed on randomly selected manual tracings of sixty-nine male and sixty-nine female cephalograms between the ages twenty to fifty years.
Results: 91.3% males correctly classified in the data, on the basis of discriminant function we made, similarly, 97.1% females were correctly classified in their specific group by the help of this discriminant function. The percentage of skulls correctly classified with this function was 94.2%.
Conclusions: 94.2% of original grouped cases correctly classified. For higher results extensive research with large sample size and both linear and angular cranial dimorphic traits for gender identification is proposed.

Keywords: Skull Dimorphism, Dental Radiology and Imaging, Lateral Cephalogram, Discriminant Function, Forensic Dentistry

1. Background

Is the patient a male or a female? This is usually the first naturally occurring thought that comes into the clinician's mind before going into the case detail. Determining sex is vital for an individuals' identification from birth till death as it is a foundational component of the biological profile. Not only the diseases but even the growth, development and aging have gender specific features. The forensic anthropologists have been vastly studied the dimorphism in teeth, hair, pelvis, skull and in bone sizes. It is only possible once the male or female has reached adolescence or adulthood.

Second best region to determine dimorphism between the sexes is the human skull. Skull bones that are available as the human remains can be used for identification of sex for civil or criminal intend when there is limitation for the application of finger printing method of human identification. Dimorphic traits of human skull are used widely reporting 77 to 92% accuracy of anthropometric measurements. Whereas, the studies conducted for the sex discrimination using cephalograms have claimed 80 to 100% accuracy (1-3). It also has been calculated that a group of traits are required for precise diagnosis instead of deliberating single character. Sex-related skeletal features are not obvious in children's bones. Elusive differences are detectable but they become more defined following puberty and sexual maturation.

Zeh et al. (2) stated determination of sex with 95% reliability when using pelvis alone, 92% using the skull alone and 98% using both the pelvis and the skull.

Other than its orthodontic use, the readily available equipment for cephalogram can make it a practicable tool of the forensic investigation as well specifically in medico-legal cases of unidentified severed heads in events of burn, murder, accidents, suicide bombing and war.

Hence, by using lateral cephalograms, this descriptive study is undertaken to evaluate potential sex differences in linear and angular lateral cephalometric readings. Discriminant function analysis is applied statistical technique for sex discrimination. The aim of the analysis is to determine whether these variables will discriminate between the gender or not.

2. Objectives

To investigate the gender dimorphic potential of cephalometric parameters.

3. Materials and Methods

The sample size for this study consists of 138 subjects. Study population comprised of adults, 69 males and 69 females between the ages 18 years to 50 years, visited Department of Orthodontics, Dr. Ishrat ul Ebad Khan institute of oral health sciences, Karachi, Pakistan. Good quality lateral cephalograms of all subjects of known sexes are randomly selected. Cephalometric points were located and marked by a single investigator. Individuals with the history of facial asymmetry, trauma, hereditary, congenital, developmental or nutritional disturbances, prolonged illness, previous orthodontics or orthognathic treatment or surgery of skull are not included.

The undermentioned linear and angular parameters (Table 1: Linear (mm) Cephalometric Variables and Table 2 Angular (°) Cephalometric Variable) were measured by using lateral cephalometric landmarks (Figure 1: landmarks) traced on acetate paper (Figure 2 Cephalometric parameters: Linear and Figure 3 Cephalometric parameters: Angular).

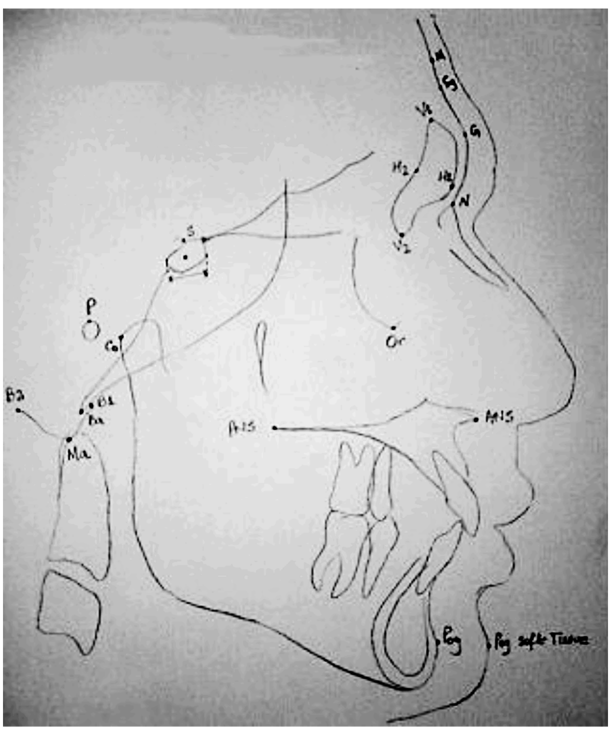


Figure 1. Landmarks

Table 1. Linear (mm) Cephalometric Variables

Variables	Description
Ba-ANS	Most inferior posterior point in the sagittal plane on the anterior rim of foramen magnum(Ba) to the tip of the bony anterior nasal spine in the median plane(ANS)
Ba-N	Most inferior posterior point in the sagittal plane on the anterior rim of foramen magnum(Ba) to the most anterior point of the frontonasal suture in the median plane(N)
N-ANS	The most anterior point of the frontonasal suture in the median plane(N) to the tip of the bony anterior nasal spine in the median plane(ANS)
N-Me	The most anterior point of the frontonasal suture in the median plane(N) to the most inferior midpoint on the mandibular symphysis(Me)
Fs-Wd	Frontal sinus width
Fs-Ht	Distance between the upper limit(V1) and lower limit(V2) of frontal sinus
Ma-SN	Lowest point of mastoid bone(Ma) to sella-nasion plane(SN)
Ma-FH	Lowest point of mastoid bone(Ma) to Frankfort plane(FH)
Ma-Ht	Porion to mastoidale
Ma-wd	Maximum width of the mastoid in the anterior-posterior direction.
ANS-Me	Lower anterior facial height
GSgN	Distance between glabella and the supraglabellare to nasion line
SgGM	Distance between supraglabellare and the glabella to metopion line
S'-Co'	Projection of sella on FH plane-projection of Condylion on FH
Sella length	The distance from tuberculum sella to posterior clinoid
Sella width	The largest antero-posterior dimension
Sella height anterior	The vertical distance, as measured perpendicular to the FH plane, from tuberculum to the sella floor
Sella height posterior	The vertical distance, as measured perpendicular to the FH plane, from posterior clinoid to the sella floor
ULTc	Ratio of total chin thickness to upper lip thickness
GPI	Glabella projection index = GSgN × 100/SgN
G-SI-PI	Glabella superior-inferior projection index-a measure of the location of glabella along the midsagittal plane = GSg/GN.

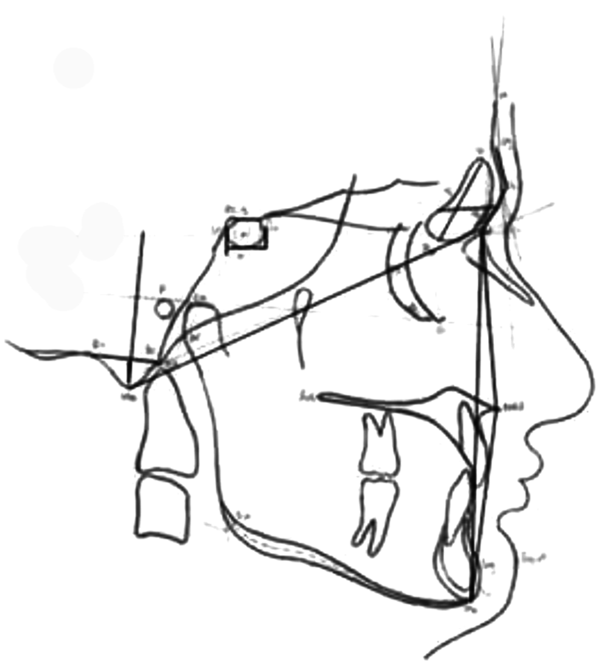
3.1. Statistical Analysis and Results

The data was analyzed employing statistical software SPSS version 16.0. Direct discriminant function analysis applied to calculate specific discriminant function equation for all parameters. It selects the minimum number of traits yielding maximum discriminatory effectiveness. Statistically the mean differences of all the measurements were significant. Mean female values of all linear variables were smaller than the male mean values except ULTc which is larger in females by 0.3 mm while all the angular measurements are smaller in males except GMSN, GMFH, GMBaN, GNGSg and GSGM with the P value 0.000. The result of all the variables are presented in Table 3 (Group Statistics according to sex and in total).Group means and standard deviations with large separations indicating these

Table 2. Angular (°) Cephalometric Variable

Variable	Description
GSgM	Angle between the metopion to supraglabellare line and the supraglabellare to glabella line
GMBaN	Angle between the glabella to metopion line and the basion to nasion line
GMSN	Angle between the glabella to metopion line and the sella to nasion line
GMFH	Angle between the glabella to metopion line and the porion to orbitale line
Ba-N-Me	Angle between basion and nasion and menton
Me-N-ANS	Angle between menton and nasion and anterior nasal spine
S-N-Me	Angle between sella and nasion and menton
SNAr	Angle between SN plane and articulare
GNGSg	Angle between lines glabella-nasion and glabella-supraglabella
GSGM	Angle between lines glabella-sella and glabella-metopion
GS-SN	Angle between lines glabella-sella and sella-nasion
SN-SMa	Angle between lines sella-nasion and sella-mastoidale
GS-GN	Angle between lines glabella-sella and glabella-nasion

Figure 2. Cephalometric Parameters: Linear



I, Ba-ANS; II, Ba – N; III, N – ANS; IV, N – Me; V, Fs – Wd; VI, Fs – Ht; VII, Ma – SN; VIII, Ma – FH; IX, Ma – Ht; X, Ma – wd; XI, ANS – Me; XII, GSgN; XIII, SgGM; XIV, S' – Co'; XV, Sella length; XVI, Sella width; XVII, Sella height anterior; XVIII, Sella height posterior; XIX, ULTc; XX, GPI; XXI, G-SI-PI.

Figure 3. Cephalometric Parameters: Angular

I, GSgM; II, GMBaN; III, GMSN; IV, GMFH; V, Ba-N-Me; VI, Me-N-ANS; VII, S-N-Me; VIII, SNAr; IX, GNGSg; X, GSGM; XI, GS-SN; XII, SN-SMa; XIII, GS-GN.

variables may be good discriminants. Wilks' lambda indicates the significance of the discriminant function. Table 4 (Wilk's Lambda) indicates a highly significant function ($P < .000$) and provides the proportion of total variability not explained, so we have 27.8% unexplained. The resulted canonical discriminant 0.850 showed high correlation between the discriminate function and independent variables. Table 5 Functions at Group Centroids (Unstandardized canonical discriminant functions evaluated at group means) shows male are more associated in classification as compare to females. Females have negative association in classification, Male versus female, 90% and 87% respectively. Table 6 (Box's M Result) Box's M statistics was 1.964 with P value 0.000, shows the sample classification coefficients that compose the discriminant function equation i.e. D = -0.122 (ba-ans) + 0.186 (n-ans + 0.410 (ma-wd). Figure 4 (Histograms of discriminant scores: Male and Figure 5: Female) Histograms of discriminant scores showed that male and female have separate distribution of the data. Classification results in Table 7 (classification results) showed, 91.3% males correctly classified in the data, on the basis of discriminant function we made, similarly, 97.1% females were correctly classified in their specific group by the help of this discriminant function. The percentage of skulls correctly classified with this function was 94.2%.

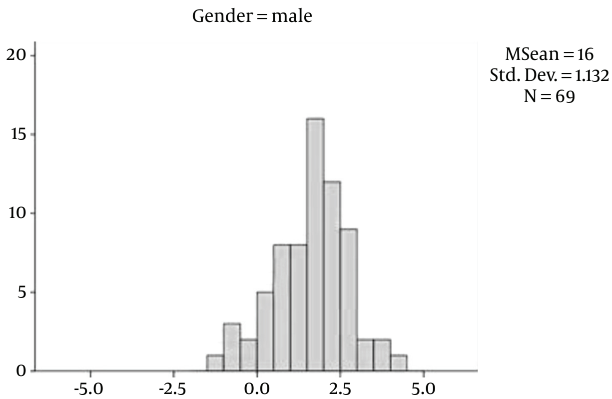


Figure 4. Histograms of Discriminant Scores: Male

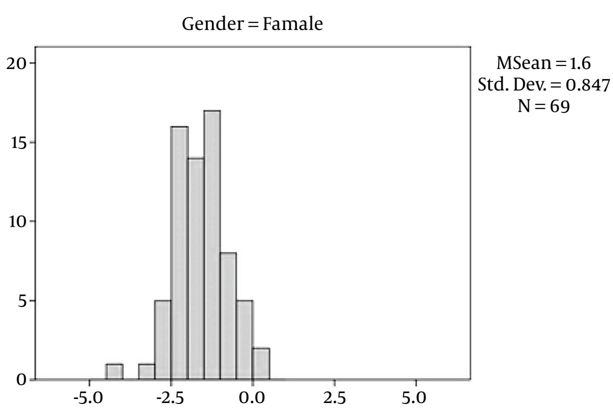


Figure 5. Histograms of Discriminant Scores: Female

5. Discussion

It is common knowledge that men regardless of their ethnicity have a larger stature than women, more robust cranial and facial features, along with greater muscularity, strength, and speed (4). Male tooth size exceeds that of female, pre and Post natal hormonal levels differ, growth rates vary, and diseases affect the sex differentially (5).

Rogers (6) reported although the craniofacial growth pattern among the two sexes is essentially the same, sexual dimorphism observed is the result of early attainment of skeletal maturity in women as compared to men. Further, there is variation in the growth of the different parts of the skull, with sexual differences being best defined in late growing structures of the skull, such as lower facial region, facial depth and mastoid process. On the other hand, cranial base and upper face are middle growing regions in which some sexual differences can be evident, but are not likely to be the most distinctive.

In total anterior face height and upper anterior face height, sex differences were highly significant but extreme typological differences appear to override the growth characteristics that are usually attributed to sexual dimorphism (7).

The mastoid region used in this study, being a part of temporal bone, is recognized as being the most protected and resistant to damage, due to its anatomical position at the base of skull, these findings have been reconfirmed by many authors Kloiber, Weels, Gejval, Spence as cited by Wall and Henke (8).

Results of the present study are consistent with these findings as all the linear measurements were greater in males as compared to females.

Results indicate that, Important size-related variables that were captured by the discriminant analysis were anterior face height, upper face height, frontal sinus height, mastoidale to SN plane, mastoidale to Frankhfort plane, and cranial base length. The derived discriminant functional equation in the present study was 82.0% accurate in differentiating the men and women. Franklin et al. (9) , reported an accuracy of 77 to 80% in sexual discrimination using 8 cephalometric variables. Naikmasur et al. (3), claimed accuracy of 81.5% and 88.2% respectively by comparing the reliability of craniomandibular parameters in South Indian and Indian immigrants of Tibetan population using 11 variables on lateral and frontal cephalograms. Hasio et al. (1), studied 100 lateral cephalograms of Taiwanese origin and claimed 100% accuracy in sex determination using 18 cephalometric parameters.

Results on a French sample, where 95.6% accuracy and was achieved by Veyre-Goulet et al. (10). Bigoni et al. (11), also claimed 99% - 100% correct sex classification on a known sex Central European sample using 3 dimensional coordinates.

The variations in the result in different population may be due to the inconsistency in the position of landmarks of the skull in different populations (12). Craniofacial growth like mastoid region, zygomatic process and the ridges of occipital bone are influenced by nutrition, environment and genetic factors (13).

Lateral radiographs are generally available to forensic anthropologists and, as shown in this and other studies, introduce greater gender discriminating accuracy into forensic practice without the need for expensive equipment or computer programs.

Table 3. Group Statistics According to Sex and in Total

Parameters	Male	Female	Total	P Value
SCo	16.1957 ± 3.82447	15.7971 ± 3.39368	15.9964 ± 3.60783	0.518
GSgN	4.1159 ± 1.29236	2.0870 ± 0.88682	3.1014 ± 1.50202	0.000
SgGM	1.1667 ± 0.65679	0.5580 ± 0.51117	0.8623 ± 0.66114	0.000
BaANS	99.8986 ± 6.95605	94.5942 ± 5.61070	97.2464 ± 6.83573	0.000
BaN	10.954 ± 8.28283	10.130 ± 5.39145	10.542 ± 8.09597	0.000
NANS	63.1739 ± 79.25683	49.8406 ± 3.93186	56.5072 ± 56.30577	0.165
NMe	12.203 ± 10.86409	11.065 ± 7.50260	11.634 ± 10.91406	0.000
FsWd	11.5507 ± 2.98174	9.2319 ± 2.03748	10.3913 ± 2.79777	0.000
FsHt	29.6159 ± 6.12861	26.5797 ± 7.09268	28.0978 ± 6.77745	0.008
MaSN	46.8406 ± 5.48426	41.3768 ± 5.40996	44.1087 ± 6.08058	0.000
MaFH	31.6594 ± 3.81993	28.0725 ± 3.76641	29.8659 ± 4.18615	0.000
MaWd	20.3478 ± 3.00405	18.5362 ± 3.64441	19.4420 ± 3.44936	0.002
MaHt	10.1304 ± 2.26815	8.7536 ± 2.43990	9.4420 ± 2.44656	0.001
ANSMe	70.4928 ± 7.16327	61.7971 ± 5.60352	66.1449 ± 7.75214	0.000
SL	7.6304 ± 1.62619	7.1304 ± 1.58033	7.3804 ± 1.61715	0.069
SW	11.3913 ± 1.47745	11.0870 ± 1.41150	11.2391 ± 1.44765	0.218
SHtPost	8.5870 ± 1.55051	8.4348 ± 1.57628	8.5109 ± 1.55960	0.568
SHtAnt	8.9710 ± 1.58319	8.4783 ± 1.58679	8.7246 ± 1.59844	0.070
GSIPI	1.0146 ± 0.36644	0.8407 ± 0.28523	0.9277 ± 0.33860	0.002
GPI	6.8353 ± 2.34182	3.3757 ± 1.56451	5.1055 ± 2.63648	0.000
ULTc	1.0150 ± 0.25998	1.1611 ± 0.30618	1.0880 ± 0.29232	0.003
GMSN	98.2754 ± 6.48728	89.2754 ± 12.00721	93.7754 ± 10.62295	0.000
GMFH	104.84 ± 5.82748	98.6957 ± 5.94411	101.77 ± 6.62586	0.000
GMBaN	77.5942 ± 5.81913	70.5797 ± 6.12230	74.0870 ± 6.91394	0.000
MSgG	170.33 ± 6.11331	174.04 ± 2.89744	172.19 ± 5.11695	0.000
BaNMe	56.1159 ± 3.82921	64.2319 ± 6.030661	60.1739 ± 4.276722	0.267
NMeANS	9.4348 ± 3.96855	10.2464 ± 3.19653	9.8406 ± 3.61313	0.188
SNMe	76.7391 ± 4.41139	77.0870 ± 4.55599	76.9130 ± 4.47128	0.649
SNAr	123.61 ± 5.67299	124.39 ± 6.39673	124.00 ± 6.03639	0.448
GNGSg	29.3913 ± 7.92097	19.3043 ± 6.90759	24.3478 ± 8.96925	0.000
GSGM	86.8406 ± 5.76660	78.8116 ± 6.03245	82.8261 ± 7.12753	0.000
GSSN	11.3478 ± 2.26109	11.7681 ± 2.40798	11.5580 ± 2.33669	0.292
SNSMa	129.12 ± 5.25395	130.36 ± 5.88610	129.74 ± 5.59367	0.192
SGN	61.0435 ± 5.29271	63.0870 ± 5.24051	62.0652 ± 5.34668	0.024

[a] Values are expressed as mean ± SD.

Table 4. Wilk's Lambda

Test of 1	Wilk's Lambda	Chi-Square	df	P Value
1	0.278	152.320	34	0.000

Table 5. Functions at Group Centroids (Unstandardized Canonical Discriminant Functions Evaluated at Group Means)

Gender	Function 1
Male	1.600
Female	-1.600

5.1. Conclusions

This is an attempt to verify the standard for sex determination based on the lateral cephalometric parameters in Pakistani population. This study was able to attain 94.2% accuracy with thirty four variable model. To obtain higher

Table 6. Box's M Result

Box's M Result	Values
Box's M	1.964
F Approx.	2.428
df1	595
df2	5.585
P Value	0.000

Table 7. Classification Results[a]

Gender (Original)	Group		Total
	Female	Female	
Female	67 (97.1)	2 (2.9)	69 (100.0)
Male	6 (8.7)	63 (91.3)	69 (100.0)

[a] 94.2% of original grouped cases correctly classified.

results further research of the technique with large sample size and both linear and angular cranial dimorphic traits for gender identification is proposed. The proper identification of landmarks, careful measurements and strict statistical methods will yield reliable results and will meet the needs of the forensic investigation in our country.

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