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Craniofacial Dimorphism in Young Jordanian Adults

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Authors' contributions

This work was carried out in collaboration between the both authors. Author WA designed the study, wrote the protocol, performed the statistical analyses and wrote the first draft of the manuscript. Author DO managed the literature searches, analyses of the study and performed the experimental process. The both authors read and approved the final manuscript.

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ABSTRACT

Aims: Was to develop a gender determination technique for young Jordanian adult population.
Study Design: using osteometric data, from Cephalometric images, and discriminate function analysis.
Place and Duration of Study: Section of Clinical Dentistry of the Jordan University Hospital, between October 2013 and July 2014.
Methodology: A total of 146 randomly selected digital lateral cephalometric radiographs of young Jordanian adult patients were employed in the investigation, 47 patients were males and 99 were females. For each lateral cephalometric radiograph, one observer using a customized analysis created in Viewbox 4-Cephalometric Software subroutines digitized 19 craniofacial skeletal landmarks. Utilizing the digitized landmarks, 18 measurements that comprised 14 linear, 3 angular and 1 proportional parameters were carried out.
Results: The results demonstrated that, with the exception of the Menton to Gonion distance, i. e., the length of the mandibular body, the mean values of all other parameters of male subjects were

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statistically significantly larger (p<0.05) than those for females. Mastoid height was found to be the best single predictor of gender and can provide an accuracy rate of 82.2%. Using Stepwise method revealed four dimensions (mastoid height, mastoid width, glabella to supraglabellare-nasion distance, and the length of skull base)were found to form the best combination of parameters most precisely depict the best possible prediction, raising the classification accuracy up to 87.7%.
Conclusion: A discriminant function equation specific for Jordanian population has also been derived from cranio-mandibular variables. The equation can now be used for a calculable and more precise prediction of gender of Jordanian young adult population.

Keywords: Sex determination; mastoid process; cranio-mandibular; discriminant analysis; craniometry.

1. INTRODUCTION

Identification of human gender from skeletal remains or radiographs presents a major challenge in the field of forensic medicine and physical anthropology. Following wide scale drastic events such as natural disasters, outbreak of wars or air traffic accidents, positive identification of victims' gender becomes, perhaps, the most difficult task to encounter. Extreme burns, disfigurement and severe decomposition of bodies render the determination of gender by examination of remains and their radiographs nearly impossible. A major role in gender identification, however, could be played by the osteological criteria that may set the foundation for full identification. Human skeleton is comprised of calcified hard tissue that may sustain severe conditions yet retain important features that may lead to valuable information [1]. The dimorphic variations of gender develop during the intrauterine life and later manifest as differences in bone weight, length, size, and mineral density. There are certain factors such as growth pattern and spurts, as well as the muscular attachments to the bones that could play a significant role in dimorphic features and have a direct bearing on gender differentiation [2]. Skeletal gender identification relies on dimorphic expression of boney characteristics produced through different pattern, rates and period of adolescent growth [1]. Males having both a longer and more intense growth bouts than females, therefore this extended growth pattern creates differences in size, classically seen in skull, where the growth spurts affect most structures [3].

The secondary sexual changes are influenced by hormones, which play role in development of musculoskeletal system [4]. These changes emerge at adolescence are seen earlier and for a shorter period in girls compared to boys who undergo pubertal changes 2-3 years later, but sustain them for a longer period. Various bones are used as tools in sexual dimorphism, most commonly pelvis and skull [5]. Development of cranium is influenced by the growth of neurocranium. Cranial characteristics such as larger male brow ridges, eyes appearing lower in the face, and larger nasal apparatus, are results of extended normal downward and forward growth of the male face relative to the female face. This is due to more intense and extended male growth spurts. The growth of female facial features begins to show around 13th years of life and maturation is completed soon afterward, while males enter a growth spurt that continues through adolescence with maturation completed in early adulthood [6]. Reported findings of past investigations carried out on different countries 'populations: Indians [7], French [8,9], Cretans [10], South African blacks [11-13], South African whites [14], Indonesians [15], Chileans [16], Koreans [17], Japanese [18], Chinese [19], and Egyptians [20] all pointed to the validity of osteometric measurements of cranio-mandibular skeletons and emphasized their role as reliable gender identifiers. It has been stressed, however, that the morphometric features of these skeletons could be subject to ethnic variations.

1.1 The Present Study

The present investigation aimed, firstly, to trace and measure a number of selected cranio-mandibular parameters on lateral Cephalograms of Jordanian subjects, using "view Box" orthodontic software. Secondly, to assess the reliability of those parameters in determining the gender of the study subjects with the help of discriminant function analysis.

2. MATERIALS AND METHODS

The present study was carried out on a representative sample comprising 146 randomly selected digital lateral cephalometric radiographs of young Jordanian adult patients, who attended the clinics of the dental department of the Jordan University Hospital (JUH). The average age of the patients who formed the sample was 20 years and ranged between 13 to 27 years. The lower limit of the age range was set at or above the age of puberty based on Krogman's proposition which stated that "the cranio-mandibular parameters are age phenomena appearing or becoming pronounced at puberty, hence sex determination below this age range may show high variation [1]. Of the total sample, 47 patients were males and 99 were females. The exclusion criteria used in selecting the test sample involved excluding patients with a history of previous orthodontic or orthognathic treatment, OPT images that showed artifacts preventing proper landmark determination and images of poor resolution.

Prior to conducting the investigation, and in compliance with the policy of the Clinical Research Authority at the JUH, signed written informed consents were obtained from all the subjects selected for the study. All subjects were made aware that their lateral cephalogram images were included in the investigation. The experimental protocol was examined and approved by the Ethics Committee and was, therefore, performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki, last edited in 2013 [21].

The Dental department at the JUH uses a computerized Kodak Dental Imaging system (Kodak laboratories, Rochester, NY, USA). The processed lateral Cephalometric radiographs were saved into the computer as "Joint Photographic Experts Group" (JPEG) format.

For each lateral cephalometric radiograph 19 craniofacial skeletal landmarks were digitized (Table 1 and Fig. 1) by one observer using a customized analysis created in Viewbox 4-Cephalometric Software (dHAL software, Kifissia, Greece). Utilizing the selected and digitized landmarks, measurements that comprised 14 linear (Fig. 2), 3 angular (Fig. 3) and 1 proportional parameters were carried out (Table 2).

Table 1. The cephalometric landmarks employed in the present investigation

Name	Abbreviation	Description
Metopion	M	Point where the line that connects the highest points of the frontal eminences crosses the sagittal plane
Supraglabellare	Sg	Most posterior midline point in the supraglabellar fossa, the concavity between glabella and metopion.
Glabella	G	Most anterior point in the midsagittal plane between the superciliary arches.
Nasion	N	Most anterior point on the fronto-nasal suture in the midsagittal plane.
V1		Upper parameter of the frontal sinus cavity.
V2		Lower parameter of the frontal sinus cavity.
H1		Anterior parameter of the frontal sinus cavity on bregma to nasion line, the line from the inner location of bregma to nasion.
H2		Posterior parameter of the frontal sinus cavity on bregma to nasion line.
Sella	S	Midpoint of sella turcica, hypophyseal fossa.
Orbitale	Or	Lowest point on the lower margin of the bony orbit.
Porion	Po	Top of the external auditory meatus.
Basion	Ba	Most inferior posterior point in the sagittal plane on the anterior rim of the foramen magnum.
Mastoidale	Ma	Lowest point of the mastoid process.
B1		Anterior parameter of the mastoidale width at the level of cranial base.
B2		Posterior parameter of the mastoidale width at the level of cranial base.
Menton	Mb	The lowest point on the symphyseal shadow of the mandible seen on a lateral cephalogram.
Gonion	Go	A point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.
Articulare	Ar	A point at the junction of the posterior border of the ramus and the inferior border of the posterior cranial base (occipital bone).
Anterior nasal spine	ANS	The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

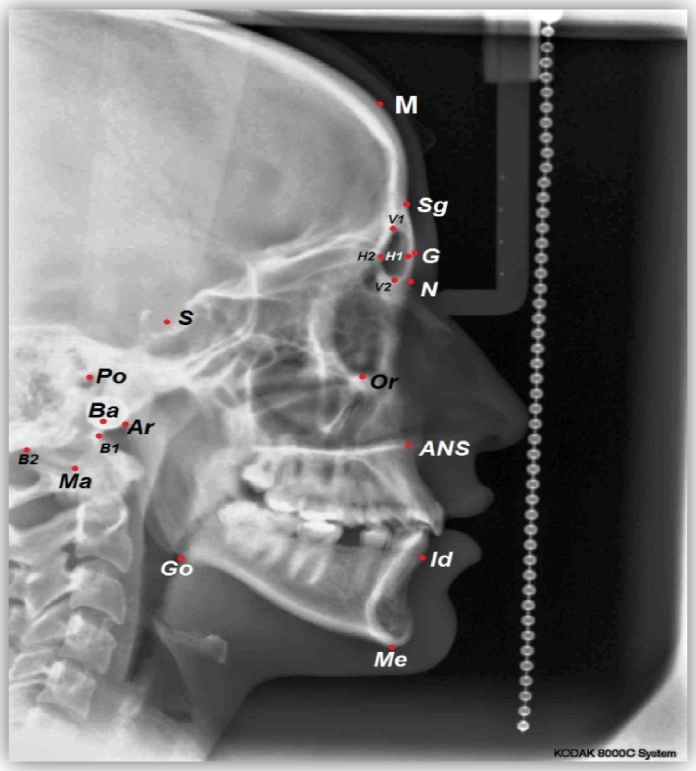

Fig. 1. A cephalometric radiograph illustrating the landmarks defined in Table-1

Table 2. The cephalometric parameters employed in the present study

Parameter	Description	
Linear measurements		
Ba-ANS	Basion to anterior nasal spine.	Depth of face.
Ba-N	Basion to nasion.	Length of skull base.
N-ANS	Nasion to anterior nasal spine.	Height of upper face.
ANS-Me	Anterior nasal spine to menton.	Height of lower face.
N-Me	Nasion to menton.	Anterior height of face.
Id-Me	Infradentale to menton.	Height of mandibular symphasis.
Ar-Go	Articular to gonion.	Height of mandibular ramus.
Me-Go	Menton to gonion.	Length of mandibular body.
FSHt	V1 to v2.	Frontal sinus height.
FSWd	H1 to h2.	Frontal sinus width.
MHt	Mastoidale to b1-b2.	Mastoid height.
MWd	B1 to b2.	Mastoid width.
Sg-N	Supraglabellar to nasion.	
GSg-N	Glabella to sg-n. (distance between glabella and the supraglabellare to nasion line)	
Angular measurements		
GM-BaN	Glabella-metopion to basion –nasion.	
GM-SN	Glabella-metopion to sella-nasion.	
GM-FH	Glabella-metopion to frankfort plane (porion –orbitale).	
Proportional		
GPI	GSgN/Sg-N * 100%	Glabella projection index.

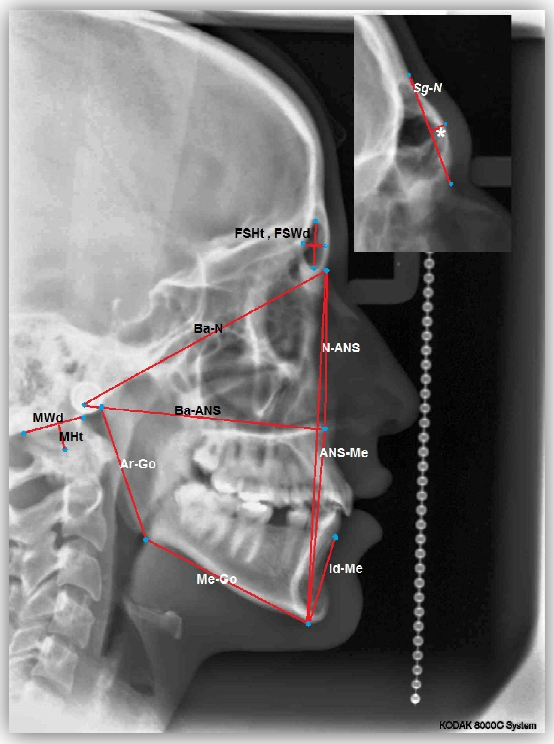

Fig. 2. A cephalometric radiograph illustrating the linear measurements defined in Table-2. *(GSgN)

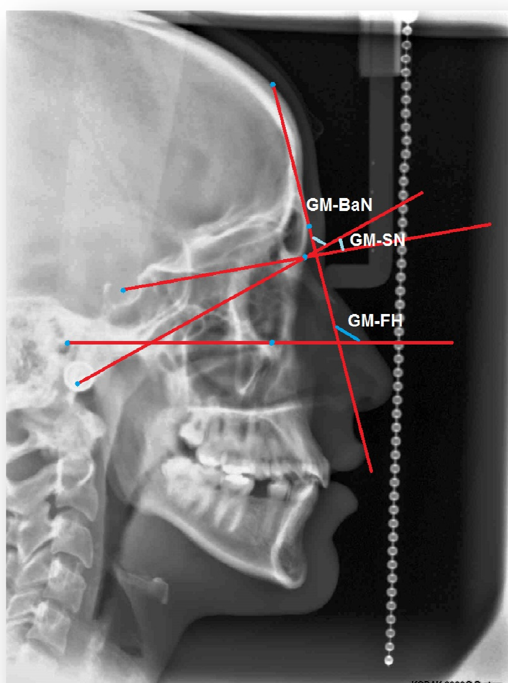

Fig. 3. A cephalometric radiograph illustrating the angular measurements defined in Table 2

In order to eliminate the possibility of inter-observer variations which, sometimes, arise in similar studies, measurements of all parameters of the entire sample were carried out by the same observer [DAO].

2.1 Statistical Treatment

All 18 measurements from each radiograph processed by Viewbox 4 -Cephalometric Software were transferred and organized according to gender that was represented by the binary variables, “1” for males and “2” for females. Of the entire sample, cephalograms of 10 randomly selected subjects were analyzed twice, separated by two weeks, by the same observer. Data sets of the two observations were statistically treated using a *paired t-test* to check for intra-observer variation. The inequality in sample size of the two investigated groups was treated using the method suggested by Peter Sanchez, 1974 [22]. This method adjusted the groups’ sizes beforehand and therefore permitted effective application of the proportional chance criterion under a wider range of circumstances. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 15.0. Data analysis was carried out by canonical discriminant function analysis to find linear combinations of those parameters that best separate the two genders. In order to select the combination of parameters that best discriminate the two genders, stepwise discriminant function analysis was used (utilizing the Wilks lambda method). A leave one out classification procedure was applied to demonstrate the accuracy rate of the original sample as well as that which resulted by cross validation, this method was used to reduce the overestimate of the predictive values.

3. RESULTS

The results of the paired *t*-test that was carried out to check the intra-observer variations indicated no statistically significant difference existed between measurements ($p>0.05$) recorded at two different occasions ($t=0.932$ for males and $t=0.937$ for females). The Descriptive statistics of all parameters of the sample indicated significant difference between sexes ($p<0.05$) except for two parameters, namely, the (Me-Go) and (FSWd) (Table 3). When the discriminant function analysis compares between two groups, as in the present investigation whereby the comparison was made between males and female, the value of the univariate *F*, presented in Table 3, equals to the squared “*t”* value. The results demonstrated that, with exception of the “Me-Go” parameter, the means of all other parameters for male subjects were larger than those for females (Table 3).

In this model, the mastoid height “MHt” was found to be the best single predictor of gender with a prediction accuracy of 82.2%. Whereas, four parameters: the mastoid height “MHt”, the mastoid width “MWd”, the glabella and the supraglabellare to nasion line distance “GSgN” and the basion to nasion distance “Ba-N” were found to form the best combination of parameters most precisely depicts the best possible prediction. The contribution fraction of the four discriminant parameters to gender determination is illustrated in Fig.4.

The discriminant function predictive equation derived from the coefficients of the four best predictors selected by the stepwise analysis (Table 4) was:

$$DF = 0.6904 * MHt + 0.4378 * MWd + 0.3789 * Ba\text{-}N + 0.3306 * GSgN.$$

Where the group centroid discriminant score for males was equal to 1.297 and for females was -0.616, as were indicated by the discriminant analysis. The sectioning point was equal to 0.3405, which was calculated by following equation:

Cut Score = [1.297+ (-0.616)] / 2 = 0.3405.

Accordingly, when a DF score is above the sectioning point; the subject being investigated is probably a male whereas, scores below that are likely to indicate female subjects.

Values of the predictive accuracies resulted from direct discriminant analysis and leave one out classification in different models, where combinations of parameters at a time were used; all parameters, angular; linear; proportional; and stepwise resulted models are summarized in Table 5.

Table 3. Depictingmeans, standard deviations, Wilks' Lambda and univariate F values of all parameters; and indicating the classification accuracy of each parameter

Parameter	Male N=47		Female N=99		Tests of equality of group means			Classification accuracy %
	Mean	SD	Mean	SD	Wilks' Lambda	F	Sig.	
Linear measurements , (mm) :								
Sg-N	40.34	5.67	37.77	5.15	0.95	7.42	0.007	71.2
N- Me	152.98	9.09	145.85	8.36	0.87	21.87	0.000	72.6
N –ANS	65.31	4.69	62.91	4.26	0.94	9.5	0.002	70.5
MWd	29.56	3.4	26.17	3.89	0.85	26.07	0.000	69.9
MHt	17.84	4.34	10.52	3.04	0.51	138.73	0.000	82.2
Me – Go	89.8	6.33	90.22	6.8	1.00	0.13	0.722	67.8
Id-Me	41.72	3.67	39.24	3.78	0.91	13.94	0.000	70.5
GSgN	4.26	1.63	3.08	1.15	0.85	25.16	0.000	71.2
FSWd	31.95	8.18	30.56	7.47	0.99	1.04	0.310	67.8
FSHt	13.23	4.00	11.07	2.74	0.91	14.49	0.000	73.3
Ba-ANS	115.65	7.36	112.18	7.35	0.95	7.09	0.009	67.1
Ba –N	129.62	7.98	123.63	7.25	0.88	20.38	0.000	70.5
Ar-Go	56.12	8.43	52.46	5.35	0.93	10.14	0.002	70.5
ANS-Me	88.67	7.08	83.85	6.96	0.9	15.13	0.000	69.2
Angular measurements , (°):								
GM-SN	97.85	7.04	94.37	4.94	0.92	11.86	0.001	72.6
GM-FH	105.86	6.09	102.39	5.21	0.92	12.65	0.001	70.5
GM-BaN	79.31	6.35	76.7	4.68	0.95	7.82	0.006	71.2
Proportional, (%):								
GPI	10.43	3.29	8.07	2.53	0.86	22.72	0.000	69.9

**Degrees of freedom =1 and 144. *Significance level considered: p<0.05*

Table 4. The outcome of the stepwise discriminant analysis indicating the parameters and their corresponding standardized coefficients which entered the discriminant equation

Parameter	Coefficient
MWd	0.4378
MHt	0.6904
GSgN	0.3306
Ba-N	0.3789

Values of the predictive accuracy of the different models (Table 5) showed that two models, namely the all parameters and the all linear measurement parameter demonstrated the same overall cross-validated sexing accuracy (85.6%). This accuracy was found only marginally improved by the step-wise method (87.0%) which affected a small increase in the overall sexing accuracy of 1.61%. The all angular measurement parameter as well as the proportional parameter models both demonstrated lower overall sexing accuracies after cross validation, with the former parameter showing a 70.5% and the latter showing a 69.9%.

Despite the variations among models in the value of the overall cross validated accuracy, they all demonstrated a sex bias accuracy towards the female group. The different models varied in the degree of bias they demonstrated in favor of the female group, with the all parameters as well as the all linear parameters; the angular; the proportional; and the step-wise method models showed bias of 21.3%; 77.3%; 69.2%; and 23.0%, respectively.

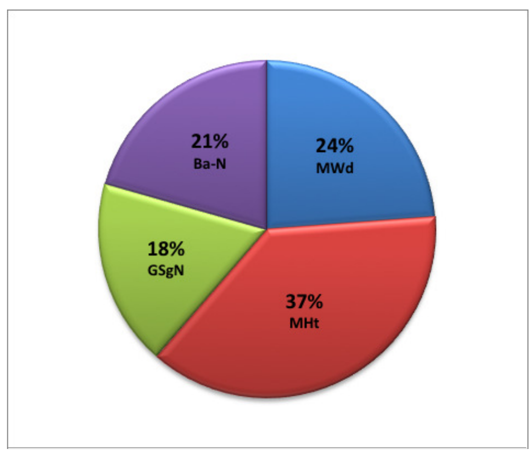

Fig. 4. The contribution fraction of the discriminant parameters to gender determination

Table 5. Classification accuracy of discriminant functions applied to parameters measured on lateral cephalogram of Jordanian young adults

Model	Classification accuracy %	Cross validated %	Classification Accuracy %		cross validated %	
			Male	Female	Male	Female
All parameters	89.7	85.6	80.9	93.9	72.3	91.9
All angular parameters	71.9	70.5	25.5	93.9	21.3	93.9
All linear parameters	87.7	85.6	78.7	91.9	72.3	91.9
Proportional parameter	69.9	69.9	27.7	89.9	27.7	89.9
Step-wise model	87.7	87.0	74.5	93.9	72.3	93.9

4. DISCUSSION

Gender identification of humans from skeletal remains or their radiographic images can be of a high accuracy if a complete skeleton was available for analysis. Since availability of an intact skeleton is unlikely, it becomes essential that a set of identifiers or predictors for each bone to be developed utilizing the morphological variables of each bone [8]. Different methods of evaluation of skull bones for dimorphism were reported to the literature. These involved a method of visual assessment of morphology, which is condemned of being a highly subjective method, thus, could not be employed in investigations conducted by more than one examiner due to inter-observer variations. In addition, the method may not be suitable for studies that involve cosmopolitan societies because of the considerable inter-population or ethnic and inter-racial differences in the skeletal bones morphology.

More accurate methods that depend on measurements and morphometry like cephalometry were advocated for use in determination of gender from skulls [7]. Despite the fact that morphometric traits are more objective, a random set of measurements may not invariably be conclusive but such a data requires rigorous statistical treatment using an appropriate technique. The most suitable and widely used statistical tool has been multivariate discriminant analysis of sex determination for skeletal measurements. The advantage of using the discriminant function analysis in association with the morphometric trait measurements is that this method of analysis classifies individuals into two or more alternative groups, in the present study the subjects were classified into male and female groups, on the bases of set measurements [19]. The method identifies which variables contribute to making the classification, thus it serves as an entirely objective statistical technique for sex determination [19]. It has been emphasized that combining the two approaches, i. e., the morphometric trait measurement and the discriminant function analysis improves accuracy as the two methods complement each other [23,24].

Lateral cephalometric radiographic images of the study subjects were used as they are more objective, standardized and reproducible [9]. This radiographic method describes the three-dimensional characters of the skull on a roentgenogram that presents a two dimensional image. Thus the morphometric traits of the cranio-mandibular superstructures and intracranial structures can be easily assessed [19].

It has been reported that the most indicative regions of the skull in terms of sexual dimorphism are the frontal regions and base of the skull which are likely to be preserved during mass disasters [1,9,19]. Accordingly, the present investigation involved cranio-mandibular traits, and all measurements made on lateral cephalometric images of our Jordanian sample. The 18 variables that were analyzed in the present study were equal to the number of variables employed in two previous reports [9, 19] and more than those adopted by Patil and Mody [19] who evaluated 10 variables; and more than those used by Barthelemy et al. [8] who analyzed only 7 variables. Obviously, the more the number of the investigated variables means more elaborate analyses are conducted which give rise to more precise and accurate outcomes.

Univariate descriptive statistics showed all the parameters except the length of the body of the mandible (Me-Go) contributed in determination of sex. The mastoid height (MHt) was found to be the best single predictor of gender with a prediction accuracy of 82.2%. The mastoid height (MHt), in addition to the mastoid width (MWd), the distance from glabella and the midpoint between supraglabellare to nasion (GSg-N) and the length of skull base (Ba-N) entered the discriminant function predictive equation of the Jordanian population.

The results showed that the mean values of all parameters except the width of the frontal sinus (FSWd) and the length of mandibular body (Me-Go) were higher in males compared to females in the range of 3.0-41.03%. These findings supported those reported by other investigators; Funayama et al. [18] found that male skulls are 8.5% larger than female skulls; other researchers [9,24] also showed that the linear dimensions of male skulls were generally greater than the corresponding measurements in female skulls. Hsiao et al. [19] reported that the mean male linear dimensions as well as proportional measurements were greater than those in females.

Mastoid height entered the discriminant predictive function and was a significant factor in sexual dimorphism. Several studies have shown that mastoid height is a consistently reliable parameter in both morphometric and cephalometric studies irrespective of the population evaluated [1,14,8,19]. An increase in mastoid height reflects growth at the base of the skull which affects an increase in the size of the mastoid bony process. Extended growth in male gives rise to an increase in mastoid size. Moreover, the relatively more vigorous musculature in males than in females, particularly the stronger sternocleidomastoids may contribute to the downward prolapse of the male mastoids more than the corresponding structures in the female. This explains why males have definitely larger mastoid height and more robust skull.

In this study the parameter that measured the length of skull base or cranium (Ba-N) entered the specific discriminant function, which correctly sexed 87.0% of young Jordanians.

The overall cross-validated accuracy for the Jordanian population was 85.6% which was improved to 87.0% by the step-wise method. This is comparable with the accuracy of 87.39% reported by Barthelemy et al. [8] in their survey on South-West France population using mandibular dimorphism. However, the accuracy arrived at in this investigation was less than the 100% accuracy reported by Hsiao et al. [19] who carried out their investigation on Taiwanese population using lateral cephalograms of cranial traits. The reason for the lesser accuracy may be ascribed to the use of different cephalometric parameters in the determination of gender. In general, the differences in the overall accuracy reported by different researchers could be attributed to the fact that the discriminant function equations are population specific and probably sensitive to ethnic and racial variations.

5. CONCLUSION

A specific discriminant function equation was created for young Jordanian adults from 18 established cephalometric craniomandibular variables. A total of 146 cases were classified into two sexual groups with 87% accuracy. Among the 18 variables, the mastoid height "MHt" alone showed the greatest efficiency as a single discriminator, with 82.2% accuracy. It was possible to determine the sex of the sample with 73.5% accuracy with four variables (MHt, MWd, Ba-N and GSgN). With the exception of the frontal sinus width and the mandibular body length, the mean values of all parameters were 3 - 41% higher in males than in females.

CONSENT

All patients were made aware that their radiographs were selected for inclusion in the present investigation. Accordingly, they all signed written informed consents in compliance with the policy of the Clinical Research Authority at the JUH.

ETHICAL APPROVAL

Written consent was obtained from all subjects who were made aware that their cephalogram images are going to be included in the study before the investigation started. The local ethics committee approved the study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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