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Sexual Dimorphism of Selected Mandibular Anthropometric Parameters in Saudi Population Sample: Application in Forensic Identification

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Abstract One of the known problems in forensic medicine is identification and sex determination which is in need of knowledge and expertise in many fields. In generating the biological profile of human remains, sex is a factor of primary significance. In cases where intact skull is not found, the mandible may play a vital role in sex determination as it is the most dimorphic bone of skull. It is well known fact that skeletal structures vary among different populations and that each therefore needs its own specific standards of assessment to optimize the accuracy of identification. The current study focuses on sexual identification from mandibular bone in Saudi sample population. The study comprised 80 Saudi persons (40 males and 40 females) their age ranged from (20-55 years) visited the Radiological Department in Elite Private Hospital in Riyadh City in Saudi Arabia Kingdom. All cases were submitted to three-dimensional (3D) Computed Tomography. All the participants' skulls were examined and six mandibular measurements were described, four of them (Mandible angle, Mandibular base length, Ramus length and Minimum ramus breadth) were measured from the lateral reconstruction 3D CT image and two measurements (Bigonial breadth and Bicondylar breadth) from axial posterior reconstruction 3D CT image. In all the studied measurements, male mandibles were found to have significantly higher values compared to female mandibles. By comparison the mean values of the studied six mandibular measurements between males and females, the results revealed that there are four mandibular measurements considered as final predictors of sex determination which are (mandible angle, mandibular base length, ramus length and the bicondylar length). The overall predictive accuracy of this prediction model was 84.95% for the whole studied group and it could correctly identify males in 84.7% and females in 85.2% cases. The study concluded that sex can be determined by using mandible dimensions with relatively high accuracy and mandible is a suitable bone for forensic analysis.

Keywords Mandible, Sexual dimorphism, CT scan, Saudi population

Introduction

Skeletonized remains are very commonly recovered in crime scenes and mass graves requiring a careful examination for assessing the individual identity (Papaioannou et al., 2012). The cadavers sent to forensic pathology centers to determine their identity are not always intact. Therefore, sometimes in case of plane crashes, natural disasters, explosions and mutilated bodies only skeletal remains or some parts of the human body are available for age, sex and race identification (Akhlaghi et al., 2012). Amongst the millions of human beings living on the earth no two persons are alike in all their measurable characters. Sex determination from unknown human skeletal remains or decomposed bodies is an important initial step in forensic investigation (Puttabanthi et al., 2012). One of the known problems in forensic medicine is identification and sex determination which is in need of knowledge and expertise in many fields (Franklin et al., 2007). The determination of sex from a skeleton is a forensic medicine priority, methods for sex assessment are based on the existence of morphoscopic features in the skeleton that manifest differently according to sex or statistical differences in skeletal measurements (Iscan 2005). Sex of an unknown individual can be determined based on the data from the morphology and metric features of bones (Vinay et al., 2013). Sexual dimorphism in the human skeleton is expressed both as differences in morphology as well as in size, with male bones being larger in general, than female ones (Bass 2005). Accuracy in sexing increases with the number of component bones available and with combination of

different parameters in different bones; so many studies have been conducted in forensic anthropology examining for example several cephalo-facial characteristics (Patil and Mody 2005). In cases where intact skull is not found, mandible may play a vital role in sex determination as it is the most dimorphic bone of skull (Duric et al., 2005). The mandible is the largest and strongest bone of the face, therefore in comparison to other facial bones, it remains for a longer time and has slower degradation rate (Puisoru et al., 2006). Recent literature attributed that there is a sexual dimorphism of the mandible with high accuracy of 86.1% (Gamba et al., 2014). Since methods for skeletal identification have a long history in physical and forensic anthropology, many literatures demonstrate that new anthropometric methods are constantly being developed. The introduction of new technologies in the field of dental radiology has made it possible for the clinician to more accurately evaluate dental structures. In recent years, cone-beam computed tomography (CT) units have gained considerable importance, and a series of units have been developed for the 3-dimensional (3D) assessment of the dento-facial region (Liu et al., 2008). It is well known fact that skeletal structures are vary among different populations and each of them needs its own specific standards of assessment to optimize the accuracy of identification (Iscan et al., 1995). Yet, there is no available specific data for sex assessment in Arab Countries (Kharoshah et al 2010) till date, sexual determination of Saudi skull has never been studied and the standard determination of sex from mandible in Saudi population using metric analysis has not been reported. The current study focuses on sexual identification from mandibular bone which is under reported in Saudi Arabian literatures.

Subjects and methods

Study sample

According to standard ethics drawn by the King Saud University Ethical Committee for human researches and after obtaining their approval, the study comprised 80 Saudi persons (40 males and 40 females) their age ranged from (20-55 years) were collected from Radiological Department in Elite Private Hospital in Riyadh City in Saudi Arabia Kingdom after obtaining the Radiological Department head's approval. After the purpose and procedure of this study had been explained to the participants, their verbal informed consent was obtained and a full history was taken from each case and all pathological, fractured, congenital and pathological deformed or mal-union mandibles were excluded after referral to the corresponding clinic for further investigations and management. Subjects should be apparently clinically free from any endocrinal, nutritional or disorders that may affect skeleton and have no history of orthodontic or maxillofacial surgery. Non Saudi origin subjects and pregnant women were excluded from the study.

Preparation of the patient

The patient asked to wear a comfortable gown and removing the metal objects prior to the exam also not to eat or drink anything for several hours before the scan.

Image acquisition

All cases were submitted to three-dimensional (3D) Computed Tomography (CT) system (ECLOS) by Hitachi Medical Corporation (Tokyo-Japan) Q2E-BW1400-2 with the following parameters: Tube voltage of 120Kv, an effective tube current of 105.0 mAs and beam collimation was 10 ×0.625 mm. All mandible 3D CT scans were acquired with a 512 × 512 mm matrix with scanner parameters in 18 combinations of reconstruction algorithm, field of view (FOV) 14×14, slice thickness as of either1.25 mm or 2.5 mm, inter-scan spacing 2mm and gantry rotation time 1.9s.

3D CT measurement

All the participants' skulls were examined after positioning on the CT examination table lying flat on one's back and six mandibular measurements were described, four of them No. (1, 2, 3, 4) were measured from the lateral reconstruction 3D CT image (figure 1) and two measurements No. (5& 6) from axial posterior reconstruction 3D CT image (figure 2) according to Krogman and Iscan 1986 description (table: 1).

Table 1: List of linear and angular mandibular measurements with definitions

The measurement	Description
1- Mandible angle (Gonion)	Intersection of planes of the ramus and the mandibular base.
2- Mandibular base length	Summed distance between gonion, mental foramen-base and gnathion.
3- Ramus length	Straight, linear distance between the condyle superior and gonion.
4- Minimum ramus breadth	Smallest anterior-posterior diameter of the ramus.
5- Bigonial breadth	Distance between two gonion.
6- Bicondylar breadth	Distance between two condylion.

Figure 1: The lateral reconstruction three dimensional computed tomography (3D CT) image of skull showing the studied four measurements of the mandible. A, Condylion; B, Gonion; C, Gnathion; BC, Mandibular base length; AB, Ramus length; D, Minimum ramus breadth.

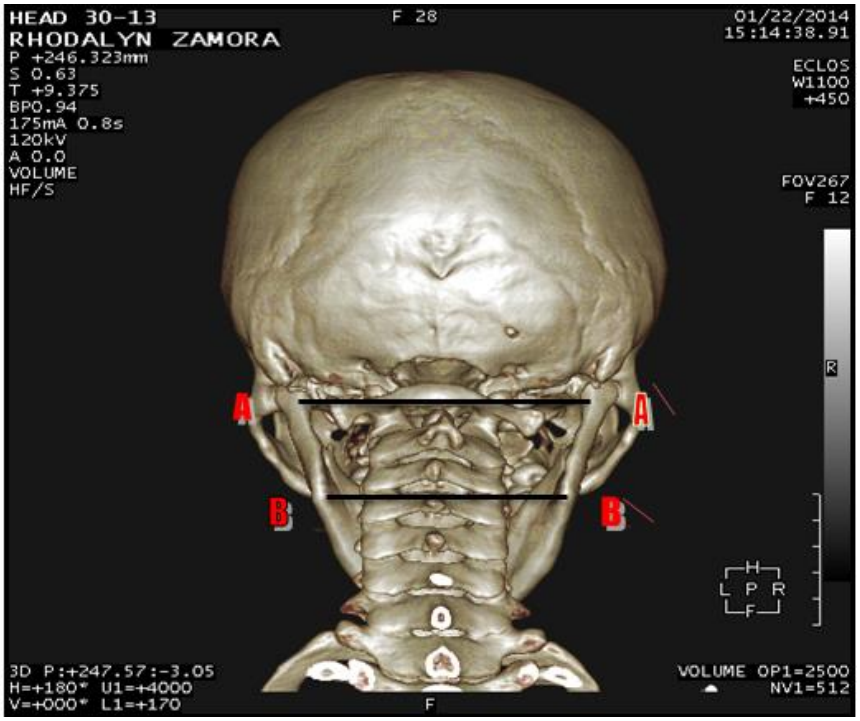

Figure 2: The axial posterior reconstruction three dimensional computed tomography (3D CT) image of skull showing the studied two measurements of the mandible. AA\, Bicondylar breadth; BB\, Bigonial breadth.

Statistical analysis

Collected data were subjected to statistical analysis using SPSS 16 program (SPSS Inc., Chicago, IL). All descriptive measures for all continuous data were entered into stepwise discriminant function procedure using Wilks' lambda, to determine which continuous variable provided the best discrimination between male and female. The discriminant analysis with the stepwise feature is being used to choose the most discriminatory variables (Vodanovic et al., 2006).

Results

Table (2) showed that male mandibles were found to have significant higher values compared to female mandibles in all the studied parameters. By comparison, the mean values of the studied six mandibular measurements between the studied groups of males and females, the results showed that the mean values of the measurements of mandible angle (gonion) in males (122.7 ± 4.2°) were significantly greater than those in females (121.4 ± 3.7°) and the mandibular

base length mean values in males (81.76 ± 1.44) were significantly lower than those in females (86.7 ± 1.1), and ramus length mean values in males (60.61 ± 5.31) were significantly higher than females (54.46 ± 4.46). Also, the mean values of bicondylar breadth in males (113.7 ± 5.4) is significantly higher than females (108.3 ± 7.1). In addition, the mean values of the minimum ramus breadth and bigonial breadth were statistically not significant between male and female samples.

Table (3) revealed that there are four mandibular measurements as final predictors of sex determination which are (mandible angle with wilks' lambda value 0.28 and F value 6.22, mandibular base length with lambda value 0.334 and F value 50.521 , ramus length with wilks' lambda value 0.411 and F value 46.65 and bicondylar breadth with wilks' lambda value 0.554 and F value 18.53) which implied high predictability with $p < 0.0001$.

Table (4) showed that the overall predictive accuracy of this prediction model was 84.95% for the whole studied group and it could correctly identify males in 84.7% and females in 85.2% cases (Table 4).

Table 2: Student's "t" test statistical analysis of the six mandibular measurements in the studied groups

Variable	Sex	Mean±SD	T-value	p-value
Mandible angle (Gonion) (mm)	M F	122.7±4.2 121.4±3.7	3.36	<0.0001
Mandibular base length (mm)	M F	81.76±1.44 86.7 ±1.1	3.58	<0.0001
Ramus length (mm)	M F	60.61 ±5.31 54.46 ±4.46	3.48	<0.005
Minimum ramus breadth (mm)	M F	32.2 ±2.91 30.67 ±1.97	0.377	>0.05
Bigonial breadth (mm)	M F	94.5 ±5.3 90.4 ±7.4	0.737	>0.05
Bicondylar breadth (mm)	M F	113.7 ±5.4 108.3 ±7.1	3.36	<0.0001

P > 0.05: non-significant; P < 0.05: significant

Table 3: Wilks' lambda test of the six mandibular measurements in the studied groups

Variable	Wilks' lambda	F-ratio
Mandible angle (Gonion)	0.28*	6.22
Mandibular base length	0.334*	50.51
Ramus length	0.411*	46.65
Minimum ramus breadth	0.664●	70.51
Bigonial breadth	0.774●	59.71
Bicondylar breadth	0.554*	18.53

** values close to zero implies high predictability;*
● values closer to one implies low predictability

Table 4: Stepwise discriminant analysis in classification matrix for males and females in the studied groups

Sex	N	Accuracy	
		(Correct) true positive (%)	(Incorrect) false negative (%)
M	40	84.7	15.3
F	40	85.2	14.8

Discussion

It is well established that discriminant function derived from one specific population cannot be applied to another as magnitude of sex-related differences vary significantly among regional population (Rosing et al., 2008) so, there is always a need to develop population-specific standards for accurate sex determination from a skeleton deriving from that population. Hence, standards have been developed for different population worldwide. When skeleton sex determination is considered, metric analyses are often found to be of superior values owing to their objectivity, accuracy, reproducibility, and lower level of inter-and intra-observer errors, in comparison with descriptive traits (Kemkes and Gobel 2006).

The present study revealed that in all the studied parameters, male mandibles were found to have higher significant values compared to female mandibles. This result may be attributed to that the maturation rate and growth pattern differs in male and female as skeletal maturity occurs earlier in females than males. Therefore, sexual difference may manifest themselves in the skull and mandible of females earlier than in the later and longer maturing males (Hu et al., 2006). By using traditional multivariate, different levels of sexing accuracy for the adult mandible are

reported in the literature, the present results revealed that the overall predictive accuracy of the prediction model was 84.95% for the whole studied group and it could correctly identify males in 84.7% and females in 85.2% cases. Generally, the percentage accuracy in the present study is comparable to that for other studies. In a study on mandible of some Egyptian population the study concluded that the overall predictive accuracy of prediction model was 83.6% in males and 84.2% in females (Kharoshah et al., 2010).The present results agree with Steyn and Iscan results which reported 81.5% accuracy in white South African sample. This study similarly affirms that the adult mandible can be used to discriminate sex with a high degree of expected accuracy in both population examined the figure was around 87% (Steyn and Iscan 1998). In another study evaluating the accuracy of sexual dimorphism in the cranium and mandible on Thailand using Krogman's cranioscopy, a very high accuracy of 95.5% for males and 82.9% for females with overall accuracy of 91.1% was detected (Sangvichien et al 2008) which is extremely varied from the present results. Iscan et al., (1995) found accuracies of 84.1% for cranium and mandible study versus 83.7% for cranium only in Japanese skull. It is interesting to note that, the present results revealed that from the six studied mandibular measurements, four of them showed statistically significant difference. These are the mandible angle, the mandibular base length, ramus length and the bicondylar breadth. In addition, the mean values of the minimum ramus breadth and bigonial breadth were higher in males than females but both are statistically non-significant. The previous results are in accordance with the results of the study on Egyptian population which concluded that from the studied mandibular measurements, three of them showed statistically higher significant in males than females which are: bicondylar breadth, gonial angle and minimum ramus breadth (Kharoshah et al., 2010). In a study on South African Whites in the mandible, the bigonial breadth was the most dimorphic measurement taken with average accuracies ranged from 80% to 86% (Steyn and Iscan 1998). In a study on Zimbabweans there was a statistically significant sex difference in mandibular angle and length. The average mandibular angle of the Zimbabweans was greater than the values reported for some black African populations but the range of variation was small (Mbajiorgu et al., 1996) while in another study Kieser and Groeneveld 1986 found 91% accuracies with combination of maxillary and mandibular measurements and 78% accuracy with gonion-gnathion (mandibular base) length. In a study on Southeast Asian the results concluded a significant size dimorphism, relative facial breadth and cranial vault breadth with highest accuracy 86.8%. (Green and Curnoe 2009).

In the present study, direct discriminant analysis employed, testing combination of variables. Each of the six variables measured of the Saudi population showed statistically significant sex differences indicating that mandible shows greatest universe sexual dimorphism in terms of the mandible angle, the mandibular base length, ramus length and the bicondylar breadth which are the best dimorphic parameters for males than females while the variables of least use for discrimination are the minimum ramus breadth and bigonial breadth. So the bigonial breadth and the minimum ramus breadth are not dimorphic in sex determination in the studied group. In a recent study on sub-adult Iranian samples the results concluded that if only the mandible is available for identification, symphysial height and mandibular bigonial breadth could be used to determine the gender with high accuracy (Akhlaghi et al., 2014). The present results are in agreement with a study in black population of Tanzania, in which the results revealed that the mandible of Tanzanian population possesses metric parameters that make it sexually dimorphic. The mean condylar width was found to be 8.46 mm, the mean value for males was 8.6 mm and was higher than that of females which was 8.0 mm but it is statistically non-significant and the mean of ramus height was higher in male mandibles than in the females while the difference was statistically significant. Overall mean for bicondylar width was found to be (79.79 mm) (Fabian and Mpembeni 2002). The present results agree with Ogawa et al., (2000) conclusion which revealed that morphological features and metric parameters of the human mandible are useful in diagnosis and are used in identification of human remains and metric parameters will put more weight in sexing and identification of ethnicity.

Conclusion and recommendations

The study has provided a preliminary evaluation for some osteometric standards designated for sex assessment from mandible in Saudi populations. The results indicate that sex can be determined using mandible dimensions with relatively high accuracy and it is a suitable bone for forensic analysis. As the current study has been carried out on live volunteers, these results should be applied with caution on dry skeletal remains and we advocate the importance of conducting further studies on larger population sample, more diverse geographic regions and larger age scales which may enhance the effectiveness of these parameters. As a new standard to facilitate the rapid and accurate identification of unknown skeletal remains are increasingly important avenue of forensic field, there is a great need for awareness of 3D CT and its importance to facilitate the work.

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الملخص العربي

الازدواجية الجنسية في بعض القياسات الأنثروبولوجية المختارة للفك السفلي في عينة من الأشخاص السعوديين: تطبيق تعريفي طبي شرعي

سحر مصطفى[1]

يعتبر التعريف و تحديد نوع الجنس من الأولويات والمشكلات المعروفة في الطب الشرعي والتي هي في حاجة إلى المعلومات و الخبراء في العديد من المجالات. وتحديد الجنس هو أحد العوامل ذات الأهمية الأساسية في التحاليل البيولوجية للرفات البشرية. في الحالات التي لا يتم فيها توفر الجمجمة سليمة، فإن الفك السفلي يلعب دورا حيويا في التعريف وتحديد الجنس لأنه من أكثر العظام التي تتمتع بالازدواجية الجنسية من بين عظام الجمجمة. و حيث أنه من المعروف جيدا أن الهياكل العظمية تتباين بين مختلف قطاعات الأشخاص في مختلف البلدان فمن الطبيعي أن يحتاج كل قطاع إلى معاييره الخاصة المحددة من التقييم لتحسين دقة التعريف. وتركز الدراسة الحالية على تحديد الجنس عن طريقة دراسة بعض قياسات عظم الفك السفلي في عينة من الأشخاص السعوديين . تتألف الدراسة من ٨٠ شخصا (٤٠ من الذكور و ٤٠ من الإناث) تراوحت أعمارهم بين (٢٠-٥٥ عاما) من المترددين على قسم الأشعة التشخيصية في مستشفى النخبة الخاصة في مدينة الرياض في المملكة العربية السعودية . وقد خضع جميع المشاركين في الدراسة للتصوير المقطعي ثلاثي الأبعاد للجمجمة. تم فحص جميع الجماجم للمشاركين عن طريق تقييم عدد ستة قياسات مختارة للفك السفلي ، أربعة منهم (زاوية الفك السفلي و طول قاعدة الفك السفلي و الطول الفرعي للفك و الحد الأدنى للطول الفرعي) تم تقييمهم بالتصوير الجانبي للجمجمة و اثنين من القياسات (الاتساع بين الركيناوين والاتساع ثنائي اللقمة) بالتصوير الخلفي المحوري و قد وجد أن الذكور داخل الدراسة قد سجلوا قيما أعلى ذات أهمية إحصائية مقارنة بالإناث في جميع القياسات. و بمقارنة القيم المتوسطة للستة قياسات التي تمت دراستها للفك السفلي بين الذكور والإناث كشفت النتائج أن هناك أربعة قياسات للفك السفلي تعتبر من القياسات النهائية المتنبئة في تحديد الجنس و هم زاوية الفك السفلي و طول قاعدة الفك السفلي و الطول الفرعي للفك و الاتساع ثنائي اللقمة. في حين كانت الدقة للنموذج التنبؤي ٨٤,٩٥ ٪ للمجموعة كلها و يمكن أن تحدد الدقة في الذكور بنسبة ٨٤,٧ ٪ و بشكل صحيح و في حالات الإناث بنسبة ٨٥,٢ ٪. وخلصت الدراسة إلى أنه يمكن تحديد الجنس باستخدام قياسات أبعاد الفك السفلي مع دقة عالية نسبيا و أن الفك السفلي يعتبر من العظام المناسبة في التحاليل الطبية الشرعية.

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