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Determination of Sex Using Computed Tomographic Measurement of The Orbit Dimensions in a Sample of Egyptian Population

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Abstract

Background: The orbit is an important anatomical landmark, orbital measures are one of the craniofacial factors that, in terms of anthropological and forensic investigations, could be used in determination of sex and ethnicity. **Aim & Objective:** The present study aimed at measuring and comparing different measurements of orbital apertures between males and females using computed tomography to evaluate the value of orbital aperture measures as a tool in sex determination in a sample of Egyptian population. **Methods:** A total number of 200 CT scans of adult 100 males and 100 females of Egyptian population ranging in age from 18-68 years were evaluated regarding orbital height (OH), orbital width (OW), orbital index (OI), interorbial distance (IOD) and biorbital distance (BOD). The obtained data were statistically analyzed using an independent t-test. The significance level was set at a threshold of $p < 0.05$. **Results:** Significant differences in gender and side were observed in the orbital measurements ($p < 0.05$). The variable with the highest sensitivity (84%), for sex discrimination, was the biorbital distance (BOD). **Conclusions:** Significant sexual dimorphism was evident in the orbital dimensions, and the sex prediction accuracy was only fairly high. Consequently, for our population under study, the orbits may serve as an auxiliary method for sex determination in forensic investigations after mass disasters.

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Key words Sex determination, computed tomography, orbital dimensions

Introduction

Sex determination is considered to be the first and most important step for identification of human skeletal remains discovered in forensic scenarios e.g. natural disasters, airplane crashes, terrorists' attacks and other forms of mass disasters, where the identification of a large number of individuals is required. In forensic examinations, sex estimation is essential parameter that aids in determining the deceased's biological profile (Jain et al., 2015).

One of the best bones for identification and sexual dimorphism is the skull. The Sex of an individual can be identified accurately in 90% of cases using skull alone (Dhanwate& Ankushrao, 2017).

Morphometric and morphological procedures are the two categories of useful techniques for estimating sex. Morphometric analysis uses statistical analysis and comparison of the measures to create a probabilistic estimation of sex, whereas the analysis of morphology is subjective and requires visual evaluation of the dimorphic characteristics (Verma et al., 2020).

In forensic medicine, many craniometric measures have been used to reliably and accurately ascertain an individual's sex. In terms of anthropological research, among the craniofacial parameters that could be utilized in sex estimation are orbital measures (Rossi et al., 2012).

The orbits are the quadrilateral, pyramid-shaped spaces between the cranium and the facial bones that are situated on either side of the skull's midsagittal plane. Its quadrilateral base creates the orbital aperture, which is superficial and anterior (Botwe et al., 2017).

Gender differences become apparent after puberty; female skulls remain infantile, while male skulls display secondary sexual traits. In certain populations, the orbital dimensions reveal notable gender disparities (Khan et al., 2021).

Male orbital cavities are small and square, but female orbital cavities are rounder and bigger (Fernandes et al., 2021).

Due to their minimal inter-observer variation, quantitative methods of determining sex are considered more reliable when used as expert witnesses in court than subjective visual descriptions. On volunteers or dried skull bones, the orbits' dimensions have been measured with calipers or rulers. The non-reproducible shape of the skull may cause these to become inconvenient. Consequently, in forensic anthropology, radiologic measurements are more precise, repeatable, and trustworthy (Ghosh et al., 2019).

Because computed tomography (CT) is not constrained by the intrinsic magnification and superimposition of structures, as radiography is, it can offer precise measurements of bone that are useful in forensic medicine (El-Farouny et al., 2021).

The present study aimed at measuring and comparing different measurements of orbital apertures between male and female using computed tomography to evaluate the usefulness of orbital aperture measurements as a tool in sex determination in sample of Egyptian population.

Materials and Methods

Type of Study: A descriptive cross sectional study using CT imaging.

Study Setting: The study was conducted in Radiology department-Ain Shams University Hospitals in Cairo, Egypt.

Data collection:

The material of the present study was taken from the Archive of radiology department; Ain Shams University Hospitals, Egypt; which is a tertiary referral center. CT scan imaging of the skull was obtained for each case. Age was confirmed by documentary evidence like birth certificates or identification cards.

Study Population:

Sample size:

Two hundreds CT skull images of Egyptian population (100 males & 100 females) of the age ranging from 18 to 68 were studied.

Inclusion Criteria:

- Availability of case records (date of birth, date of imaging).
- 18 years old or more Egyptian subjects of both sex.

Exclusion Criteria:

Subjects with any of the following conditions will be excluded:

- History of bone diseases, stunted growth or nutritional deficiency.
- Evidence of any craniofacial abnormality such as congenital lesions, tumors, facial fractures.
- Previous orbital surgery.
- Old healed skull fracture.

Study tools:

Imaging procedure

Multislice Computed Tomography (MSCT) scans of Head and Neck (bone window) have been collected from the archive of radiology department-Ain Shams University Hospitals.

Measurements of the chosen variables:

Various parameters related to both orbits were measured on virtual skulls of 200 adult patients. Measurements were taken by using sliding calipers graduated to 0.1 cm.

Age and gender of the patients were recorded on a data sheet. Using bone window, the margins of the orbital aperture were identified on coronal sections and the orbital dimensions were measured bilaterally using a digital caliper calibrated in cm.

All measurements were taken by two observers one of them was lecturer of Diagnostic and Interventional Radiology.

The orbital width (OW) was measured as the maximum distance between the medial and lateral walls.

The orbital height (OH) was measured as the maximum vertical diameter between the orbital roof and floor (Figure 1A).

The interorbital distance (IOD) was defined as the minimal distance between the medial orbital walls in coronal planes (Figure 1B).

The longest distance between the lateral margins of the right and left orbital apertures was the biorbital distance (BOD) (Figure 1B).

The orbital index (IO) was calculated by dividing (the orbital height by the orbital width) multiplied by 100. (OH/OW)*100.

Ethical Considerations

- Approval was obtained from the Ethical Committee Ain Shams University, code number (FWA 000017585).
- Approval was obtained from the head of radiology department.
- Approval was obtained from the director of the archive of radiology department.

Statistical analysis:

The obtained data were revised, coded and organized for statistical analysis using SPSS version (24) software. Data were presented and suitable analysis was done according to the type of data obtained for each parameter.

Results

Table (1) demonstrated that there is a statistically significant difference between right and left orbit as regard orbital height p-value < 0.05. While orbital width and orbital index there is no significant difference between right and left orbit p-value >0.05.

Table (2) showed that right eye height is highly significant to differentiate between males and females. Mean right eye height is higher in males than females. Right eye Width is highly significant to differentiate between males and females. Mean right eye width is higher in males than females. OI of right eye is non-Significant to differentiate between males and females.

Table (3) showed that left eye height is significant to differentiate between males and females. Mean left eye height is higher in males than females. Left eye Width is highly significant to differentiate between males and females. Mean left eye width is higher in males than females. OI of left eye is non-Significant to differentiate between males and females.

Table (4) demonstrated that IOD is non-significant to differentiate between males and females. But BOD is highly significant to differentiate between males and females. The mean of BOD is higher in males than females.

Table (5) & figure (2) showed that:

The cut-off point level for right eye height was 37 mm, with sensitivity 67%. The cut-off point level for right eye width was 34 mm, with sensitivity 58%. The cut-off point level for left eye height was 37 mm, with sensitivity 62%. The cut-off point level for left eye width was 33 mm, with sensitivity 78%. The cut-off point level for biorbital distance was 90 mm, with sensitivity 84%.

Table (6) a univariate logistic regression analysis showed that the best single parameter measured in the current study for determining the sex is biorbital distance (BOD), with the highest odds ratio 6.163 and a significant p-value 0.000. The ranking of the significant parameters from the most efficient to the least efficient is: BOD, Right eye width, Left eye width, Right eye height, Left eye height.

Table (7) a multivariate logistic regression analysis showed that the best combination of the measured parameters for determining sex is bi orbital distance (BOD) and right eye width.

Table (1): Paired t-test comparing right eye and left eye regarding height, width and Orbital index in both males and females in studied cases.

		Right	Left	T	P	Sig.
		No.=200	No.=200			
Eye height (mm)	Mean±SD	38.04 ± 4.75	37.33 ± 2.82	2.231	0.027	S
	Range	30 – 45	25 – 45			
Eye width (mm)	Mean±SD	34.07 ± 2.13	33.97 ± 2.21	0.734	0.464	NS
	Range	24 – 42	26 – 39			
Orbital index	Mean±SD	111.76 ± 12.1	110.22 ± 8.19	1.758	0.080	NS
	Range	87 – 131	85 – 140			

P-value > 0.05: Non significant (NS); P-value < 0.05: Significant (S).

Table (2): Independent t-test comparing between male and female studied cases regarding height, width and orbital index of right eye.

All cases		Sex		T	P	Sig.
		Female	Male			
		No.= 100	No.= 100			
Right eye height (mm)	Mean±SD	37.00 ± 2.34	39.09 ± 6.13	-3.184	0.002	HS
	Range	31 – 43	30 – 45			
Right eye width (mm)	Mean±SD	33.25 ± 1.82	34.89 ± 2.12	-5.878	0.000	HS
	Range	27 – 37	24 – 42			
Orbital index of right eye	Mean±SD	111.46 ± 7.30	112.06 ± 15.52	-0.350	0.727	NS
	Range	93 – 131	87 – 131			

P-value > 0.05: Non significant (NS); P-value < 0.01: Highly significant (HS).

Table (3): Independent t-test comparing between male and female studied cases regarding height, width and orbital index of left eye.

All cases		Sex		T	P	Sig.
		Female	Male			
		No.= 100	No.= 100			
left eye height (mm)	Mean±SD	36.82 ± 2.61	37.84 ± 2.94	-2.596	0.010	S
	Range	31 – 42	25 – 45			
left eye width (mm)	Mean±SD	33.32 ± 2.22	34.62 ± 2.01	-4.342	0.000	HS
	Range	26 – 39	26 – 39			
Orbital index of left eye	Mean±SD	110.82 ± 8.27	109.63 ± 8.11	1.027	0.306	NS
	Range	92 – 140	85 – 133			

P-value > 0.05: Non significant (NS); P-value < 0.05: Significant (S); P-value < 0.01: Highly significant (HS).

Table (4): Independent t-test comparing between male and female studied cases regarding interorbital distance (IOD) and biorbital distance (BOD).

All cases		Sex		T	P	Sig.
		Female	Male			
		No.= 100	No.= 100			
IOD (mm)	Mean±SD	27.20 ± 2.99	27.93 ± 2.59	-1.846	0.066	NS
	Range	21 – 36	23 – 36			
BOD (mm)	Mean±SD	90.79 ± 4.58	94.10 ± 4.68	-5.054	0.000	HS
	Range	80 – 102	72 – 106			

P-value > 0.05: Non significant (NS), P-value < 0.01: Highly significant (HS).

Table (5): Receiver operating characteristic (ROC) Curve comparing between right eye and left eye measurements as a predictor of male sex in all cases.

Parameter	AUC	Cut off Point	Sensitivity	Specificity	PPV	NPV
Right eye						
Height	**0.690**	>37	**67.0**	**66.0**	**66.3**	**66.7**
Width	**0.736**	>34	**58.0**	**77.0**	**71.6**	**64.7**
Left eye						
Height	**0.628**	>37	**62.0**	**64.0**	**63.3**	**62.7**
Width	**0.684**	>33	**78.0**	**53.0**	**62.4**	**70.7**
BOD	**0.718**	>90	**84.0**	**54.0**	**64.6**	**77.1**

AUC: area under curve, PPV: Positive predictive value, NPV: Negative predictive value.

Table (6): Univariate logistic regression analysis for predictors of male sex in all cases.

	Uni-variate							
	Constant	B	SE	Wald	P-value	Odds ratio (OR)	95% C.I. for OR	
							Lower	Upper
Right								
Height>37	-0.693	1.371	0.300	20.948	**0.000**	3.941	2.191	7.091
Width>34	-0.606	1.531	0.312	24.039	**0.000**	4.623	2.507	8.526
Left								
Height>37	-0.521	1.065	0.293	13.210	**0.000**	2.901	1.633	5.151
Width>33	-0.879	1.386	0.314	19.513	**0.000**	3.998	2.162	7.394
BOD>90	-1.216	1.819	0.339	28.843	**0.000**	6.163	3.174	11.968

B: beta factor, SE: Standard error, C.I: confidence interval for odds ratio, p-value <0.05: Significant.

Table (7): Multivariate Logistic regression analysis for predictors of male in all cases.

	Multi-variate						
	B	SE	Wald	P-value	Odds ratio (OR)	95% C.I. for OR	
						Lower	Upper
Constant	-1.857	0.352	27.839	0.000	0.156		
Right							
Height>37	0.663	0.384	2.989	0.084	1.941	0.915	4.117
Width>34	0.783	0.364	4.621	**0.032**	2.187	1.072	4.465
Left							
Height>37	0.241	0.377	0.408	0.523	1.272	0.608	2.662
Width>33	0.398	0.385	1.069	0.301	1.489	0.700	3.167
BOD>90	1.254	0.381	10.812	**0.001**	3.503	1.659	7.394

B: beta factor, SE: Standard error, C.I: confidence interval for odds ratio, p-value <0.05: Significant.

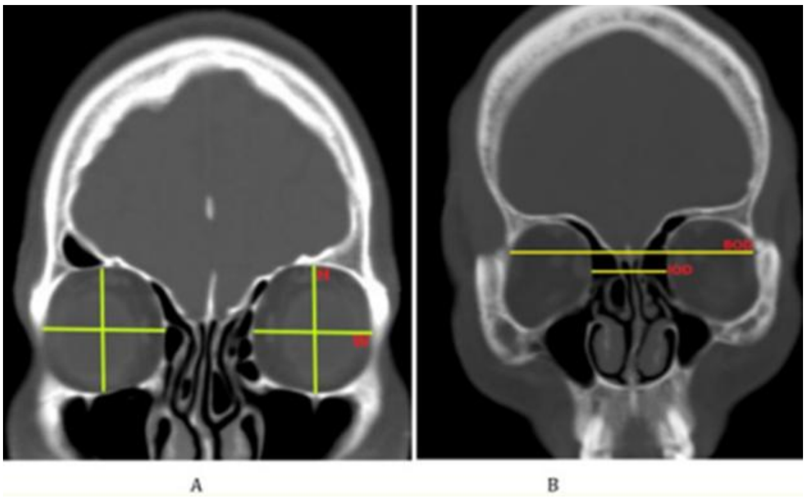
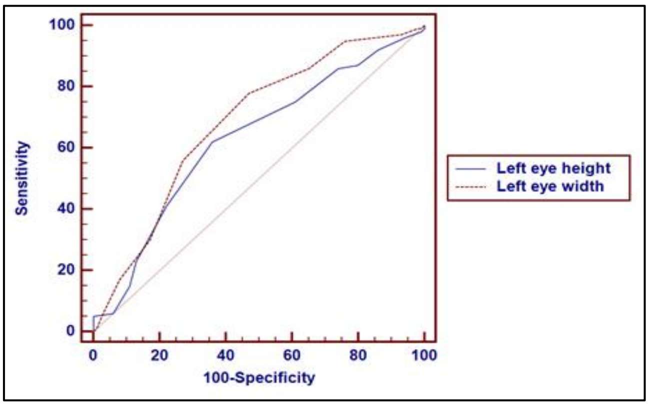


Figure (1): Orbital measurements; A: Orbital height and width, B: Biorbital distance and Interorbital distance (Beryl et al., 2022).



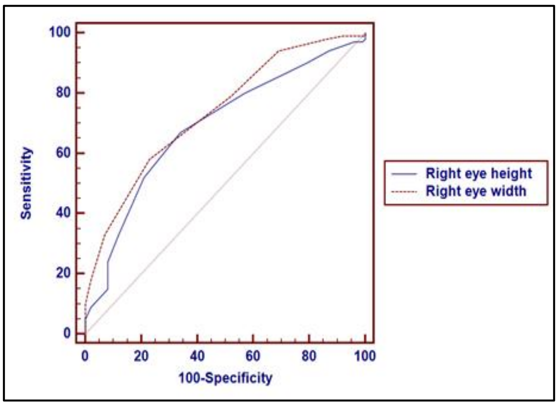


Figure (2): Receiver operating characteristic (ROC) Curve comparing between right eye and left eye measurements as a predictor of male sex in all cases.

Discussion

The current study demonstrated that there was a statistically significant difference in orbital height between the right and left orbits, with the right orbit having a higher orbital height; however, no statistically significant difference was found between the right and left orbits in terms of orbital index or breadth.

Kaya et al. (2014) revealed that on the left side, the OH was statistically substantially higher for each sex and for all subjects. But in females, right OW was statistically substantially higher.

On the other hand, Kaplanoglu et al. (2014) found that right orbital width was statistically higher and significant than the left orbit. There was no statistically significant difference between right and left orbital heights.

In another study by Mandour and Fetouh. (2014) found that the right side's orbital height and width were noticeably higher than the left's.

The current study revealed that there was a statistically significant difference between males and females as regard orbital width and orbital height. Males had greater average width and height than females.

This was in agreement with the study conducted by Kaya et al. (2014) who found that the differences in orbital breadth and height between males and females were statistically significant. Males were noticeably larger than females in both the left and right orbital measurements (orbital height and width).

Similar findings were reported by Attia et al. (2019) who found that the differences in orbital breadth and height between males and females were statistically significant. The majority of the measurements showed higher mean values in males, with the exception of the left orbital width, which showed a modest rise in females. This could be explained by their study's smaller sample size.

Similarly, Rossi et al. (2012) concluded that males' orbital aperture width was noticeably wider than females'. Nevertheless, there were no statistically significant differences in the orbital aperture height between the sexes. Once more, this can be explained by the differing methodologies employed—MSCT was used in the current study, whereas Caldwell radiography (X-rays) were used by Rossi et al.

On the other hand, Ji et al. (2010) found that there was no significant difference in the orbital height between males and females. The racial differences between Chinese and Egyptians as well as the redused sample size employed by Ji et al. could be the cause of this discrepancy.

According to the current study, the difference was statistically not significant between male and female as regard orbital index in both right and left eyes.

This was in agreement with Jeremiah et al. (2013), who found that there were no statistically significant differences in the orbital indices for both the right and left orbits of the two sexes.

On the other hand in 2015, Biswas et al. found that the left orbital index significantly differed in males and females. The female skull's orbital index was higher than the male skulls'. There were no appreciable differences between the two sexes when it came to the right side.

Three types of orbits have been conventionally characterized, using the orbital index as the standard:

a. Megaseme (Large): An orbital index of 89 or higher is required. Except for Eskimos, Orientals exhibit this type.
b. Mesoseme (Intermediate): The orbital index range is 89–83. The Caucasians exhibit this type.
c. Microseme (Small): The orbital index is 83 or less. Africans tend to exhibit traits of this kind (Biswas et al., 2015).

The current study classified the sample of Egyptians as having the Megaseme (large) orbit as the orbital indices for both males and females were larger than 89%.

This was in agreement with Sanad et al. (2017) who classified the Egyptians population is belonging to the Megaseme category as the orbital indices for both males and females were larger than 89% (91.1& 94.8 respectively).

The present study revealed that, there was no statistically significant difference between males and females as regard inter orbital distance. On the other hand, biorbital distance was considerably greater in men than in women.

This was in accordance with Mani et al. (2020) who found that between male and female individuals, all orbital measurements except intraorbital distance were statistically significant.

Biswas et al. study (2015) demonstrated that there was a considerable difference in the intraorbital distance between the skulls of men and women. Higher values, though, are reserved for women. It is possible to attribute the discrepancy between the current study and the Biswas et al study to racial and regional factors.

Of all the measured parameters of the orbit, the best single parameter measured in the current study for determining the sex is biorbital distance (BOD), with the highest odds ratio 6.163 and a significant p-value 0.000, followed by right eye width. Left eye height was the parameter with the lowest value of discrimination.

In agreement to our study, Jain et al. (2015) found that the biorbital distance was the most accurate parameter, with a 76.0% accuracy rate.

According to Beryl et al. (2022), The width of the left orbit was shown to be the most effective sex distinguishing variable in their study (77.1%).

Jain et al. (2015) discovered that inter-orbital distance was the most accurate metric (76.0%) and the most dependable one based on univariate analysis. Also, Mani et al. (2020) revealed that, IOD was the most effective sex differentiating factor (63%).

Jain et al. (2015), Kaplanoglu et al. (2014), Attia et al. (2019), Mani et al. (2020), Beryl et al. (2022), Biswas et al. (2015) were in agreement to our study as they found that the orbits' dimensions revealed a considerable sexual dimorphism and a quite strong sex prediction accuracy. As a result, the orbits might be employed as an auxiliary technique for determining sex.

In contrast, Kaya et al. (2014) claimed that the orbital variables' effectiveness in sex discrimination in the Turkish population was insufficient. Since these factors could accurately distinguish between the sexes in between 60.0% and 75.0% of people.

Conclusion and Recommendations

The orbits' dimensions revealed reasonably strong sex prediction accuracy and significant sexual dimorphism. Consequently, it is possible that the orbits will be utilized as a supplementary technique for determining sex in forensic investigations in our studied population. We recommend accurate and reliable modern imaging techniques such as MSCT should gain access to forensic medicine in Egypt and should pioneer post mortem investigations. Also further research with a larger sample size and more number of measurable variables is recommended to further confirm the findings of our study.

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استخدام الأشعة المقطعية فى معرفة الجنس عن طريق قياس أبعاد العظم الحجاجى فى عينة من الشعب المصرى

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الملخص العربي

الخلفية العلمية: الحجاج هو معلم تشريحي أساسي والقياسات الحجاجية هي واحدة من العلامات القحفية الوجهية التي يمكن استخدامها في التحديد الجنسي والعرقي فى الدراسات الأنثروبولوجية والطب الشرعي.

الهدف والغرض: هدفت الدراسة الحالية إلى قياس ومقارنة القياسات المختلفة للفتحات الحجاجية بين الذكور والإناث باستخدام التصوير المقطعي المحوسب لتقييم فائدة مقاييس الفتحة الحجاجية كمساعد في تحديد الجنس في عينة من السكان المصريين.

الطريقة: تم فحص مجموعه مكونة من 200 صورة بالتصوير المقطعي المحوسب ل 100 من الذكور البالغين و 100 من الإناث البالغات من السكان المصريين الذين تتراوح أعمارهم بين 18-68 سنة من حيث الارتفاع الحجاجى ، العرض الحجاجى، المؤشر الحجاجى، المسافة بين الحجاجية و المسافة ثنائية الحجاجية. تم تحليل البيانات التي تم الحصول عليها إحصائيا باستخدام اختبار ت مستقل. تم أعتبار الأهمية عند $p < 0.05$.

النتائج: أظهرت القياسات الحجاجية اختلافاً جانبياً وجنسياً كبيرًا ($p < 0.05$).

وكانت المسافة ثنائية الحجاج هى المتغير الأكثر تمييزًا بحساسية 84%.

الاستنتاجات: أظهرت الأبعاد الحجاجية إزدواج الشكل الجنسي بشكل كبير ودقة عالية إلى حد ما في التنبؤ بالجنس. لذلك ، يمكن استخدام قياسات الحجاج كطريقة مساعدة لتحديد الجنس في تحقيقات الطب الشرعي أثناء الكوارث الجماعية لسكاننا الذين شملتهم الدراسة.

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