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KEY WORDS: SELLA TURCICA, SEX, AGE, SUBADULT, EGYPTIANS

Abstract

Introduction: The sella turcica has gained importance as a stable bony landmark in cephalometric studies.

Aim of the work: The aim of the work was to explore the changes that accompany postnatal ontogeny of the sella turcica until full development, and to verify its contribution in age estimation and sexual assignment among Egyptians.

Subjects and methods: Six selected measurements of the sella turcica of 215 Egyptian patients were assessed using Multidetector Computed Tomography (MDCT). The patients represented different ages and were referred to the Radiodiagnosis and Intervention Department. The gathered data were then subjected to statistical analysis including correlation and regression analysis.

Results: The measurements of the sella showed a strong correlation with age. Three selected measurements demonstrated significant sexual dimorphism (sella width, sella height anterior and median in the subjects aged 20 to 25 years). Six regression equations were derived. The accuracy achieved by the combined parameters in the younger group (aged less than 25 years) was higher than that of the older individuals.

Conclusion: The results achieved from the current study are useful tools in the determination of age and sex in both forensic and bio-archeological disciplines. However, further studies concerning the shape are strongly suggested.

Successful age estimation remains an imperative element of any medicolegal investigation, and a challenging task for both forensic experts and physical anthropologists worldwide (Joseph Prahlow 2010). Sex determination is of the utmost importance in the osteoarcheological domain to make accurate reconstructions of the biological profile of ancient human remains of past populations (Álvarez-Sandoval et al. 2014). In fragmented skulls, which are encountered in either natural or manmade disasters such as cases of fire, plane crashes, violence or terrorist's attacks, most of the classical characteristic signatures are obscured. Hence, sex and age determination become more difficult in medicolegal examination (Pope 2004).

The sella turcica has gained importance as a stable osseous landmark seen on lateral cephalometric radiographs (Axelsson et al, 2004) as well as in craniofacial superimposition techniques (Standerwick et al 2008, Gkantidis 2015). It is a saddle-shaped depression of the sphenoid bone located in the middle cranial fossa that houses the pituitary gland. The sphenoid bone is one of the bones forming the skull base. The sella is concave in sagittal projection and convex in coronal projection. The borders of this part of the sphenoid bone are formed anteriorly by the anterior clinoids and the sellar tuberculum, whereas the posterior clinoids form the dorsum sella (square part of the sphenoid bone). The floor of the sella turcica is the posterior part of the roof of the mostly asymmetrical sphenoidal sinus **(Figure 1)**. Sella turcica is divided into three segments, consisting of an anterior wall, a floor, and a posterior wall (Tekiner et al. 2015). There are three basic morphological types of sella: circular (the most common), round or flat (the least) (Konwar et al. 2016). The development of the sella turcica is interrelated with that of the hypophysis celebri (the pituitary gland), which must be completed before the sella turcica can be formed. A deviation in the development of the pituitary gland may lead to a deviation in the morphology of the sella turcica (Kjær 2015).

Although the overall development of cranial base synchondroses has received less attention than that of long-bone growth plates, it appears to be more genetically controlled than environmentally affected. Many genes have been proven to be fundamental in the development of the craniofacial complex in differentiation and migration of neural crest cells (Cobourne 2000, Simo˜es-Costa et al. 2013).

Although there is a general agreement that most of the sex specific traits are only developed during adolescence (Scheuer et al. 2000), there is an ongoing debate about whether we can differentiate between females and males before puberty. However, this sexual dimorphism is minor compared to what is seen in adults and therefore, it will be more difficult to conclude the sex of younger individuals.

Despite the existence of numerous studies on skeletal growth worldwide (Bilfeld et al 2013, Bilfeld et al 2015, Pujol et al 2016), fewer studies have been conducted among Egyptians to determine the pattern of skeletal growth and consequently subadult age estimation (Boccone et al. 2010, Badr El Dine et al 2016).

The field of forensic radiology has undergone rapid expansion and is a globally growing subspecialty of forensic medicine and radiology (Baglivo et al. 2013). Today, post-mortem radiology or necro radiology known as “Virtopsy” has been used as an adjunct or possible alternative for the conventional autopsy in many mortuaries around the world (Whitby et al. 2005). Recent advances in high resolution CT scanners, together with the improvement of software, have been refining 3D images year by year (Sidler et al. 2007). This provides a great deal of detailed information, much of which cannot be obtained using standard radiographic techniques (Flach et al. 2014).

The objective of the present study is therefore to elucidate the changes that accompany postnatal ontogeny in the sella turcica until full development, its significance and feasibility for age estimation, as well as sex determination using reconstructed CT images.

Subjects and Methods

Sample. The analyzed sample consisted of 215 Egyptian patients (126 males and 89 females), presenting to the Diagnostic and Interventional Radiological Department, for Multi-Detector Computerized Tomography (MDCT) of the head for various reasons. The patients represented different ages, from birth up to 35 years of age, to cover the skull development.

The protocol of the study was reviewed by the local ethical committee.

Patients with a history of head trauma, craniofacial fractures, cleft palates, surgery, endocrinal disturbances and any bony pathology (congenital or acquired), genetic bone disorders, abnormal skull shape, as well as poor quality radiographs were excluded from the study.

MDCT Protocol for Image Acquisition. Multi Detector Computer Tomographic (MDCT) scanning was performed using a 20 Detectors Helical CT Scanner Imaging Machine (SOMATOM Definition AS, Siemens, Germany). The patients laid supine on the scanner. The scan parameters and protocols differed according to the patient's age and indications of the examination, with the lowest radiation dose for younger patients. Scan parameters included slice thickness ranging from 0.6 mm up to 1 mm with no gap. Images were transferred to workstations where multiplanar reformatting was generated in sagittal planes. Measurements were performed in mid-sagittal plane.

To abolish differences due to measurement error, all the measurements were taken twice during two different periods with an interval of four weeks. The average values were calculated for further analysis. All measures were taken by the same radiologist to minimize errors.

Reconstruction and Post-Processing Considerations. Reconstruction of high-quality 3D models using multiplanar reformatting were performed on workstations using commercially available software (Siemens Syngo 3D).

Measurements on the Skull 3D-CT Images. The size of the sella was quantified by six measurements obtained on virtual skeletons in millimeters.

Statistical Analysis.

- To facilitate the interpretation of results, the sample was divided using five-year intervals.
- Data obtained was analyzed with a Statistical Analyses Package for Social Sciences Software (SPSS) **(**Armonk, NY: IBM Corp**)** version 20.
- Descriptive statistics were achieved for each measurement (the means, standard deviations and standard errors). Student's t-test was applied to each age category to attain an initial approximation of sexual dimorphism for any variable. A p-value of <0.05 was considered statistically significant. In addition, the 95% confidence interval of the mean values was computed.
- Accuracy was calculated, accuracy which Rate of Agreement = (True positives + True negatives) / Total tested x 100.
- The correlation between age and each of the selected parameters was evaluated using Pearson correlation coefficients.
- Linear regression analysis was performed to derive regression equations for age estimation.

Results

Age and sex distribution of the studied population are demonstrated in **Table 1**.

All the studied variables showed significant differences between different age groups (**Table 2**).

Linear growth curves were applied to analyze the growth pattern and the age 25 years was chosen, as the variables approximately start to slow down starting from this age. **Figure 3**

Descriptive statistics of the measured sella variables according to each age group and sex are shown in **Table 3** regarding the mean, standard deviation, standard errors and 95% confidence interval for the mean. Student's t-test was applied to assess sexual difference in each age group.

Significant correlation was recorded between the sella variables and the age **(Table 4)**. The highest correlation coefficient was exhibited by the sella area (0.536) and the sella height posterior (0.531), while the lowest was by the sella height anterior (0.179).

For the sake of clarity, the different variables will be elucidated separately:

Sella Width and Length. Overall, the width is bigger in females in most of the age groups. The sella width is wider in females than in males from birth until 5 years old. However, no significant difference is detected. A significant difference is noticed between both sexes in the age group, 20 - <25 years.

Sella length measurements are more or less similar in both sexes and in all age groups, except in the age group 5- <10 years, yet this difference is not statistically significant. A significant difference was only recorded in between both sexes in the age group 10- <15 years. **(Table 3)**

Sella Height (Anterior, Posterior and Median). The female sella height anterior is larger than males with a significant difference in the age 20 to less than 25 years. The same applies for the sella height median. Sella height posterior is larger in females but still not statistically significant.

Sella Area. The figures are similar in both sexes. The males show bigger area in the younger groups (up to 15 years) but this difference is not statistically significant.

Age Estimation from Sella Turcica Measurements. For age determination, linear regression equations were obtained first using each of the selected measurements separately.

Table 5

Six combined regression equations were built up for age determination, three formulae for those younger than 25 years, and three others for the older ages. **Tables 6 & 7.**

Table 8 illustrates the present research in comparison with other studies, in terms of methodology and selected variables.

Discussion

A total of six identified parameters were recorded to delineate the growth of the sella turcica in both sexes in the current research. MDCT was applied to take the measurements, as it elucidates minute differences of the skull's bony features which could not be demonstrated clearly by a conventional lateral cephalometric radiograph.

The age was selected on purpose so that no considerable change occurs in the size of the sella turcica after 25 years, however the sample age was extended to 35 years. This age was also chosen in the study conducted by Hassan et al 2016 in the Malay population.

Choi et al 2001 reported that dimensional changes of the normal sella has a linear tendency with age until 26 years of age. After that age, no remarkable change was noticed.

In the present study, obviously, Pearson correlation coefficients between age and the sella selected parameters showed a significant correlation (particularly the sella area and the sella height posterior). Compared with the study of Hasan et al 2016 among the Iraqi population, they reported that all parameters showed a significant correlation with age, however the Sella width had the largest correlation coefficient (0.73). Andredaki et al 2007 recorded a correlation between the sella measurements and age, however all correlation values were low (r ranged from 0.00 to 0.08 in both sexes).

The current study depicts that the sella length was greater in males from ages 5 to 10 years. Afterwards, it was higher in females until 20 years, yet this variation was not statistically significant. This is in partial agreement with what was reported by Axelsson et al (2004) in their research among a Norwegian sample aged 6 to 21 years, where they reported greater measurements for the sella length among males, as well as a significant difference in the age group of 12 to 21 years.

In the present study, the mean length of the sella was greater than that reported by Sathyanarayana et al 2013. They studied the size of sella among an Indian sample between the ages of 9-27 years where the mean length reached 8.8 mm in the ages of 9-14 years and 9.6 mm in the group aged 15-27 years. The current study demonstrated that the sella width was bigger in females than in males in the age group of less than 5 years, which is consistent with previous studies on other bones (femur, ilium and scapula) (Rissech et al 2008, Rissech et al 2005, Badr El Dine et al 2016).

From the ages of 5 to 10 years, the sella width was bigger in males with no significant difference. This could be explained by the small sample size of females in that group.

In the current study, females showed greater measurements for sella width and length in the age group of 10 to 15 years, yet it was not statistically significant. The pubertal growth spurt takes place two years earlier in females than males (more evident in long bones), leading to a dramatic change and increase in the size of the pituitary gland and consequently an increase in size of the pituitary fossa in this age (10-15 years). Equilibration between both sexes is achieved with the late growth acceleration spurt in males.

The results of the present study revealed that the mean anterior, median and posterior height were larger in females than in males in the age group of 10 to 20 years, coinciding with what was reported by Rai et al 2016 among the Indian population.

When comparing the sella height between both sexes, none of these dimensions showed significant differences in any of the age groups except for the anterior and median ones in the ages of 20 to 25 years. This is in partial agreement with what was reported by Hassan et al 2016 as the anterior height was the only significant parameter between males and females.

After the onset of puberty, the discrepancies between the male and female skull become obvious as the male skull develops some adult characteristics. However, only three variables (Sella width, sella height anterior and median) showed significant sexual differences, particularly in the age group pf 20-<25 years. The other variables did not contribute to sexual determination.

Andredaki et al 2007 in his study among Greeks reported a significant difference between both sexes regarding the sella anterior height.

The results of the current study are in agreement with Ize-Iyamu 2014 who stated that greater sella measurements are prevalent in the 15 to 25-year-old age groups. The overall measurements were lower than what was that reported among the Jordanian population (Abu Ghaida et al. 2017).

Additionally, the sella length among both sexes was lower than those recorded by Shah et al 2011 among the Pakistani population. The sella area in the current research was larger than that of the Iraqi sample (Andredaki et al 2007).

The discrepancies between the results of the current work and previous studies reflect structural differences of the sella turcica between different populations. It was postulated that skeletal maturation is affected by the growth hormone which is further influenced by genetic and environmental factors (chronic illness and nutritional status). Moreover, differences in the technique employed for measurement add additional point of difference between researches.

Interestingly, although the area of the sella increases with age by about 0.1 mm, it yielded that the highest correlation coefficient was recorded with age. Added to that, when this parameter was implicated in the regression equation, the lowest SEE was obtained relative to the other parameters.

When the linear regression equation was applied to the sample, the accuracy of estimated ages from a single parameter turned out to be worse than that obtained from the combined model. A low value of SEE indicates greater reliability in the estimated age. The use of the variables each alone resulted in errors in estimating ages ranging from 8.169 to 9.522 years. Regarding the accuracies obtained, the values were still lower from that proposed by forensic anthropologists (80- 85%) to be applied with confidence in identification purposes *(Krogman et al 1986, Bidmos et al 2003)* However, Kraniotia et al 2017 recommended that any obtained accuracies less than 80% should be treated with caution.

In the current study, the sella anterior height exhibited the lowest correlation with age as well the highest SEE when used in the equation (9.522).

Since precise age estimation is a relevant issue in the forensic context and the regression equations derived from one population could not be applied to another one, the studied sample was divided into two groups according to the age of the full development of sella turcica (25 years). Thus, regression equations were calculated for age estimation for both sexes and in the case of undetermined/unknown sex.

Six regression equations were formulated from the gathered data. The best model that provided a lower SEE, a higher R^2 and a better accuracy was that concerning females aged less than 25 years (SEE value of 3.636, R^2 of 0.771 and accuracy 77%), followed by the equation that could be applied in the case of an unknown/ unidentified sex with an accuracy of 65% and a SEE of 4.438 which is very close to that of the SEE of the male formula (4.913). This means that the range of error was about 3 to 4 years. The latter equation is helpful for age estimation in the case when no sexual differences are revealed (archeological and anthropological remains) and when the skeletal remains are fragmentary with peri- or postmortem damage.

The accuracies of the equations of the older age groups (>25 years) were not satisfactory. The error in age estimation within the three equations were very close (error of 2 years). Any of the formulated equations could be used for age determination among adult populations.

Several strengths distinguishing this current study from previous ones deserve appreciation. Firstly, the sample size covers both sexes to delineate the growth pattern of the sella over diverse ages. Secondly, the implementation of modern radiological modalities and measurements of the sella on the 3D reconstructed CT images provide an excellent anatomic representation of bones devoid of artifacts. Thirdly, it is the first attempt to formulate regression equations from the sella for age estimation, yet the accuracy is still controversial.

However, by adding other available bony parameters, it could be of value in forensic anthropology.

There are several limitations in the current study that should not be neglected. Firstly, the morphological shape of the sella turcica was not assessed. Despite this limitation, six measurements were analyzed to pick the overall size of the sella, which is in excess to the previous studies concerning the sella. Secondly, the relationship between the size of sella and facial morphology must be studied.

Conclusion

In conclusion, the study has provided new findings characterizing the growth of sella turcica among both sexes. Moreover, it is the first study to formulate regression models for age estimation from sella measurements among Egyptians. However, the equations of the younger groups (less than 25 years old) yielded better results, but still need to be applied with caution in the forensic identification context.

Recommendations

Further research is warranted that applies the formulated equations among larger samples with evenly distributed age groups in parallel with the morphological analysis of the sella.

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Table 1. Age and Sex of the Studied Sample

Age (years)	Sex				Total (n=215)	t test
	Male (n=126)		Female (n=89)			
	No	%	No	%		
<5	14	70%	6	30%	20	χ^2 =4.8636 (p =0.561)
5-10	11	68.75%	5	31.25%	16	
10-15	15	65.22%	8	34.78%	23	
15-20	17	60.71%	11	39.29%	28	
20-25	19	54.29%	16	45.71%	35	
25-30	24	48%	26	52%	50	
30-35	26	60.47%	17	39.53%	43	
Range	4-35		0.4-35		0.4-35	
Mean ±SD	19.73±10.23		21.67±8.71		20.35±9.66	t= -1.454 P =1.474

S.D.: standard deviation.

χ^2: Chi square test, * p value is significant when $p \leq 0.05$.

Table 2. Distribution of Sella Turcica Measurements and Age Groups

Variable (mm)	Age (years)	Mean	SD	SEE	Minimum	Maximum	F	p value
Sella width	<5	7.8	1.94	0.43	4.00	12.00	16.97	<0.001*
	5-	9.44	1.79	0.45	6.00	12.00		
	10-	10.26	2.70	0.56	6.00	19.00		
	15-	11.32	1.70	0.32	8.00	15.00		
	20-	12.40	1.54	0.26	10.00	16.00		
	25-	11.58	1.85	0.26	6.00	15.00		
	30- 35	11.63	1.77	0.27	8.00	15.00		
	Total	11.04	2.27	0.15	4.00	19.00		
Sella length	<5	8.05	1.36	0.30	6.00	11.00	7.56	<0.001*
	5-	8.31	2.21	0.55	5.00	11.00		
	10-	8.87	1.84	0.38	7.00	14.00		
	15-	9.82	1.79	0.34	7.00	14.00		
	20-	10.66	1.68	0.28	7.00	13.00		
	25-	9.82	1.40	0.20	7.00	13.00		
	30-35	9.79	1.83	0.28	6.00	13.00		
	Total	9.57	1.85	0.13	5.00	14.00		
Sella height anterior	<5	1.55	1.15	0.26	1.00	5.00	3.73	0.0015*
	5-	2.00	1.59	0.40	1.00	5.00		
	10-	2.13	1.87	0.39	1.00	7.00		
	15-	2.46	2.43	0.46	1.00	10.00		
	20-	3.29	3.15	0.53	1.00	14.00		
	25-	3.86	2.75	0.39	1.00	11.00		
	30-35	2.30	2.16	0.33	1.00	8.00		
	Total	2.73	2.49	0.17	1.00	14.00		
Sella height posterior	<5	1.85	1.66	0.37	1.00	7.00	23.94	<0.001*
	5-	5.31	1.40	0.35	2.00	7.00		
	10-	5.74	1.63	0.34	3.00	9.00		
	15-	5.96	1.91	0.36	1.00	9.00		
	20-	6.57	1.97	0.33	1.00	11.00		
	25-	7.16	1.82	0.26	1.00	11.00		
	30-35	6.67	1.69	0.26	1.00	10.00		
	Total	6.03	2.27	0.16	1.00	11.00		
Sella height median	<5	5.00	1.12	0.25	3.00	7.00	16.04	<0.001*
	5-	6.56	0.89	0.22	5.00	8.00		
	10-	6.70	1.22	0.25	5.00	9.00		
	15-	7.43	1.10	0.21	6.00	9.00		
	20-	7.97	1.67	0.28	5.00	14.00		
	25-	8.08	1.40	0.20	4.00	12.00		
	30-35	7.47	1.35	0.21	5.00	11.00		
	Total	7.31	1.59	0.11	3.00	14.00		
Sella area	<5	0.36	0.12	0.03	0.12	0.62	24.85	<0.001*
	5-	0.51	0.13	0.03	0.25	0.65		
	10-	0.61	0.17	0.04	0.34	1.09		
	15-	0.72	0.14	0.03	0.48	0.97		
	20-	0.85	0.23	0.04	0.52	1.80		
	25-	0.82	0.19	0.03	0.48	1.30		
	30-35	0.75	0.17	0.03	0.40	1.21		
	Total	0.71	0.23	0.02	0.12	1.80		

*: Statistically significant at $p \leq 0.05$

Table 3. Descriptive Statistics of the Measured Variables Classified According to Each Age Group and Sex

								95% confidence		
Variable (mm)	**Age (years)**	**Sex**	**Mean**	**SD**	**SEE**	**Minimum**	**Maximum**	**Lower bound**	**Upper bound**	**t test (p value)**
Sella width	**<5**	**male**	1.36	1.08	0.29	1.00	5.00	0.73	1.98	0.2612
		female	2.00	1.26	0.52	1.00	4.00	0.67	3.32	
	5-	**male**	2.18	1.83	0.55	1.00	5.00	0.94	3.41	0.5168
		female	1.60	0.89	0.40	1.00	3.00	0.48	2.71	
	10-	**male**	1.87	1.55	0.40	1.00	5.00	1.01	2.72	0.365
		female	2.63	2.39	0.84	1.00	7.00	0.62	4.62	
	15-	**male**	2.53	2.72	0.66	1.00	10.00	1.13	3.92	0.863
		female	2.36	2.01	0.61	1.00	6.00	1.01	3.71	
	20-	**male**	1.95	2.01	0.46	1.00	8.00	0.97	2.91	0.004*
		female	4.88	3.56	0.89	1.00	14.00	2.79	6.77	
	25-	**male**	3.50	2.55	0.52	1.00	8.00	2.42	4.57	0.3789
		female	4.19	2.93	0.57	1.00	11.00	3.01	5.37	
	30-35	**male**	2.31	2.13	0.42	1.00	8.00	1.44	3.16	0.9842
		female	2.29	2.26	0.55	1.00	7.00	1.13	3.45	
Sella length	**<5**	**male**	1.79	1.76	0.47	1.00	7.00	0.76	2.80	0.7997
		female	2.00	1.55	0.63	1.00	4.00	0.37	3.62	
	5-	**male**	5.73	1.01	0.30	4.00	7.00	5.04	6.40	0.0776
		female	4.40	1.82	0.81	2.00	6.00	2.14	6.65	
	10-	**male**	5.07	1.28	0.33	3.00	8.00	4.35	5.77	0.0039*
		female	7.00	1.51	0.53	5.00	9.00	5.73	8.26	
	15-	**male**	5.88	2.39	0.58	1.00	9.00	4.65	7.11	0.7842
		female	6.09	0.83	0.25	5.00	8.00	5.53	6.64	
	20-	**male**	6.37	1.95	0.45	2.00	11.00	5.42	7.31	0.5156
		female	6.81	2.04	0.51	1.00	9.00	5.72	7.89	
	25-	**male**	7.17	1.93	0.39	4.00	11.00	6.35	7.98	0.9805
		female	7.15	1.76	0.35	1.00	10.00	6.44	7.86	
	30-35	**male**	6.77	1.48	0.29	4.00	10.00	6.17	7.36	0.6539
		female	6.53	2.00	0.49	1.00	10.00	5.49	7.55	
Sella height anterior	**<5**	**male**	5.00	1.24	0.33	3.00	7.00	4.28	5.71	1.000
		female	5.00	0.89	0.37	4.00	6.00	4.06	5.93	
	5-	**male**	6.55	0.82	0.25	5.00	8.00	5.99	7.09	0.9143
		female	6.60	1.14	0.51	5.00	8.00	5.18	8.01	
	10-	**male**	6.73	1.22	0.32	5.00	9.00	6.05	7.41	0.8450
		female	6.63	1.30	0.46	5.00	9.00	5.53	7.71	
	15-	**male**	7.41	1.12	0.27	6.00	9.00	6.83	7.98	0.9224
		female	7.45	1.13	0.34	6.00	9.00	6.69	8.21	
	20-	**male**	7.42	1.26	0.29	5.00	9.00	6.81	8.02	0.0315*
		female	8.63	1.89	0.47	6.00	14.00	7.61	9.63	
	25-	**male**	7.92	1.10	0.22	6.00	10.00	7.45	8.38	0.4328
		female	8.23	1.63	0.32	4.00	12.00	7.57	8.89	
	30-35	**male**	7.35	1.60	0.31	5.00	11.00	6.70	7.99	0.4819
		female	7.65	0.86	0.21	6.00	9.00	7.20	8.09	
Sella height posterior	**<5**	**male**	0.36	0.13	0.04	0.12	0.62	0.28	0.44	0.8438
		female	0.35	0.09	0.04	0.26	0.50	0.25	0.44	
	5-	**male**	0.51	0.11	0.03	0.30	0.65	0.43	0.58	0.8220

Variable (mm)	Age (years)	Sex	Mean	SD	SEE	Minimum	Maximum	95% confidence Lower bound	Upper bound	t test (p value)
		female	0.50	0.18	0.08	0.25	0.65	0.27	0.71	
	10-	male	0.57	0.19	0.05	0.34	1.09	0.46	0.67	0.1789
		female	0.67	0.10	0.04	0.55	0.87	0.58	0.75	
	15-	male	0.74	0.15	0.04	0.48	0.97	0.66	0.81	0.4678
		female	0.70	0.11	0.03	0.53	0.88	0.62	0.77	
	20-	male	0.80	0.18	0.04	0.52	1.24	0.71	0.88	0.1910
		female	0.90	0.28	0.07	0.64	1.80	0.75	1.04	
	25-	male	0.77	0.14	0.03	0.48	1.14	0.71	0.83	0.0744
		female	0.87	0.22	0.04	0.53	1.30	0.77	0.95	
	30-35	male	0.74	0.19	0.04	0.40	1.21	0.66	0.81	0.6619
		female	0.76	0.14	0.03	0.44	1.02	0.68	0.83	
Sella height median	<5	male	5.00	1.24	0.33	3.00	7.00	4.28	5.71	1.000
		female	5.00	0.89	0.37	4.00	6.00	4.06	5.93	
	5-	male	6.55	0.82	0.25	5.00	8.00	5.99	7.09	0.9143
		female	6.60	1.14	0.51	5.00	8.00	5.18	8.01	
	10-	male	6.67	1.35	0.35	4.00	9.00	5.92	7.41	0.9437
		female	6.63	1.30	0.46	5.00	9.00	5.53	7.71	
	15-	male	7.47	1.18	0.29	6.00	9.00	6.86	8.07	0.9718
		female	7.45	1.13	0.34	6.00	9.00	6.69	8.21	
	20-	male	7.42	1.26	0.29	5.00	9.00	6.81	8.02	0.0315*
		female	8.63	1.89	0.47	6.00	14.00	7.61	9.63	
	25-	male	7.92	1.10	0.22	6.00	10.00	7.45	8.38	0.4328
		female	8.23	1.63	0.32	4.00	12.00	7.57	8.89	
	30-35	male	7.35	1.60	0.31	5.00	11.00	6.70	7.99	0.4819
		female	7.65	0.86	0.21	6.00	9.00	7.20	8.09	
Sella area	<5	male	8.00	1.80	0.48	6.00	13.00	6.96	9.03	0.6847
		female	7.67	1.21	0.49	6.00	9.00	6.39	8.93	
	5-	male	9.64	1.57	0.47	7.00	12.00	8.58	10.68	0.9694
		female	9.60	2.07	0.93	7.00	12.00	7.02	12.17	
	10-	male	10.40	2.03	0.52	8.00	14.00	9.27	11.52	0.4398
		female	11.00	0.93	0.33	9.00	12.00	10.22	11.77	
	15-	male	11.65	1.66	0.40	9.00	15.00	10.79	12.49	0.8710
		female	11.55	1.51	0.45	10.00	14.00	10.53	12.55	
	20-	male	12.84	1.61	0.37	10.00	17.00	12.06	13.61	0.5749
		female	12.50	1.97	0.49	7.00	15.00	11.45	13.54	
	25-	male	12.04	1.78	0.36	8.00	15.00	11.28	12.79	0.6275
		female	12.27	1.51	0.30	9.00	15.00	11.65	12.87	
	30-35	male	12.35	1.62	0.32	8.00	15.00	11.69	13.00	0.9900
		female	12.35	1.87	0.45	8.00	16.00	11.39	13.31	

*: Statistically significant at $p \leq 0.05$

Table 4. Pearson's Correlation between the Measured Sella Variables and the Age of the Whole Studied Sample

	Age (years)	
	r	**p**
Sella width	0.460*	<0.001*
Sella length	0.305*	<0.001*
Sella height anterior	0.179*	0.008*
Sella height posterior	0.531*	<0.001*
Sella height median	0.456*	<0.001*
Sella area (mm^2)	0.536*	<0.001*

r: Pearson coefficient

*: Statistically significant at $p \leq 0.05$

Table 5. Linear Regression Equations for Age Estimation from the Measured Variables among the Whole Sample Population

	R^2	Adjusted R^2	Accuracy	SEE	t	p	Equation
Sella width	0.212	0.208	20%	8.593	0.377	0.707	-1.100 + (Sella width x 1.960)
Sella length	0.093	0.089	8%	9.219	1.600	0.111	5.313 + (Sella length x 1.590)
Sella height anterior	0.032	0.028	2%	9.522	19.304*	<0.001*	18.633 + (Sella height anterior x 0.694)
Sella height posterior	0.282	0.279	27%	8.199	4.361*	<0.001*	6.925 + (Sella height posterior x 2.257)
Sella height median	0.208	0.204	20%	8.613	0.095	0.925	0.262 + (Sella height median x 2.774)
Sella area (mm^2)	0.288	0.284	28%	8.169	2.461*	0.015*	4.476 + (Sella area x 22.670)

R^2 means coefficient of correlation of the function, SEE: standard error of estimate.

t, p: t and p values for Student t-test

*: Statistically significant at $p \leq 0.05$

Table 6. Linear Regression Models for Age Estimation from Sella Turcica Measurements among Males and Females Aged Less than 25 Years

Regression models	R^2	Accuracy	SEE	Adjusted R^2
Age estimation in males = -15.101 + (Sella width × -0.162) + (Sella length × 1.872) + (Sella height anterior × 0.675) + (Sella height posterior × 1.392) + (Sella height median × 0.594) + (Sella area × -0.669)	0.595	59%	4.913	0.560
Age estimation in females = -17.647 + (Sella width × 0.608) + (Sella length × 1.586) + (Sella height anterior × 0.842) + (Sella height posterior × 1.630) + (Sella height median × -0.175) + (Sella area × 1.574)	0.771	77%	3.636	0.736
Age estimation in cases of unknown sex = -14.722 + (Sella width × 0.056) + (Sella length × 1.665) + (Sella height anterior ×0.766) + (Sella height posterior × 1.432) + (Sella height median × 0.219) + (Sella area × 2.016)	0.651	65%	4.438	0.632

R^2 means coefficient of correlation of the function, SEE: standard error of estimate.

Table 7. Linear Regression Models for Age Estimation from Sella Turcica Measurements among Males and Females Aged More than 25 Years

Regression models	R^2	Accuracy	SEE	Adjusted R^2
Age estimation in males = 39.632+ (Sella width × -0.141) + (Sella length × -0.426) + (Sella height anterior × -0.336) + (Sella height posterior × -0.219) + (Sella height median × -0.479) + (Sella area × 2.823)	0.117	11%	2.963	0.007
Age estimation in females = 38.776+ (Sella width × -0.202) + (Sella length × -0.642) + (Sella height anterior × -0.533) + (Sella height posterior × -0.494) + (Sella height median × -0.215) + (Sella area × 6.846)	0.157	15%	2.844	0.017
Age estimation cases of unknown sex = 38.339 + (Sella width × -0.101) + (Sella length × -0.466) + (Sella height anterior × -0.400) +(Sella height posterior × -0.249) + (Sella height median × -0.283) + (Sella area × 2.428)	0.135	13%	2.848	0.074

R2 means coefficient of correlation of the function, SEE: standard error of estimate.

Table 8. Comparison of the Present Study with Previously Published Findings on the Sella Turcica Measurements

Authors	Populations	Research subjects	Number	Number of variables
Present study	**Egyptians**	**MDCT**	**215**	6
Shah AM et al (2011)	Pakistan population	Cephalometric radiographs	180	3
Ize-Iyamu IN et al (2014)	Nigerians	Cephalometric radiographs	106	3
Rai AR Et al (2016)	Indians	Cephalometric radiographs	36	6
Hasan et al (2016)	Malay population	CT (1.25 mm thickness and 1.25mm Spacing)	183	7
Sathyanarayana HP et al (2013)	South Indians population	Cephalometric radiographs	180	3
Hasan et al (2016)	Iraqi Population	CT	71	7

Figure 1.

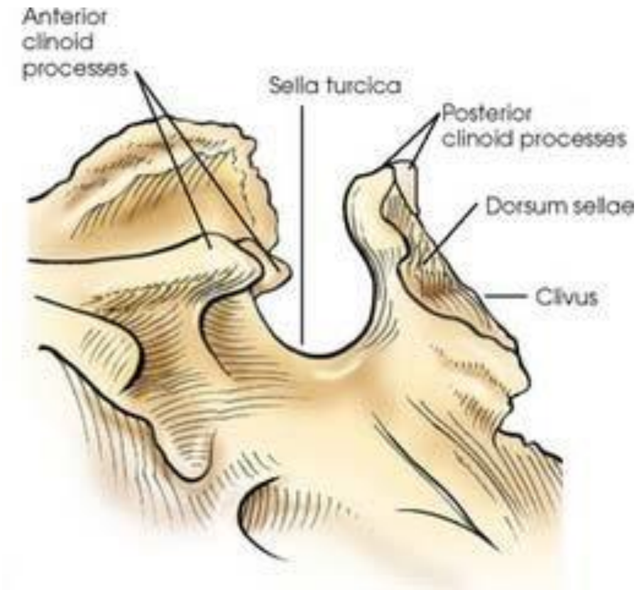
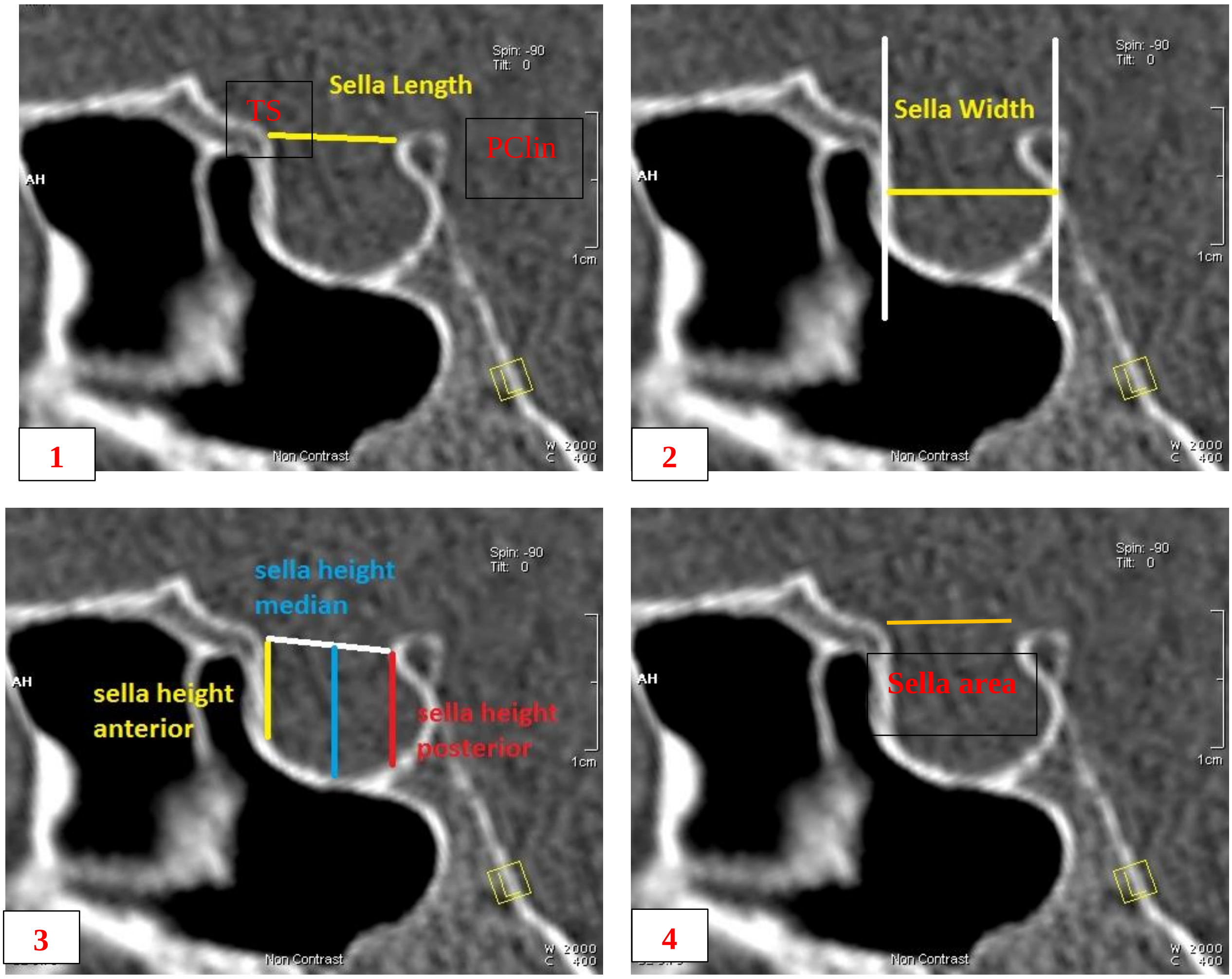
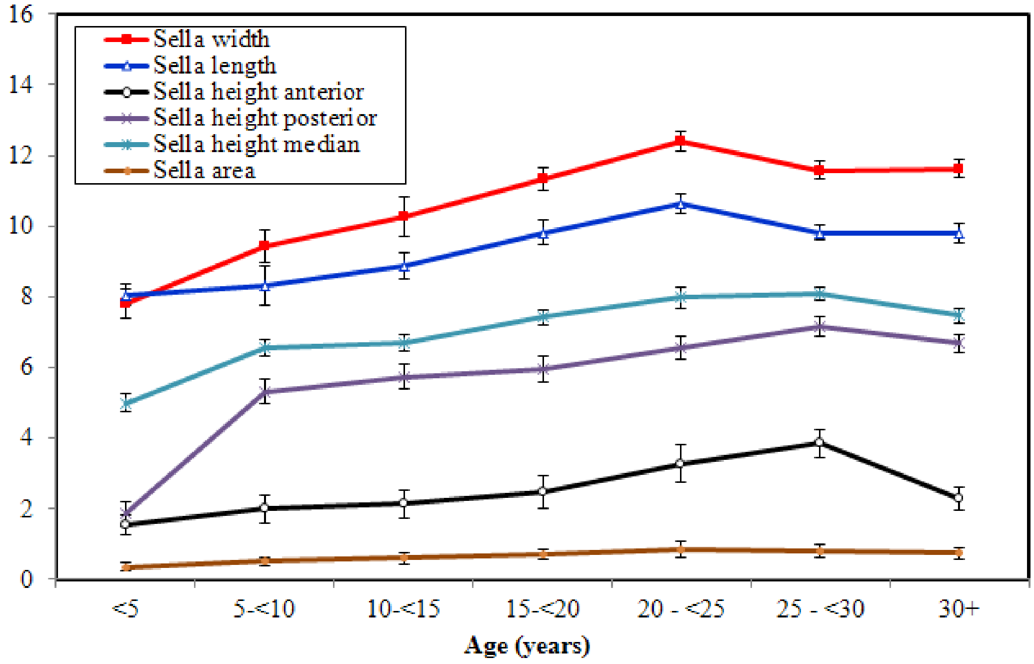

Anterior clinoid processes
Sella turcica
Posterior clinoid processes
Dorsum sellae
Clivus

Figure 2.



Sella Length
TS
PClin
Sella Width
sella height median
sella height anterior
sella height posterior
Sella area
1
2
3
4

Figure 3.



Sella width
Sella length
Sella height anterior
Sella height posterior
Sella height median
Sella area
16
14
12
10
8
6
4
2
0
<5
5-<10
10-<15
15-<20
20 - <25
25 - <30
30+
Age (years)

Figure Captions

Figure 1. Anatomy of Sella turcica

Figure 2. 3D-volume rendered reconstructions of the Multidetector CT slices of the Sella turcica. Sagittal view. 1. Sella length. 2. Sella width. 3. Sella height anterior, Sella height posterior and Sella height median. 4. Sella area.

Description of the Sella Turcica Selected Measurements According to Andredaki et al. 2007

Measurement	Description
1. Sella width (mm)	The distance extending from the most anterior to the most posterior point of the sella, parallel to the Frankfort plane (FH). It represents the largest antero-posterior dimension.
2. Sella length (mm)	The distance extending from the tuberculum sella (TS) to the posterior clinoid (PClin).
3. Sella height anterior (mm)	The perpendicular distance (vertical) from the tuberculum sella (TS) to the sella floor. It is measured perpendicular to the FH plane.
4. Sella height posterior (mm)	The vertical distance from the posterior clinoid (PClin) to the sella floor. It is measured perpendicular to the FH plane
5. Sella height median (mm)	The vertical distance, from the sella floor to a point midway between the PClin and the TS. It is measured perpendicular to the FH plane.
6. Sella area (mm^2)	The area included by the outline of the sella and capped by a line joining the PClin to the TS.

Figure 3. Linear growth curves of the selected Sella measurements among the whole sample.