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Volumetric Variations of the Human Orbit and Its Relation to the Eye ball and Morphology of Frontal and occipital cerebral Cortex Magnetic Resonance Imaging Study

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Abstract: Background: The orbit of eye is a craniofacial structure that can be exposed to different types of disorders. The measurements of the orbital volume have important for estimating craniofacial asymmetry during clinical examination and for estimation of the sternness of the hurt and prospected complications in planning for surgical operation and in postoperative assessment. **Aim of the work:** This investigation was designed to identify the volumetric variations of human orbit and evaluate the volumetric relations between the orbit, eyeball and frontal and occipital cortical gray matter by MRI. **Subjects and methods:** Fifty healthy individuals of both sexes aged from 20 years to 60 years were examined. The participating individuals were selected from MRI scanning unit, Radiology Department, Tanta University Hospital. The volume of orbit, eye ball and their relation to the cortical gray matter volume of frontal and occipital lobes were measured by MRI using the slicer 4.8.1 software and the effect of age, gender and side difference were evaluated. Frontal and occipital gyri volumes were calculated by Free Surfer to understand how the orbit and eyeball varied in correlation with both visual- and frontal cortical gyri which are related indirectly with visual processing. Data were statistically analyzed. **Results:** There was rightward asymmetry of orbital volume in males and females with significant positive correlation with age and a statistically highly significant difference between males and females. There was rightward asymmetry of eye ball volumes in males. It was found that the volume of eye ball decreased significantly with advanced in ages particularly in males, whereas, a non-significant correlation in females. There was highly significant difference of the total mean values of the right and left eye ball volumes between males and females. Orbital and eye ball volumes were weakly correlated, whereas the orbital and eyeball volumes were also found to be related with frontal lobe gyri than with occipital lobe gyri. **Conclusion:** It could be concluded that the effect of normal aging, gender and side differences was observed on orbital cavity and eyeball. Also, orbital and eyeball volumes were weakly correlated, and that the structural relationship of frontal lobe was more relevant than the functional relationships between orbit, eyeball and occipital lobe of the visual system.

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Key words: MRI; orbit; eyeball; frontal lobe; occipital lobe.

1. Introduction

The orbits are present on either side of the root of the nose in the form of bony cavities. They contain the eyes and the paired peripheral organs of vision. It can be divided into two portions, the eyeball present anteriorly, while the posterior portion is composed of the musculature, blood vessels and nerve supply of the eyeball, all components of the orbit are maintained in fatty matrix, cellular, the so-called adipose body of the orbit **(Hayek et al., 2006).**

In human evolution, there is a relationship between human brain and morphology of face. Modern humans have been a small faces and large brains which presented spatial conflicts amide these two anatomical blocks. Eye morphogenesis is influenced by brain growth and the orbit responds to facial growth, undergoing different evolutionary processes **(Weale, 1982; Waitzman et al., 1992; Mak et al., 2006 & Bruner et al., 2014).**

In modern humans, the facial block shifts under the neurocranial block, and the frontal parts are subsequently situated directly beyond the orbital roof. Therefore, the orbits are relatively affected by a spatial connection with the frontal cortex. Moreover, the eye size controls the orbital and visual cortical size as the increased ocular bulk associated with bigger orbits and visual cortices. Though, more researches are required concerning the anatomical association between the eye, orbit and visual cortex which is important for explaining the relationship between these anatomical structures **(Bruner and Holloway, 2010; Pearce and Dunbar, 2012 & Pearce and Bridge, 2013)**.

The orbit is a craniofacial construction that can be influenced by many factors such astraumatic, congenital, vascular and endocrine and neoplastic diseases. The measurement of bony orbital size in these cases, may have significant clinical uses for assessing asymmetry of craniofacial, the sternness of damage and probable complications in both planning before operation and during post-surgical evaluation. There are many tools for evaluating bony orbital volume. The water-filling method was the ideal standard parameter for assessment of size except can be applied merely in cadaver skulls **(Forbes et al., 1985 & Acer et al., 2009)**. In children and normal subjects which are sensitive to the radiation exposure, the scanning by magnetic resonance (MR) are characterized by a lack of radiation, which permitting MR scan safe and suitable for adults and children **(Chau et al., 2004b).**

So, this study was designed to identify the volumetric variations of human orbit and evaluate the volumetric relations between the orbit, eyeball and frontal and occipital cortical gray matter by MRI.

2. Subjects and Methods

Fifty healthy individuals were evaluated for the volume of orbit, eye ball and their relation to the cortical volume of frontal and occipital lobes by Magnetic Resonance Imaging (MRI). These subjects were chosen from CT and MRI scanning units of Radiology Department in Tanta University Hospital. Data were collected from individuals with normal orbits. According to the exclusion criteria of this study, no one had any underlying craniofacial anomaly, congenital malformations, local or systemic conditions that may affect the measurements such as hyperthyroidism, exophthalmos, or orbital mass. Subjects with osseous wall pathology of the orbit either traumatic or neoplastic and any positive criterion indicating a neurological pathology were excluded from the study group. The protocol of this work was approved by the research ethics committee in Faculty of Medicine Tanta University.

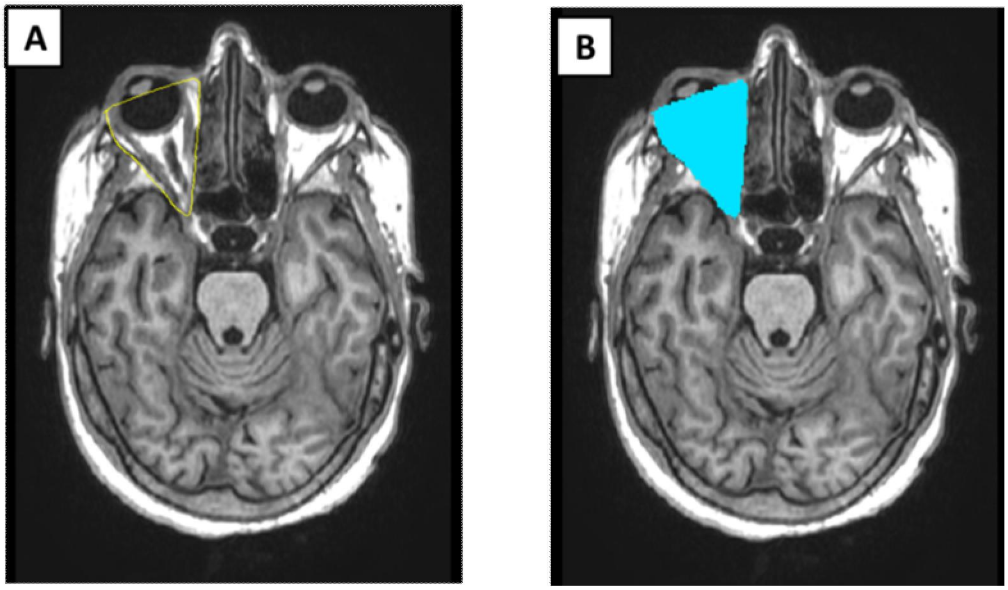


Fig. (1): Normal T1-weighted axial MRI of head showing (A) outlines of the orbital cavity between orbital base, medial and lateral walls and (B) defining orbit to create 3D model.

Subjects were classified into two groups, according to sex; male group and female group.

Male group included 24 subjects and then divided according to age into:

- **Group I (G I):** It included 12 males aging between 20-40 years old (24 orbits).
- **Group II (G II):** It included 12 males aging between 41-60 years old (24 orbits).

Female group included 26 subjects and then divided according to age into:

- **Group I (G I):** It included 13 females aging between 20-40 years old (26 orbits).
- **Group II (G II):** It included 13females aging between 41-60 years old (26 orbits).

MRI scanning machine

The study was done at MRI scanning unit at Radiology Department, Tanta University Hospital. The machine was the GE signa 1.5 Tesla system.

MRI processing:

In this study the following volumes were measured:

1. Magnetic resonance imaging (MRI) of the orbital and eye ball volumes (Figs. 1, 2 & 3):

By using 3D slicer 4.8.1 software that provides reliable morphometry of these structures by manual and semi-automated tracing.

2. Magnetic resonance imaging (MRI) of cortices volume of the frontal and occipital gyri:

By using FreeSurfer software version 6.0which is open source software for processing and analyzing of human brain MRI images.

Delineation of the studied regions:

Delineation was done by drawing outlines to define the orbital cavity and eye ball manually or by using 3D slicer 4.8.1 software semi-automated tools in every slice and create 3D model of both orbital cavity and eye ball **(Figs. 1, 2 & 3)**.

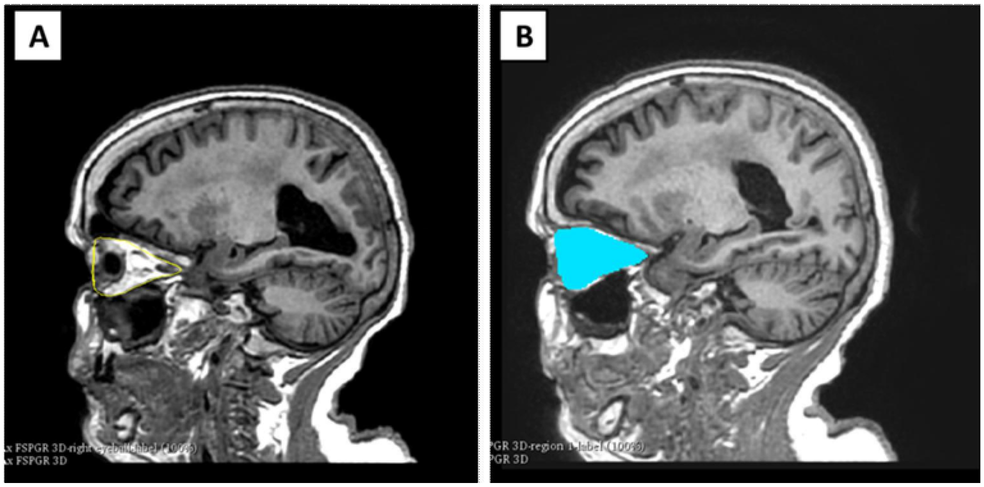


Fig. (2): Normal T1-weighted sagittal MRI of head showing outlines of the orbital cavity between orbital base, superior and inferior walls and (B) defining orbit to create 3D model.

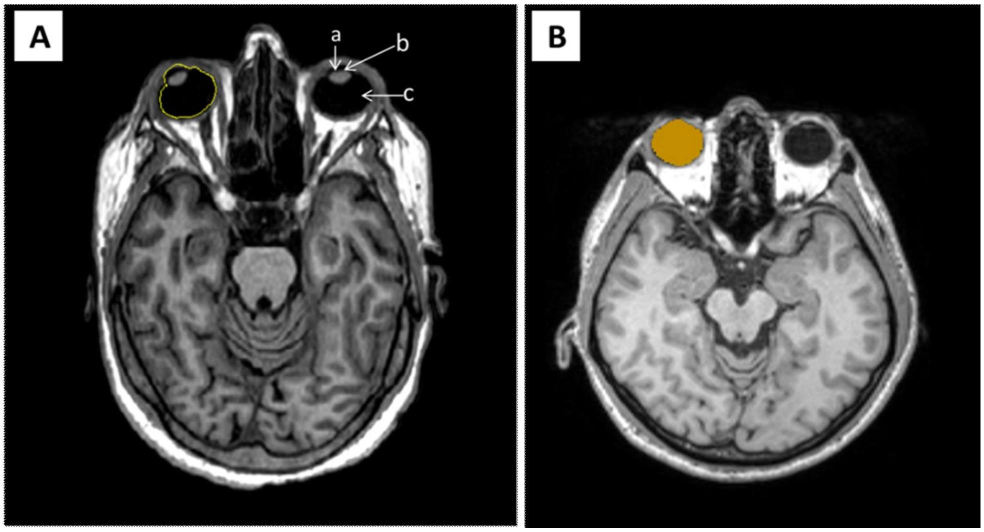


Fig. (3): Normal T1-weighted axial MRI of head showing outlines of the eye ball (A) and filling of ROI (anterior chamber (a), lens (b) and vitreous humor (c)) to create 3D model (B).

2. Magnetic resonance imaging (MRI) of frontal and occipital gyri volume measurement (Fischl et al., 1999):

MRI data acquisition:

MRI acquisition was performed on 1.5T MRI, the sequence used is Sagittal T1 SPGR (Spoiled Gradient Recall), with the following scan parameters: Slice thickness = 1 mm, TR = 7.7ms, TE = 3.5 ms, frequency = 256, phase = 256, FOV (field of view) =

25.6cm, Flip angle = 10º ASSET = 1.5), two 3D T1 weighted images were acquired for each subject.

Data processing (FreeSurfer):

Cortical reconstruction and volumetric segmentation were performed with the FreeSurfer image analysis, which is documented and freely available for download online **(http://surfer.nmr.mgh.harvard.edu/).**

Statistical analysis:

The obtained data of this study were recorded and analyzed using statistical Minitab 17 software (Minitab Inc., USA). Mean ± standard deviation (SD) of all measurements were performed in male and female groups, Paired Student's t-test was used for comparison of changes occurring between right and left orbits within the same group either males or female. Unpaired Student's two-Sample-test was used for comparison of changes occurring in two different sex groups at the same time. Pearson correlation between variables was done using correlation coefficient "r" to detect if the change in age was accompanied by corresponding change in the orbital and eye ball volumes in male and female groups. Simple linear regression (bivariate regression) was done to detect the proportion of variance in orbital volume that can be explained by eye ball volume. The proportion of variance in the outcome variable was explained by the predictor variable and illustrated by R Square (R^2). Multiple linear regression (multivariate regression) was done to detect the proportion of variance in orbital volume that can be explained eye ball volume and age variables. The proportion of variance in the outcome variable was explained by the predictor variable and illustrated by R Square (R^2). For all the comparisons P value≤ 0.05 was considered significant and $P \leq 0.001$ was considered highly significant. Whereas, if P value was > 0.05, insignificant difference was present.

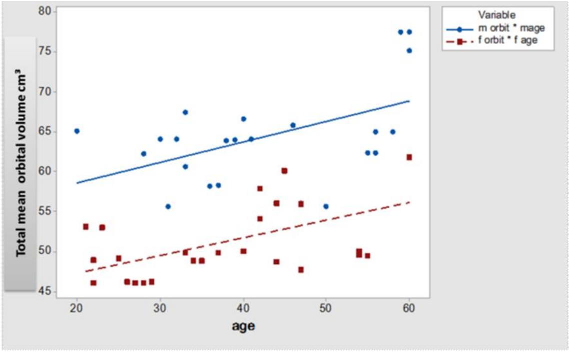
3. Results

The mean values of right and left orbital cavity volume in males and females were described in (Table 1) showing rightward asymmetry of orbital cavity volumes in both males and females.

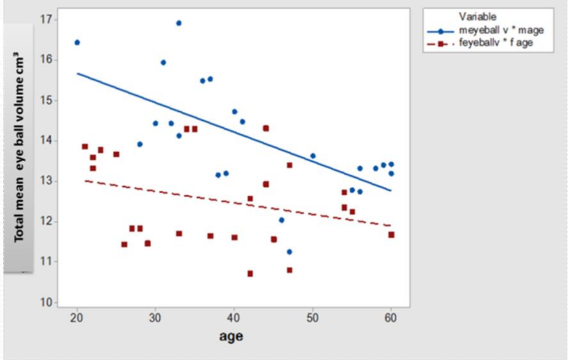
The results revealed that the volume of orbital cavity was significantly differed between males and females (Table 2). Significant positive association was found the among the orbital volume and the sex groups between as shown by additional statistical analysis (Table 3) (Graph 1).

There was a statistically highly significant difference between males and females regarding the total mean values of right and left orbital cavity volume ($P < 0.001$**) (Table 4).

The mean values of right and left eye ball volume in females and males were described in (Table 5). Although the volume of right eye ball was larger than that of the left, there was a statistically insignificant difference between them in males ($P= 0.1$). In females the volumes amide the right and left eye balls was differed significantly ($P= 0.003$). Concerning the males, highly significant differences was found between the eye ball volume (both right and left sides) and the age. Whereas, in females a non-significant association between the volume of the eye ball and the age was recorded in the present study (Table 6). In contrast, in males a highly significant negative association was found amide the total mean values of eye ball volume and the age ($P \geq 0.001$). Additional statistical analysis, illustrated that difference was highly significant concerning the total mean values of the right and left eye ball volumes between males and females ($P < 0.001$) (Graph 2).

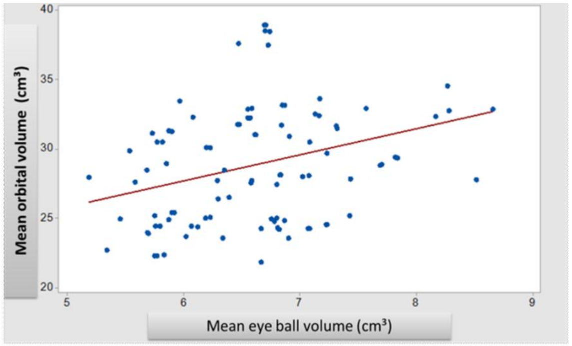


Graph (1): Scatter plot and linear regression showing significant positive correlation between age and the total mean orbital volume in males (blue circles, solid regression line) and females (red squares, dotted regression line).

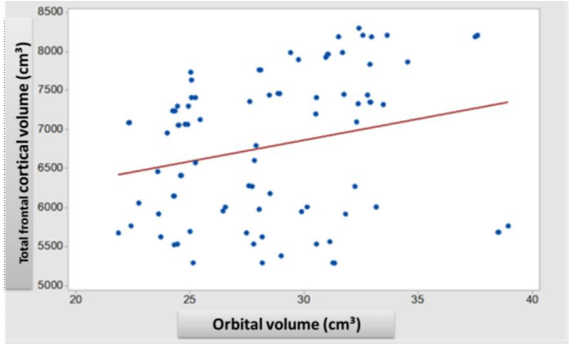


Graph (2): Scatter plot and linear regression showing highly significant negative correlation between age and the total mean eye ball volume in males (circles, solid regression line) and insignificant correlation in females (squares, dotted regression line).

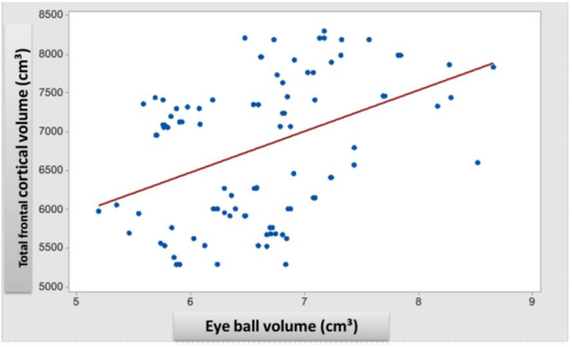
Correlation between orbital and eye ball volumes: Bivariate regression analysis of the relationship between orbital and eye ball volumes showed that these two variables were significantly correlated (R = 0.311, t = 3.242 and P =0.002). This correlation was weak as it was present in 8.8% of entire population (Adjusted R^2 = 0.088) (Table 8) (Graph 3).



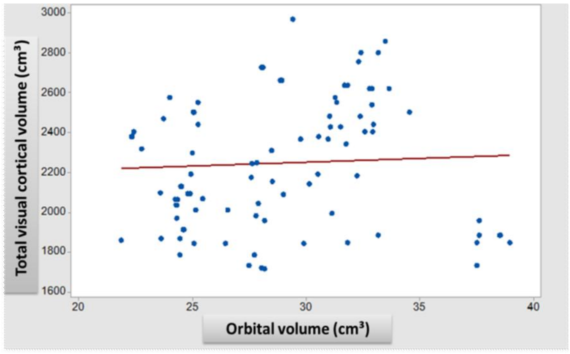
Graph (3): Scatter plot and linear regression showing a significant positive correlation between the orbital volume and eye ball volume.



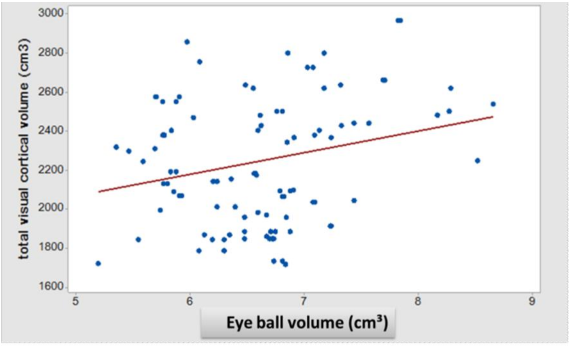
Graph (4): Scatter plot and linear regression showing a significant positive correlation between orbital volume and total frontal cortical gray matter volume. (R =0.252, P= 0.01*). Persons with larger orbital volume have lager total frontal cortical gray matter volume.



Graph (5): Scatter plot and linear regression showing a highly significant positive correlation between eyeball volume and total frontal cortical gray matter volume. (R =0.406, P< 0.001**). Persons with larger eyeball volume have lager total frontal cortical gray matter volume.



Graph (6): Scatter plot and linear regression showing insignificant correlation between orbital volume and total visual cortical gray matter volume. (R =0.051, P= 0.6). The orbital volume wasn't affected by total visual cortical gray matter volume.



Graph (7): Scatter plot and linear regression showing a significant positive correlation between eye ball volume and total visual cortical gray matter volume. (R=0.254, P= 0.01*). The persons with larger eyeball volume have larger total visual cortical gray matter volume.

By applying the least square multivariate regression analysis, post taken in consideration an age in the correlation among orbital and eye ball volumes became statistically highly significant (R = 0.599, Adjusted R2= 0.359, t = 6.396, P = 0.000) (Table 9).

Correlation between orbit, eye ball, and frontal cortical gray matter volumes was described in (Table 10) (Graph 4 & 5) indicating that bivariate regression analysis using FreeSurfer derived frontal lobe ROIs indicated that orbital volume was significantly correlated with the total frontal cortical gray matter volumes. the eyeball volume was highly significantly correlated with the total frontal cortical gray matter volumes.

By applying the least square multivariate regression analysis, after taken in consideration the correlation among both orbital cavity, eyeball volumes and total frontal cortical volume were still statistically highly significant.

Correlation between orbit, eye ball and occipital cortical gray matter volumes was described in (Table 11) (Graph 6 & 7) indicating that orbital volume vs. total visual cortical gray matter volume obtained using FreeSurfer, showed that these two variables were insignificantly correlated. Whereas, Bivariate regression analysis of eyeball volume vs. total visual cortical gray matter volume obtained by FreeSurfer, showed significant positive correlation between these two variables.

Table 1: Mean ± SD and range of orbital volume in right and left sides and paired t-test significance between them in males and females.

Orbital cavity volume (cm^3)	**Right side**		**Left side**		**t test**	
	mean± SD	**Range**	**mean± SD**	**Range**	**t value**	**P value**
Male	**32.611± 3.064**	27.81- 38.53	**32.043±3.313**	27.47-38.95	2.7	**0.01***
Female	**26.076± 2.413**	21.83-31.34	**25.311±2.631**	22.29 -31.13	2.76	**0.01***

Table (2): Showing the orbital volume (Mean±SD) of the two different age groups in both males and females.

Parameter	**Groups**	**Mean ± SD**		**t value**		**P value**	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**
Right orbital volume (cm^3)	Group I	**31.429 ± 1.926**	**24.793 ± 1.707**	2.01	3.161	**0.05***	**0.004***
	Group II	**33.792 ± 3.588**	**27.356 ± 2.376**				
Left orbital volume (cm^3)	Group I	31.098 ± 1.860	**23.865 ± 1.09**	1.428	3.313	0.1	**0.003***
	Group II	32.987 ± 4.188	**26.756 ± 2.95**				

*Group I (20-40 years), Group II (41-60 years)

Table 3: Showing the relationship between the age and the orbital volume in males and females from 20-60 years.

Parameter	**Correlation with Age**	
	r	**P**
Male orbital cavity volume	**0.497**	**0.01***
Female orbital volume	**0.584**	**0.002***

Table 4: Sex differences between the total mean values of orbital volumes.

Measured parameter (cm^3)	**Male**	**Female**	**t value**	**P value**
	Total mean (R+L) ± SD	**Total mean (R + L) ± SD**		
Orbital volume	**64.65 ± 6.30**	**51.39± 4.85**	8.385	**0.000****

P≤ 0.05 =Significant (*), P≤ 0.001 =highly Significant (**)

Table 5: Mean, ± standard deviation (SD) and range of right and left eye ball volumes and paired t-test significance between them in males and females.

eye ball volume (cm^3)	**Right side**		**Left side**		**t test**	
	mean± SD	**Range**	**mean± SD**	**Range**	**t value**	**P value**
Male	7.037± 0.738	5.687-8.657	6.936±0.659	5.58- 8.27	1.58	0.1
Female	**6.313 ± 0.566**	5.46 -7.43	**6.209±0.562**	5.19 - 7.23	3.33	**0.003***

P≤ 0.05 =Significant (*)

Table 6: The eye ball volume (cm³) of the two different age groups in males and females (Mean±SD).

Parameter	**Groups**	**Mean ± SD**		**t value**		**P value**	
		Male	**Female**	**Male**	**Female**	**Male**	**Female**
Right eyeball volume (cm^3) 0	Group I	**7.5 ± 0.711**	6.448 ± 0.572	3.922	1.231	**0.001****	0.2
	Group II	**6.573 ± 0.404**	6.177 ± 0.548				
Left eye ball volume (cm^3)	Group I	**7.370 ± 0.55**	6.387 ± 0.599	4.27	1.483	**0.000****	0.1
	Group II	**6.501 ± 0.44**	5.63 ± 1.740				

Group I (20-40 years) & Group II (41-60 years), P≤ 0.05 =Significant (*), P≤ 0.001 =highly Significant (**)

Table 7: The relationship among the age and the eye ball volume in males and females 20-60 years.

Parameter	**Correlation with age**	
	r	**P**
Male eye ball volume	**-0.654**	**0.001****
Female eye ball volume	-0.319	0.1

P≤ 0.05 =Significant (*), P≤ 0.001 =highly Significant (**)

Table 8: Sex differences among the total mean values of the eye ball volumes.

Measured parameter (cm^3)	Male	Female	t value	P value
	Total mean (R+L) ± SD	Total mean (R + L) ± SD		
Eye ball	**13.97±1.36**	**12.52±1.12**	4.131	0.000**

P≤ 0.05 =significant (*) P≤ 0.001 =highly significant (**) R: right. L: left.

Table 9: bivariate regression analysis between the orbital and the eye ball volumes.

Parameter	Eye ball volume			
	R	Adjusted R^2	t	P
Orbital volume	0.311	0.088	3.242	0.002*

P ≤ 0.05 =Significant (*)

Table9: least square regression analysis between orbital and eye ball volumes after including age.

Parameter	Eye ball volume and age			
	R	Adjusted R^2	t	P
Orbital volume and age	0.599	0.359	6.396	0.000**

P ≤ 0.05 =Significant (*), P ≤ 0.001 =highly Significant (**)

Table 10: Bivariate regression analyses of orbital and eye ball volumes vs. frontal lobe gyri volumes obtained using FreeSurferversion 6.0 generated frontal lobe gyri volumes.

Frontal lobe gyri volumes	Orbital volume				Eye ball volume			
	R	R^2	t	P	R	R^2	t	P
Total frontal cortex	0.252	0.063	2.573	0.01*	0.406	0.165	4.401	0.000**
Superior frontal gyrus	0.178	0.032	1.794	0.07	0.387	0.149	4.15	0.000**
Caudal middle frontal gyrus	0.250	0.062	2.556	0.01*	0.420	0.177	4.584	0.000**
Rostral middle frontal gyrus	0.215	0.046	2.177	0.03*	0.390	0.152	4.197	0.000**
Medial orbito frontal gyrus	0.374	0.140	3.993	0.000**	0.420	0.177	4.586	0.000**
Lateral orbito frontal gyrus	0.274	0.075	2.826	0.006*	0.414	0.172	4.507	0.006*
Pars opercularis	0.134	0.018	1.344	0.1	0.205	0.042	2.072	0.04*
Pars orbitalis	0.023	0.001	0.228	0.8	0.185	0.034	1.868	0.06
Pars triangularis	0.080	0.006	0.799	0.4	0.153	0.023	1.533	0.1
Frontal pole	0.477	0.228	5.375	0.000**	0.277	0.077	2.858	0.005*

P ≤ 0.05 =Significant (*), P ≤ 0.001 =highly Significant (**)

Table 11: Bivariate regression analyses of orbital and eyeball volumes vs. occipital lobe gyri volumes obtained using FreeSurfer version 6.0-generated occipital lobe gyri volumes.

Occipital lobe gyri volume	Orbital volume				Eyeball volume			
	R	R^2	t	P	R	R^2	t	P
Total visual cortex	0.051	0.003	0.502	0.6	0.254	0.064	2.598	0.01*
Lateral occipital gyrus	0.061	0.004	0.602	0.5	0.233	0.054	2.37	0.02*
Cuneus	0. 03	0.001	0.302	0.7	0.238	0.056	2.422	0.01*
Pericalcarinegyrus	0.260	0.067	2.662	0.003*	0.236	0.055	2.399	0.01*
Lingual gyrus	0.168	0.028	1.685	0.09	0.139	0.019	1.394	0.1

P ≤ 0.05 =Significant (*), P ≤ 0.001 =highly Significant (**).

4. Discussion

In the present study, the volumes of 100 orbits of 50 healthy individuals were evaluated by using the MRI. The mean orbital volume of adult Egyptian males were similar to the results of Deveci et al. (2000) in Caucasians (28.41 ± 2.09 ml) and greater than Furuta (2001) in Japanese subjects (males 23.6 ± 2.0 mL, females 20.9 ± 1.3 ml), Ye et al. (2006) in Korean peoples (23.94 ± 3.47 ml), Chau et al. (2004b) in Chinese (females: 19.81 ± 2.23 ml, males:22.20 ± 1.38 ml), in Caucasians subjects was 25.17 ± 0.06 ml (Regensburg et al., 2008), whereas, Ji et al. (2010) who reported that the average orbital volumes were 26.02 ml and 23.32 ml in three dimensional computerized tomographic images of Chinese males and females respectively. The differences might be attributed the racial variation, the dissimilar radiological methods, in addition to the size of sample.

With regard to the two sides of the orbital capacity in subjects, the volumes of left and right orbit in both males and females was differed significantly. This result agreed with some investigators who recorded that orbital volume was differed significantly among the right and left sides and they stated that the orbital volume parameter was only which showing a significant variation amide the two orbits (Forbes et al.,1985) similar to the result of the present study. In contrast Ji et al. (2010) reported that a non-significant variation was reported between the orbital volume and the two sides in normal Chinese adult population.

With respect to age, the current study showed a positive correlation between the age and the measured orbital volume in both males and females. The size of the orbit increased significantly according to the age group, where it increased in subjects of 20-40years than 40-60 years, in coordination with the results of Furuta (2001) who established that the size of orbit increased significantly at 18-40years than greater than 40 years. These data proposed that the cause may be attributed to an overall bony expansion of the whole bony orbit leading to increased in the volume of orbit. Some contradicted results found that orbital bony volume elements decreased with advanced in ages which might lead to the manifestation of aging in the orbit particularly after joined with changes in surrounding soft tissue (Kahn and Shaw,2008 & Yoo et al.,2013). Also, some authors found that the orbital volume reduced with advancing in age, where, the mean orbital volume of peoples at 20years of age was higher than of 40years old (Kim et al.,2012). These finding can be explained by some researchers, where the content in the total orbital fat was higher in advancing ages and proposed that expansion of fat is the main cause for increasing the volume of orbit (Darcy et al.,2008).

Regarding to sex, in the present study it was found that orbital volume in males was higher than that in females with statistically high significant difference. These results were confirmed by Baek et al. (2002); Kim et al. (2012) & Shyu et al. (2015) who found that the mean size of orbital in male was statistically higher than in female. This difference may be due to the larger glabello-maximal length of the male cranium relative to that of females (Oladipo et al., 2009).

MRI is the best method of eyeball measurement because it not exposed the subjects to the ionizing radiation and give maximal contrast resolution of soft tissues, in addition to an ability for multiplanar (Acer et al., 2011). The mean values of eye ball volume in the present study, were higher than the values obtained by Chau et al. (2004a), who reported 6.70 cm^3 mean volume and lower than the data of Hahn and Chu (1984) (mean volume 9.26 cm^3), Thaller (1997) (8.15 cm^3) and Bite et al. (1985) (8.94 cm^3 mean volume).

The difference in measuring eye ball volume between the current study and the previous authors might be due to many causes. Chau et al. (2004a) reported the mean eye ball volume in all entire population without specification to males and females. While Thaller, (1997) used a method of water displacement and Bite et al. (1985) used CT images. Also, Acer et al. (2009) used the planimetric method, and found the eye ball volume obtained was averaged in males and females 7.49 and 7.06 cm^3, respectively.

In the present study, the age was negatively correlated ($P \geq 0.001$) with the eye ball volume in Egyptian males and insignificant correlation in females. This result was coincident with Ibinaiye, et al. (2014) who recorded significant correlation between age and eyeball for both eyes and indicated that the eyeball volume started to decline after age of forty. Also, Master et al. (2015) reported that orbital size increased and eye ball volume decreased with an advancement of age. On the other hand, Özer et al. (2016) observed that there was insignificant correlation between the age and the eye ball volume in both males and females in Turkish population.

These finding can be explained by Salvi et al. (2006) who reported that age dystrophic changes occur in corneal epithelium, stroma and endothelium. So, cornea of elderly is thinner than that of young age group which indicating changes of the eyeball with age. They added that irreversible process in the vitreous are occurred with the progressing in age, which are characterized by deterioration in the components of collagen fibrils and hyaluronic acid which subsequently leading to shrinkage of vitreous body.

There was statistically high significant difference of eye ball volumes between males and females. These findings were coincident with Acer et al. (2009) who observed statistically significant difference of eye ball volumes between Turkish males and females. On the other hand, Özer et al. (2016) reported that there was a statistical difference in the antro-posterior diameter of the eyeball on the right and left sides for both genders in Turkish population but there was no difference in eyeball volumes.

In the present study, the relationship between orbital and eye ball volume showed that these two variables were significantly correlated ($t = 3.242$, $P = 0.002$), even though with a comparatively low R^2, somewhere average eye ball capacity elucidates merely 8.8% of the difference in average orbital size in entire population (Adjusted $R^2 = 0.088$). This finding was coordinated with the finding of Pearce & Bridge (2013) in which the variables were found to be correlated significantly, yet gave low R^2 value (0.17). Also, Masters et al. (2015) reported a correlation between eye ball and orbital volume with low $R^2 = 0.15$. Low adjusted R^2 of this study was considerably lower than the expectant in case of the eye ball volume directly prescriptions orbital volume in human beings. The overall absence of effect of the eyeball size on the development of orbital volume detected in the current work too corroborated by preceding researchers (Chau et al., 2004a) who reported that the orbit size was fairly associated with volume of eyeball ($r = 0.13$, $P > 0.005$).

In the least squares multivariate regression analysis, the relationship between orbital and eye ball volumes was statistically highly significant (Adjusted $R^2 = 0.359$, $P < 0.001$) after counting age in consideration. Whereas, after including the sex, the relationship between orbital and eye ball volumes was insignificant. Masters et al. (2015) reported that in the least-squares regression analysis, after comprising age and sex beside the ocular size the correlation among eyeball and orbital volumes was non-significant and reported that age was contributed to greatly to eye ball size and considered as a predictor of orbital size. This difference between two studies might be due to the unavailable visual acuity measures in the present study.

The relation between eye ball and orbit may explain development of myopia and hypermetropia. Abnormal axial length of the globe may lead to both Hypermetropia and myopia: the axial length of the globe is long in myopia, while in case of hypermetropia is short. Such these conditions (myopia and hypermetropia) may change the normal linkeamide eye size and orbit (Chau et al., 2004a). Appreciative the development of certain forms of myopic refractive error such as astigmatism and juvenile-onset myopia depending of the degree of correlation between the sex and age and both orbital volume and eye ball, might have effects. In a sample of Chinese adults, the comparative size of the eye in relation to the orbit volume had been established to be linked with near sightedness. With regard to body size, there are a negative allometric relationship between the orbit and eye (Masters, 2012). In high-myopic people, the large eye ball relative to orbital size was compressed and malformed not in favor of the walls of the orbit (Palmowski-Wolfe et al., 2009).

In the present study, the orbital and eye ball volumes were strongly correlated with the total frontal cortical gyri volumes ($P \leq 0.01$). There were statistically highly significant positive correlations between both orbital volume, eye ball volume and frontal lobe cortical gyri even after accounting for the variance of age ($P < 0.001$). These findings were in agreement with Masters et al. (2015) who demonstrated that the volume of orbit was correlated significantly with frontal lobe size.

In the current study, the analysis of the relationship between orbital volume and total occipital lobe cortical volume, showed that these two variables were insignificantly correlated ($P= 0.6$). However, after accounting for the variance of age the relationship was significant ($P = 0.005$). The relationship between orbital volume and the occipital cortical region of interest (ROIs) was return again insignificant with addition of sex. These results were in agreement with Masters et al. (2015) who concluded that the orbit was merely a modest interpreter of visual cortical structure in human beings, and both the orbit and eyeball were usually more anatomically linked with the frontal lobes than they were functionally linked with the visual cortex of the occipital lobes.

In the present study, the analysis of the relationship between eye ball volume and total occipital lobe cortical volume, showed that these two variables were positively correlated ($t = 2.598$, $P= 0.01$) with eye ball volume, elucidation 5.5% of the total variance for these collective visual cortical areas (Adjusted $R^2= 0.055$). This weak correlation was confirmed by Pearce & Bridge (2013) who reported that some relationships are found among the components of the visual system and the eye, however, these correlations were non-significant (week). Additionally, after age and sex were included in the current study the correlation was non-significant among the total of the visual cortical gray matter volumes and the volume of eye ball. This result was approved by Masters et al. (2015) who suggested that the eye ball can't be taken as strong interpreter of morphology of visual cortex, particularly during searching for intra-specific variations amide adult subjects.

The different associations with orbital structures were not limited to the visual cortical areas, as the present study confirmed that the volume of orbit was significantly associated with frontal lobe sizes that were not linked with vision. Furthermore, the illustrative importance of the model particularly in case of age inclusion beside the volume of the orbit was substantially high for the frontal lobe than for the occipital lobe. This was motivating, where the upper face and the frontal lobes are closely incorporated in terms of morphogenesis, and owing to the physical contiguity among the anterior cranial fossa, housing the prefrontal cortex, and the orbital areas (Enlow, 1990 & Bruner, 2015).

Conclusion

The effect of normal aging, gender and side differences was observed on the selected regions (orbital cavity and eyeball). Obtained results provide useful baseline data that may be used in further statistical studies to track individual changes with time.

Results of this study revealed that orbital and eyeball volumes were non-significantly correlated, and that eyeball volume explained only a small part of the differences in orbital volume. The volumetric relationship between the orbit/eyeball and cerebral gyri cortical gray matter linked with visual performance was somewhat weaker in assessment with the frontal lobe gyri cortical gray matter. This relationship indicated that structural relationship of frontal lobe in the anterior skull was more appropriate than the functional linkes among the anterior and posterior aspects of the visual system.

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Conflict of interest:

The authors declare that there is no conflict of interest associated with this work.

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