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ORIGINAL ARTICLE

# Normative Measurements of Orbital Structures in the Hong Kong Population

**TY Ko, JHM Cheng, YS Luk, JLS Khoo**

*Department of Radiology, Pamela Youde Nethersole Eastern Hospital, Hong Kong*

## ABSTRACT

***Objective:*** *We sought to establish normative measurements of orbital structures in the Hong Kong population using computed tomography (CT), and to evaluate for differences according to sex and age.*

***Methods:*** *CT paranasal sinus examinations were retrospectively reviewed. Differences according to sex and age were analysed using Student's* t *test and Pearson's correlation, respectively.*

***Results:*** *Data of 256 patients (F:M=141:115, age range, 21-91 years) were included. Normal measurements of the diameters of the extraocular muscles (EOMs) [mean ± 2 standard deviations] were: medial rectus 3.5 ± 1.3 mm; lateral rectus 3.2 ± 1.3 mm; superior rectus and levator palpebrae superioris (superior muscle group) 3.4 ± 1.3 mm; and inferior rectus 3.8 ± 1.7 mm. The normal ranges for other orbital structures were as follows: globe diameter 25.8 ± 2.8 mm; optic nerve diameter 4.4 ± 1.7 mm; and interzygomatic line 97.7 ± 7.8 mm. The normal position of the globe was 16.7 ± 5.2 mm. Sex differences were noted in the means of EOM thickness, globe size, interzygomatic lines ($p = 0.0002$, $p = 0.0002$, $p < 0.0001$ respectively), and anterior globe position ($p = 0.0045$). A positive correlation was found between age and the sum of the mean diameters of the EOMs ($r = 0.17$, $p = 0.0072$).*

***Conclusion:*** *Our results may help radiologists and clinicians to interpret CT scans of Hong Kong patients with suspected EOM enlargement, proptosis, or other changes in orbital morphology more quantitatively.*

***Key Words:*** *Anatomy; Asian continental ancestry group; Exophthalmos; Extraocular muscles; Orbit*

## 中文摘要

### 香港人口眼眶結構的正常尺徑

**高子恩、鄭希敏、陸嬈、邱麗珊**

**目的：**我們試圖建立使用電腦掃描（CT）對香港人口的眼眶結構進行規範測量，並評估其性別和年齡差異。

***Correspondence:*** *Dr TY Ko, Department of Radiology, Pamela Youde Nethersole Eastern Hospital, Hong Kong*
*Email: benkty@gmail.com*

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**方法：**回顧分析CT鼻旁竇檢查，分別使用Student's *t*檢驗和Pearson相關係數分析按性別和年齡劃分的差異。

**結果：**納入256例患者的資料（女性：男性 = 141：115，年齡介乎21-91歲）。眼外肌（EOM）直徑的正常測量值（平均值±2標準偏差）包括：內直肌3.5±1.3 mm、側直肌3.2±1.3 mm、上直肌和上瞼提肌（上肌群）3.4±1.3 mm、下直肌3.8±1.7 mm。其他眼眶結構的正常範圍如下：球形直徑25.8±2.8 mm、視神經直徑4.4±1.7 mm、雙眼顴間隙線為97.7±7.8 mm。眼球的正常位置為16.7±5.2 mm。EOM的厚度、球體大小、雙眼顴間隙線和前眼球位置呈性別差異（分別為$p = 0.0002$、$p = 0.0002$、$p < 0.0001$和$p = 0.0045$）。年齡與EOMs的平均直徑總和呈正相關（$r = 0.17$，$p = 0.0072$）。

**結論：**研究結果可有助於放射科醫生和臨床醫生更定量地解釋疑似香港患者EOM增大、眼底突出或其他眼眶形態改變的CT報告。

## INTRODUCTION

Many disease entities affect the thickness of the extraocular muscles (EOMs), as well as the position of the globe, with Grave's ophthalmopathy one of the commonest examples to affect both as part of its disease process.[1] It is therefore important to establish normative values for the orbital structures of concern in order to detect abnormal findings on imaging. Studies have shown differences in normal values in populations of different ethnicities.[2,3] No comprehensive normative measurements for orbital structures have been published regarding the Hong Kong Chinese population, hence the conception of this study. Different imaging modalities are available for the measurement of the orbital structures, including computed tomography (CT), magnetic resonance imaging, and ultrasound.[4] Despite the superiority of magnetic resonance imaging in evaluating soft tissue such as EOMs, CT remains the more readily available modality in Hong Kong, therefore was the modality of choice in this study. The aim of the present study was to establish normative measurements of orbital structures in the Hong Kong Chinese population using CT, and to evaluate any sex- or age-related differences.

## METHODS

The imaging data from a total of 289 consecutive patients referred to the authors' department for CT scans of the paranasal sinuses (with or without intravenous contrast) during the period February 2016 to February 2018 were retrospectively reviewed. Only Hong Kong Chinese patients were included; other ethnicities were excluded. Cases of hyperthyroidism, known orbital abnormalities, and studies with significant imaging artefacts were excluded.

The examinations were performed with two CT scanners, Toshiba Aquilion 64 (Toshiba Medical, Tochigi, Japan) and Siemens Somatom AS+ (Siemens Healthcare, Erlangen, Germany). Acquisitions consisted of 0.5-mm axial sections with or without intravenous contrast administration. The EOMs and the optic nerve sheath complexes were measured perpendicular to the orbital wall in the coronal plane. The axial and sagittal axes were aligned along the ipsilateral optic nerve, and the maximum diameters were measured on coronal reconstructions (Figure 1). The superior rectus and the levator palpebrae were measured together as a single superior muscle group, as the two were not readily distinguishable at their maximal thicknesses. The superior muscle group and inferior rectus muscle were measured vertically, whereas the medial rectus muscle, lateral rectus muscle, and optic nerve sheath complex were measured horizontally.

For the measurements of the interzygomatic line, globe sizes, and globe positions, the superior-inferior axis was aligned along the falx cerebri in the coronal plane, along the anterior-posterior axis formed by the crista galli in the axial plane, and along the optic nerve in the sagittal plane.[5] Measurements of these structures were then done in the axial plane. The interzygomatic distance was measured at the level of lenses. The globe size was measured as the maximal diameter perpendicular to the interzygomatic line. The globe positions were measured as the maximal dimensions perpendicular to the interzygomatic line and the anterior margin of the globe (Figures 2 and 3). All images were viewed under constant window and level settings of width 300 HU and level 40 HU during the measurements, to prevent slight

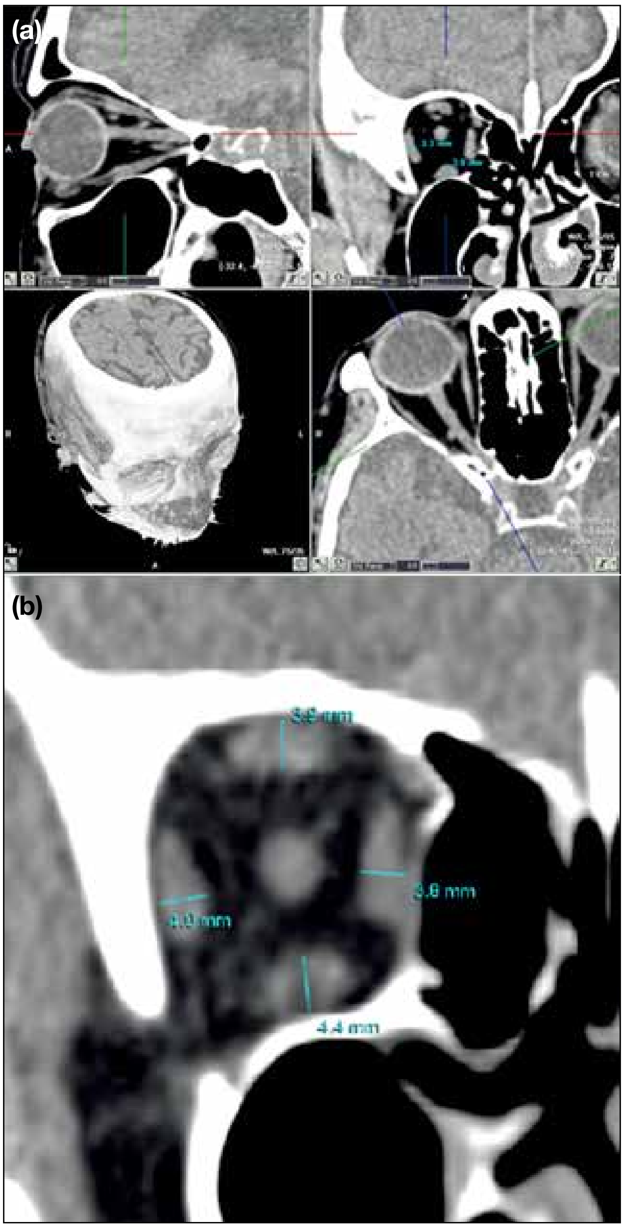


**Figure 1.** (a) Selected images of the right orbit. The extraocular muscles were measured on coronal view with the axial and sagittal axes aligned along the ipsilateral optic nerve. (b) Selected magnified image of the right orbit. The extraocular muscles were measured on coronal view with the axial and sagittal axes aligned along the ipsilateral optic nerve.

**Figure 2.** Axial image of the orbits at the level of the lenses. The interzygomatic line was measured as the distance between the two zygomas at the level of the lenses. The globe sizes were measured as the maximal dimensions perpendicular to the interzygomatic line.

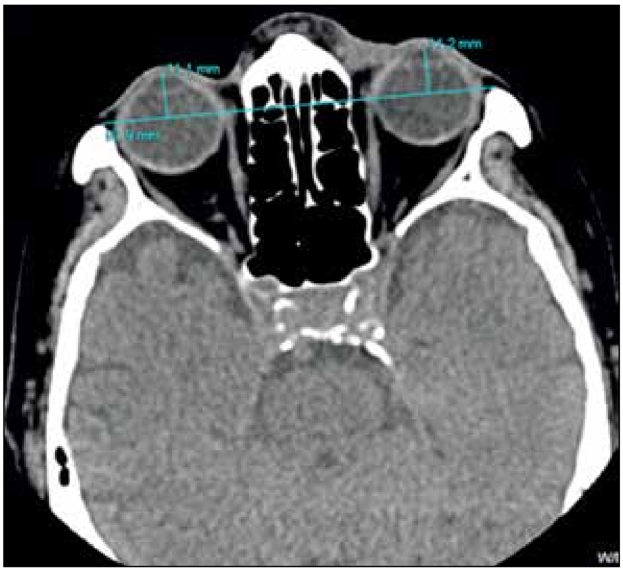

**Figure 3.** Axial image of the orbits at the level of the lenses. Globe positions were measured as the maximal dimensions perpendicular to the interzygomatic line and the anterior margin of the globe.

variation of the measurements with change in window settings.

## Statistical Analysis

The corresponding dimensions of the left and right orbits were averaged for each patient for further analysis. The superior muscle group, and lateral, medial and inferior rectus muscles were added together to provide a sum of all the EOMs in each patient. Ninety-five percent normal cut-off values were obtained by adding and subtracting two standard deviations from the mean. The independent *t* test was used to compare data between men and women. Pearson's correlation was used to analyse the relationship between age and the orbital structures. A p value of <0.05 was considered statistically significant.

# RESULTS

A total of 256 cases with 512 normal orbits were included (115 men and 141 women). The patients were aged 21 to 91 years (mean age, 58.2 years). The mean measured diameters of the rectus muscles were 3.5 mm, 3.2 mm, 3.4 mm, and 3.8 mm in the medial, lateral, superior group, and inferior rectus muscles, respectively (Table 1).

The EOMs were found to be thicker in men than in women (p = 0.0002) [Table 2]. With the exception of the medial rectus muscle, all measurements were significantly different between men and women (all p < 0.05). The globe sizes and interzygomatic line distances were larger in men than in women (p = 0.0002 and p < 0.0001 respectively). The globe position values were also larger in men (p = 0.0045), meaning that the globes were more anteriorly positioned in men than in women. No significant difference was noted between the measurements of optic nerve sheath complexes in men and those in women (p = 0.2806).

No consistent correlation with age was found in any of the individual measured structures (Table 3). Comparing age with the sum of all EOMs, a significant positive correlation was noted ($r = 0.17$, p = 0.0072).

**Table 1.** Mean values and normal ranges of sizes of orbital structures.

| Structure | Mean ± 2 SDs, mm | Normal range, mm |
|---|---|---|
| Medial rectus | 3.5 ± 1.3 | 2.2-4.8 |
| Lateral rectus | 3.2 ± 1.3 | 1.9-4.4 |
| Superior muscle group | 3.4 ± 1.3 | 2.1-4.7 |
| Inferior rectus | 3.8 ± 1.7 | 2.1-5.5 |
| Sum of all muscles | 13.8 ± 4.7 | 9.1-18.6 |
| Optic nerve sheath complex | 4.4 ± 1.7 | 2.7-6.1 |
| Globe size | 25.8 ± 2.8 | 23.0-28.6 |
| Globe position (anterior) | 16.7 ± 5.2 | 11.5-21.9 |
| Globe position (posterior) | 9.1 ± 5.0 | 4.1-14.1 |
| Interzygomatic line | 97.7 ± 7.8 | 89.9-105.5 |

Abbreviation: SD = standard deviation.

**Table 2.** Sex differences in sizes of orbital structures.

| Structure | Wome mean ± 2 SDs, mm | Me mean ± 2 SDs, mm | p Value |
|---|---|---|---|
| Medial rectus | 3.4 ± 1.3 | 3.6 ± 1.3 | 0.0611 |
| Lateral rectus | 3.0 ± 1.2 | 3.4 ± 1.3 | <0.0001 |
| Superior muscle group | 3.3 ± 1.2 | 3.5 ± 1.3 | 0.0008 |
| Inferior rectus | 3.7 ± 1.7 | 4.0 ± 1.7 | 0.0049 |
| Sum of all muscles | 13.4 ± 4.6 | 14.5 ± 4.5 | 0.0002 |
| Optic nerve sheath complex | 4.3 ± 1.6 | 4.5 ± 1.6 | 0.2806 |
| Globe size | 25.5 ± 2.6 | 26.1 ± 2.8 | 0.0002 |
| Globe position (anterior) | 16.3 ± 4.3 | 17.2 ± 5.8 | 0.0045 |
| Globe position (posterior) | 9.2 ± 4.4 | 9.0 ± 5.8 | 0.4169 |
| Interzygomatic line | 96.1 ± 6.7 | 99.7 ± 7.3 | <0.0001 |

Abbreviation: SD = standard deviation.

# DISCUSSION

The EOMs are long fusiform structures that stretch from the orbital apex to the globe. Enlargement of the EOMs is observed in multiple disease entities, including Grave's ophthalmopathy, primary and metastatic neoplasms, inflammatory conditions, and trauma.

Varying the window settings has an impact on the measurements of EOMs.[6] In the present study, a standard 'soft tissue' window of width 300 HU and level 40 HU was used in accordance with the routine practice of the authors' centre.

Compared with other studies conducted in Asia (Turkey[6], Korea[7], and Thailand[8]), the mean measured diameters of the rectus muscles in the present study were slightly thinner for all of the individual muscles (Table 4). Such differences could be due to underlying genetic, socioeconomic, and nutritional factors. Some of the studies also measured the EOMs in the axial plane instead of the coronal plane as in this study. Differences in window settings may have also contributed. Caution must therefore be maintained regarding window settings when referring to the measurements of the current study in clinical practice.

In the present study, men were found to have significantly larger globe sizes, interzygomatic line distances, and

**Table 3.** Correlations of sizes of orbital structures with age.

| Structure | Pearson's correlation ($r$) | p Value |
|---|---|---|
| Medial rectus | <0.01 | 0.9416 |
| Lateral rectus | 0.18 | 0.0037 |
| Superior muscle group | 0.14 | 0.0274 |
| Inferior rectus | 0.22 | 0.0004 |
| Sum of all muscles | 0.17 | 0.0072 |
| Optic nerve sheath complex | 0.04 | 0.4934 |
| Globe size | -0.12 | 0.0639 |
| Globe position (anterior) | -0.06 | 0.3161 |
| Globe position (posterior) | -0.01 | 0.9962 |
| Interzygomatic line | 0.01 | 0.8911 |

**Table 4.** Normal measurements of sizes of orbital structures compared with other studies.

| Structure | Ozgen and Ariyurek (1998)[6] | Lee et al (2001)[7] | Lerdlum et al (2007)[8] | Present study |
|---|---|---|---|---|
| Medial rectus, mm | 4.2 | 3.7 | 3.7 | 3.5 |
| Lateral rectus, mm | 3.3 | 3.4 | 3.6 | 3.2 |
| Superior muscle group, mm | 4.6 | 4.0 | 3.8 | 3.4 |
| Inferior rectus, mm | 4.8 | 4.1 | 4.0 | 3.8 |
| Sum of all muscles, mm | 16.9 | 14.0 | 15.0 | 13.8 |
| Optic nerve sheath complex, mm | 4.4 | 4.2 | N/A | 4.4 |
| Interzygomatic line, mm | 99 | 105 | N/A | 97.7 |
| Window setting (level/width), HU | 50/250 | 10-15/300-330 | 50/350 | 40/300 |

Abbreviation: N/A = not available.

sums of EOM thickness. This result is in accordance with other similar studies. In another study, however,[5] it was noted that the ratio of the interzygomatic line distance to the diameters of the EOMs showed no statistically significant difference between women and men. It was therefore proposed that differences between the diameters of EOMs depend on head size rather than sex.

One of the focuses of the current study was to determine the normative value of the globe position as an aid in determining the presence or absence of proptosis. It is known that the normal values of globe positions vary with ethnicity.[2,3] With the difference in terms of facial structure such as deeper eye sockets in Caucasians, normative measurements of globe positions in Western populations may not be directly applicable to the Hong Kong population. Two common options to gauge the globe position are to measure the distances between the anterior or posterior margins of the globe and the length of the interzygomatic line.[5,7-9] We have chosen to measure the distances between the anterior margins of the globe for the following reasons. First, the distance from the anterior margin is often longer than the distance between the posterior margins, resulting in a lower margin of error in measurements. Second, abnormalities such as staphyloma more often affect the posterior margin of the globe, which may reduce the accuracy of measurements. The commonly quoted figures for the definition of proptosis from Western sources are >21 to 23 mm anterior to the interzygomatic line.[10-12] In the present study, the upper limit of the normal range was 21.9 mm, which falls within the range for proptosis. This could be due to factors other than facial structure affecting the measurement, for example the high prevalence of myopia in the Asian population, which affects the shape of the globe.[13,14]

**Table 5.** Sex differences in normal position of the globe as measured by the distance between the interzygomatic line and the anterior or posterior margin of the globe.

| | Women | Men | p Value |
|---|---|---|---|
| Globe position (anterior), mm | 16.3 ± 4.3 | 17.2 ± 5.8 | 0.0045 |
| Globe position (posterior), mm | 9.2 ± 4.4 | 9.0 ± 5.8 | 0.4169 |

In our findings, men had more anteriorly positioned globes compared with women (p = 0.0045). The normal range for men was 17.2 ± 5.8 mm; for women it was 16.3 ± 4.3 mm. Studies that measure degrees of proptosis using exophthalmometry have shown conflicting results, with some showing sex differences and other showing none.[2,15] Other studies using CT to measure the position as the distance between the interzygomatic lines and the posterior margins of the globe noted no significant sex differences.[5,7] For a more direct comparison, we have converted our measurements by subtracting the distance between the interzygomatic lines and the anterior margins of the globe from the globe size in individual orbits (Table 5, Figures 2 and 3). When measuring the globe position in this way, our findings also showed no significant difference between women and men (p = 0.4169), suggesting that larger globe sizes in men most likely contribute to the more anterior globe margins in men than in women.

Previous studies have shown a tendency for the EOMs to slightly enlarge with age,[5,7] but the differences did not attain statistical significance. The same observation was made in the current study, with most individual EOMs showing positive weak correlation ($r < 0.2$). Furthermore, no correlation was found between age and globe position ($r = -0.06$).

The limitation of our study is that the data were collected retrospectively, and the eye movement/gaze could not be standardised. It is noted that eye movements during imaging may affect the diameters of the EOMs, with some studies asking the patient to maintain a forward gaze and gentle eye closure during scanning. However, this effect was minimised in our study with a mixture of various gazes and a considerable population size. In addition, we believe that including cases with some side gaze is important in establishing normative values, since it may not be always possible to obtain a primary gaze in daily practice (eg, in patients with inability to comprehend or cooperate).

In conclusion, the normative measurements of orbital structures established in our study of the Hong Kong Chinese population may help radiologists and clinicians to quantitatively interpret CT scans of patients with suspected EOM enlargement, proptosis, or other changes in the orbital morphology.

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