Normal Measurements of Extraocular Muscle Using Computed Tomography

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Objective: *Establish criteria for the diameters of normal extraocular muscles using computerized tomography in a Thai population.*
Material and Method: *Diameters of extraocular muscles (medial, lateral, superior complex, and inferior rectus) were calculated for 200 patients on coronal direction of screening paranasal sinuses. The effects of age and sex were also analyzed*
Result: *Normal ranges for the diameters (mean $\pm$ 2 SDs) of extraocular muscles were 3.7 $\pm$ 0.9 mm for medial rectus, 3.6 $\pm$ 1.2 mm for lateral rectus, 4.0 $\pm$ 1.4 mm for inferior rectus and 3.8 $\pm$ 1.4 mm for the superior group. The mean diameter of the extraocular muscles in male patients was not significantly larger than in female patients ($p > 0.05$). There was also no statistically significant correlation between age, diameter of each extramuscular muscle and the sum of all four muscles.*
Conclusion: *The present result may help radiologists and ophthalmologists to accurately assess enlargement of the extraocular muscles, particularly in Oriental populations.*

Keywords: *Extraocular muscle, Normal measurement, Computed tomography*

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In diagnosing or differentiating orbital disease, it is important to know the normal orbital dimensions such as the diameters of the extraocular muscles. Enlargement of the extraocular muscles may be due to primary neoplasm, non-specific inflammation, metastatic tumor, vascular malformation, infection, acromegaly and trauma, as well as Graves' ophthalmopathy, the most common cause[1-3]. There are different imaging techniques to evaluate and measure the dimension of the extraocular muscle and optic nerve-sheath complex such as echography, computed tomography (CT) and magnetic resonance imaging (MRI).

In the authors' opinion, measuring one diameter of an extraocular muscle using CT is the useful way to quantitatively evaluate the size of that muscle in a practical and easy-to-use method, particularly in developing countries such as Thailand.

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The objective of the present study was to present the normative measurements of the extraocular muscles revealed by computerized tomography.

Material and Method

Subjects

All CT images were obtained from patients who were referred to the authors' department for screening sinus CT from Jan 2004 to June 2005. Most patients were diagnosed with either chronic sinusitis or nasal polyposis and whether they would undergo functional endoscopic sinus surgery (FESS) or not. All patients were confirmed to be free of clinical evidence or history of endocrine disease or any orbital disorder by reviewing the outpatient records. Scan with artifacts (dental material, etc.) causing errors in measurements of extraocular muscle, and CT scans with abnormal orbital findings were excluded.

Sample size calculation

From the previous study[4] by Ozgen et al, the medial rectus muscle is about 4.2 mm in maximal diameter (SD = 0.4)

$$\text{Sample size (n)} = z^2_{\alpha/2}\,\sigma^2 / d^2$$

confidence interval = 95%, $z_{\alpha/2} = Z_{0.05/2} = 1.96$, variance, $\sigma^2 = (0.4)^2$, acceptable error, d = 6%

$$\text{Sample size (n)} = (1.96)^2\,(0.4)^2 / (0.06)^2 = 170 \text{ patients}$$

Four hundred normal orbits from 200 patients were retrospectively evaluated by two radiologists. There were 104 males and 96 females. The age range was 10 and 78 years (mean 43 years).

Method

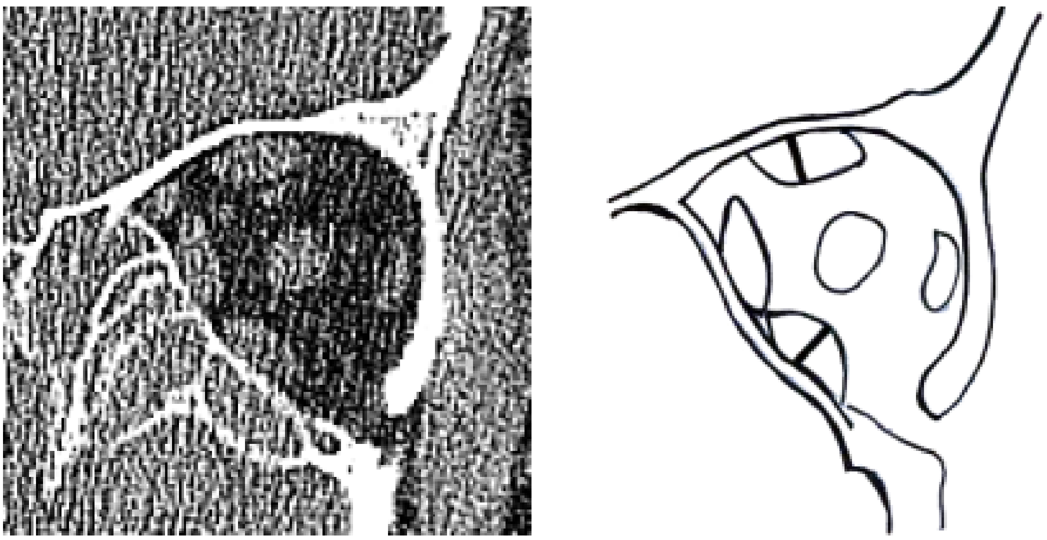
CT images were performed with Somatom sensation 4 (Siemens, Germany). The images were obtained using a bone algorithm with 3-mm sequential from glabella to anterior clinoid process and 4.5-mm sequential from anterior to posterior clinoid process. The scanner gantry was angled perpendicular to the hard palate. Data was acquired on coronal plane without the use of intravenous contrast material. All images were filmed with intermediate window settings.

In the measurement of the extraocular muscles, same magnification factor and constant window settings were performed for accurate comparison of the muscle size between different patients, using window width and window level 350 and 50 HU, respectively. Because they could not be reliably distinguished from each other, the superior rectus and the levator palpabrae were measured together as a single muscle group, *the superior muscle group*, before they became separate with a fat plane between them. The diameter of each muscle was measured at its maximum and perpendicular to the orbital wall, horizontal diameter for medial and lateral recti and vertical diameter for inferior rectus and superior muscle group (Fig. 1, 2). For each muscle, measurements were done in three consecutive images for achieving accurately maximal diameter.

Statistical analysis

A pilot interobserver study between two radiologists was performed to assess the reliability and reproducibility of this measurement method, using 50 patient cases. The interobserver reliability coefficient was 0.7 for lateral rectus muscle and 0.8 for inferior rectus muscle, superior group and medial rectus muscle ($p < 0.05$).

Diameters of the medial, lateral, and inferior rectus muscles and superior muscle group were summed to achieve a total of all muscles in any individual. The paired sample t test was used to compare data obtained



A B

Fig. 1 (A) Coronal CT scan of 20-year-old man with sinonasal polyp and sinusitis, showing maximal vertical diameter of the superior group and inferior rectus muscle of the left orbit
(B) Picture showing measurement of the maximal vertical diameter of these muscles that are perpendicular to the orbital wall

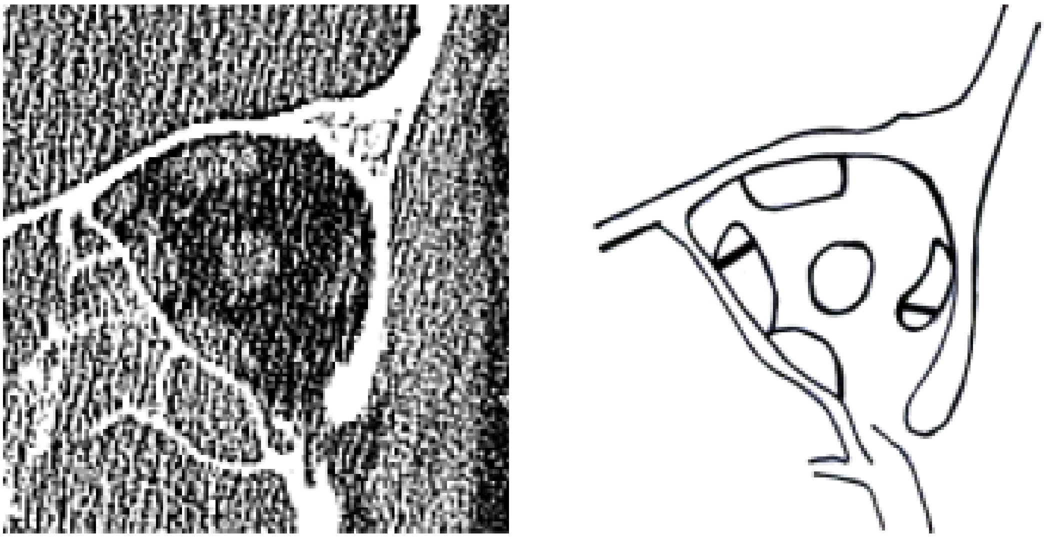


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Fig. 2 (A) Coronal CT scan of the same patient as Figure1, showing maximal horizontal diameter of medial and lateral rectus muscles
(B) Picture showing measurement of the maximal horizontal diameter of these muscles, also perpendicular to the orbital wall

from the right and left orbits. The independent sample t test was used to compare data obtained from male and female patients. The authors calculated the relation using Pearson's correlation. Ninety-five percent normal cutoff values were computed by adding and subtracting two SDs from the mean. A p-value of less than 0.05 was considered statistically significant. All statistics in the present study were done using SPSS for Windows (SPSS version 11.5, Chicago, IL).

Results

Mean values and normal ranges for the diameters of extraocular muscles, the difference in ranges between right and left orbit data are given in Table 1. No statistically significant difference was found between data for the right and left orbits ($p > .05$). Mean width of rectus muscle was 3.7 mm in medial rectus, 3.6 mm in lateral rectus, 3.8 mm in superior group, and 4.0 mm in inferior rectus muscles (Table 1).

In male cases, the mean width of the rectus muscle was 3.8 mm in the medial rectus, 3.7 mm in the lateral rectus, 3.9 mm in the superior group, and 4.1 mm in the inferior rectus muscles. In women, the mean width of the rectus muscle was 3.6 mm in the medial rectus, 3.6 mm in the lateral rectus, 3.7 mm in the superior group and 3.8 mm in the inferior rectus. The mean diameters of the extraocular muscles in male patients were larger than those in female. However, there was no statistically significant difference between male and female patients ($p > .05$) (Table 2).

In relation to age, the authors found no consistent correlation with the mean diameters of the single extraocular muscles. There was also no correlation between age and the sum of all four muscles (Table 3).

Table 1. Normal measurements of extraocular muscles as seen on CT (n = 200)

Extraocular muscles	Mean (mm)	Mean ± 2 SD (mm)	Normal range (mm)
Medial rectus	3.7	3.7 ± 0.9	2.8-4.6
Lateral rectus	3.6	3.6 ± 1.2	2.4-4.8
Superior group	3.8	3.8 ± 1.4	2.4-5.3
Inferior rectus	4.0	4.0 ± 1.4	2.6-5.4
Sum of all muscles	15.0	15.0 ± 3.6	11.4-18.6

Table 2. Normal measurements of extraocular muscles as seen on CT, according to sex

Extraocular muscle	Male (mean $\pm$ 2 SD) (mm) n = 104	Female (mean $\pm$ 2 SD) (mm) n = 96
Medial rectus	3.8 $\pm$ 0.8	3.6 $\pm$ 1.0
Lateral rectus	3.7 $\pm$ 1.3	3.6 $\pm$ 1.2
Superior group	3.9 $\pm$ 1.4	3.7 $\pm$ 1.2
Inferior rectus	4.1 $\pm$ 1.4	3.8 $\pm$ 1.4
Sum of all muscles	15.4 $\pm$ 3.8	14.6 $\pm$ 3.2

Table 3. Correlation between the extraocular muscle and age

	Pearson's correlation (*r*) n = 200
Medial rectus	-0.02
Lateral rectus	0.22
Superior group	0.37
Inferior rectus	0.23
Sum of all muscles	0.31

Discussion

The extraocular muscles are long, thin, well-defined structures stretching from the orbital apex to the globe. Their longitudinal section shows a slightly fusiform shape, while in coronal section they are rectangular or oval on CT scanning. Measuring diameters of extraocular muscles in the axis perpendicular to the orbital wall is also used in CT imaging worldwide[5-7]. For a practical and easy-to-use method, the authors preferred to measure only one maximal cross-sectional diameter of the muscle, horizontal diameter for lateral and medial rectus muscles and vertical diameter for the superior group and inferior rectus muscle.

Some researchers evaluated diameters of extraocular muscles with varying window settings[7-9]. Every change in the window level and width settings results in different values with respect to the muscle size. This means that window settings should be the same to accurately compare the muscle sizes both between different patients and between different CT examinations of the same patient. For this reason, the authors' normative data would be valid for specific window level and width settings with window width and window level 350 and 50 HU, respectively. In the present study, the authors also present that the extraocular muscle can be well visualized even in bone algorithm of screening paranasal sinuses if using optimal window width and window level. A pilot interobserver study with this method of measurement was achieved, showing rather good reliability coefficiency, 0.7 and 0.8 ($p < 0.05$).

According to the present study, the mean diameter of the rectus muscle was 3.7 mm, 3.6 mm, 3.8 mm and 4.0 mm in medial, lateral, superior complex and inferior rectus muscle, respectively. The present data were compared with the mean muscle diameters obtained in other studies (with window level 50-70 and width setting, 250-350 HU, respectively) as shown in Table 4[4,5,12]. Most of these studies including the present study shows similar ranking of thickness of extraocular muscles, inferior > superior > medial > lateral, but in the present study thickness of the lateral rectus muscle was slightly larger. This may be due to a more oblique course of the lateral rectus muscles than the medial rectus muscle, so its horizontal thickness measured in coronal section in the present study was slightly larger than that measured in axial plane in other studies but with no significant difference for the medial rectus.

The sum of the diameters of all extraocular muscles may help as an overall index to evaluate patients' measurements, particularly in patients with Graves' disease, in which the diameter of an individual muscle remains in the normal range although the muscle is actually minimally enlarged. Differences between diameters of healthy contralateral extraocular muscles may also be helpful. In the present study, the mean

Table 4. Normal measurement of extraocular muscle, comparing with the other studies

Study	Medial rectus	lateral rectus	Superior group	Inferior rectus	Sum of all muscles
Jacob (1980)	3.7	1.3	6.5	4.5	19.7
Nugent (1990)	4.1	2.9	3.8	4.9	18.1
Ozgen (1998)	4.2	3.3	4.6	4.8	16.9
Jong Soo Lee (2001)	3.7	3.4	4.0	4.1	14.0
Present study	3.7	3.6	3.8	4.0	15.0

sum of the diameters of all muscles (15.0 mm) was not much different from Jong Soo Lee et al (14.0 mm) but tended to be smaller than other studies from the Western, which reported values between 16.9 mm and 19.7 mm as shown in Table 4[4,5,12]. The authors think that differences may be related to the ethnic factors, socioeconomic and nutritional conditions between Oriental and Western populations.

The present study revealed that the mean diameters of the extraocular muscles are a little larger in males than females but not statistically significant. This may be due to a larger head size usually found in male patients[10,11]. In relation to age, there was also no significant correlation with the mean diameters of the single extraocular muscles and the sum of all four muscles.

According to a retrospective study, preventing extraocular muscle contraction during the scan by asking the patient to maintain forward gaze and gentle eye closure cannot be done. However, this is not in routine orbit protocol of many centers. The other limitation is that the normative values of extraocular muscles from the present study being useful for only imaging in coronal plane.

In conclusion, the present results may help radiologists and ophthalmologists to accurately assess the enlargement of the extraocular muscle with a practical quantitative method. To obtain better information on normal extraocular muscle thickness, according to race, a comparative epidemiological study between Oriental and Western populations is recommended.

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ค่าปกติการวัดขนาดของกล้ามเนื้อตาโดยใช้เครื่องเอกซเรย์คอมพิวเตอร์

สุกัลยา เลิศล้ำ, ปิยพร บุญศิริคำชัย, เอกพล เศรษฐ์สกล

วัตถุประสงค์: *การศึกษานี้มีวัตถุประสงค์เพื่อหาค่าปกติการวัดขนาดของกล้ามเนื้อตาโดยใช้เครื่องเอกซเรย์คอมพิวเตอร์ เป็นการศึกษาชนิดย้อนหลัง*

วัสดุและวิธีการ: *โดยทำการวัดขนาดของกล้ามเนื้อตาของผู้ป่วยที่มารับการตรวจคัดกรองโพรงอากาศรอบจมูกโดยใช้เครื่องเอกซเรย์คอมพิวเตอร์ ที่แผนกเอกซเรย์โรงพยาบาลจุฬาลงกรณ์ตั้งแต่มกราคม พ.ศ. 2547 ถึง มิถุนายน พ.ศ. 2548 ผู้ป่วยที่มีความผิดปกติของต่อมไร้ท่อและโรคทางตาจะถูกตัดออกจากการศึกษานี้ ภาพถ่ายเอกซเรย์คอมพิวเตอร์ที่มีสิ่งรบกวนการวัด (เช่น ฟันปลอม) ที่ทำให้การวัดผิดพลาดจะถูกตัดออกจากการศึกษานี้เช่นกัน การศึกษามีผู้ป่วยทั้งหมด 200 คน (ชาย 104 คน และ หญิง 96 คน, อายุเฉลี่ย 43 ปี) ทำการวัดขนาดกล้ามเนื้อตาจากภาพถ่ายเอกซเรย์คอมพิวเตอร์เพื่อคัดกรองโพรงอากาศรอบจมูกโดยวัดขนาดกล้ามเนื้อแต่ละมัดช่วงที่ใหญ่ที่สุดในแนวตั้งฉากกับผนังเบ้าตาในระนาบ coronal เพียงอย่างเดียว*

ผลการศึกษา: *พบว่า ค่าปกติการวัด (mean $\pm$ 2 SDs) ของกล้ามเนื้อ medial rectus คือ 3.7 $\pm$ 0.9 มม., ของกล้ามเนื้อ lateral rectus คือ 3.6 $\pm$ 1.2 มม., ของกล้ามเนื้อ superior group คือ 4.0 $\pm$ 1.4 มม. และของกล้ามเนื้อ inferior rectus คือ 3.8 $\pm$ 1.4 มม. นอกจากนี้ยังพบว่าขนาดกล้ามเนื้อตาในผู้ชายใหญ่กว่าผู้หญิงอย่างไม่มีนัยสำคัญทางสถิติ ($p > 0.05$) และไม่พบความสัมพันธ์อย่างมีนัยสำคัญทางสถิติระหว่างอายุ, ขนาดกล้ามเนื้อตาแต่ละมัด และผลรวมของขนาดกล้ามเนื้อทั้งสี่มัด*

สรุป: *ผลการศึกษานี้จะช่วยให้รังสีแพทย์และจักษุแพทย์มองเห็นขนาดกล้ามเนื้อตาได้อย่างแม่นยำ โดยเฉพาะในผู้ป่วยในซีกโลกตะวันออก*