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Original Article

Echographic study of extraocular muscle thickness in normal Indian population

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Abstract

Purpose: To establish normative data of extraocular muscle (EOM) dimensions, both vertically and horizontally, using a reproducible echographic method in various age groups.
Methods: Two hundred eyes of 100 healthy subjects (50 males and rest females) were included in this prospective observational study. All subjects were divided into 5 groups with an interval of 10 years from 10 to 60 years. Each group contained 10 male and 10 female healthy subjects. A single operator took measurements at 4 mm distance from the globe plane after drawing a perpendicular line on the globe to the muscle belly.
Results: The average age of subjects was 37.28 ± 17.14 years. Intraobserver reproducibility was very high (intersession concordance correlation co-efficient = 0.995). Mean horizontal and vertical diameters of recti were 3.0775 and 8.26 mm, respectively. Mean muscle thickness of superior rectus/levator palpebral superioris (LPS) muscle complex and LPS was 4.56 and 1.45 mm, respectively. Extraocular muscle diameter increases up to the middle age, then it starts decreasing. There was no statistically significant correlation between diameter of each EOM, both eye and gender ($p \geqslant 0.05$). There was a non-significant change in extraocular muscle thickness with age.
Conclusion: The study provides normative data for extraocular muscle thickness in both genders of various age groups in Indian population. Muscle dimensions do not change significantly with age, between the eyes and gender.

Keywords: EOM, Extraocular muscle, Grave's ophthalmopathy

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Introduction

The accurate assessment of the dimensions of extraocular muscles is of vital clinical importance in the management of patients with orbital, extraocular muscular and neuro-ophthalmologic disorders. Subjective assessment of these structures may be controversial and inaccurate to diagnose or assess the changes during the follow up. There are several diseases that can affect the morphology of extraocular muscles such as primary neoplasm, vascular malformation, acromegaly, orbital myositis, muscle hematoma, orbital apex syndrome, pansinusitis, as well as Graves' ophthalmopathy,[1] the most common cause of muscle thickening.[2,3] In differentiating and diagnosing several of such diseases and to analyze pathologic changes quantitatively it is important to determine normal ranges of dimensions of the muscles first.

There are different imaging techniques to evaluate and measure the dimensions of the extraocular muscles and optic nerve-sheath complex such as ultrasound echography, computed tomography (CT) and magnetic resonance imaging

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(MRI). Of these, echography is the safest and most cost-effective method and appears to be the best option for a baseline quantitative evaluation of a muscle over other imaging techniques. Echography is useful in detecting the change in extraocular muscle thickness when associated with orbital abnormalities during the therapy. The technique of an extraocular muscle evaluation including dimensions using ultrasound was developed by McNutt and Ossoining.[4,5] However the reproducibility of the technique is questionable.

Normal muscle diameters have been reported earlier in different races with very high variation in measurements. A study was reported on normal extraocular muscle measurements in Indian population in 1990 by Arora et al.[6] with a relatively small sample size without uniform age-distribution. Thus there is a need for extraocular muscle thickness database in Indian population with a larger sample size.

The objective of the present study was to assess the reproducibility of a new technique for muscle thickness measurements and establish a normative database of measurements of the extraocular muscles using ultrasound across different age groups in Indian population and to assess the relationship between the muscle thickness and various other variables.

Material and methods

This prospective study included 100 healthy subjects at L.V. Prasad Eye Institute, Hyderabad, India from July to October 2012. Prior approval from the institutional review board of L.V. Prasad Eye Institute, Hyderabad was taken and informed written consent was obtained from each subject. All participants underwent a comprehensive ocular examination including best-corrected visual acuity (BCVA), slit-lamp biomicroscopy and dilated fundus examination. Subjects with any evidence of orbital or ocular disease, extraocular muscle disorder and history of extraocular or intraocular surgery were excluded. Images with poor quality or inability to measure were excluded.

Extra ocular muscle thickness measurement protocol

Extraocular muscle is surrounded by a smooth sheath *called Tenons' capsule*, that produces distinct, highly reflective interface between the muscle and soft tissue on ultrasound examination. Muscle fibers are relatively compact and homogeneous than the surrounding area. Therefore, normal extraocular muscles produce low to medium homogeneous reflectivity internally on A scan and relatively less echo dense on B scan than the surrounding fat soft tissue.

Echographic evaluation of the extraocular muscle was done for all subjects in both eyes with closed lid by an experienced optometrist following a comprehensive eye checkup. All echographic measurements were performed using OTI 3000 (OPKO instrumentation, USA) instrument, which has an advanced noise reduction algorithm, using a 10 MHz probe of 0.20 mm lateral resolution. The muscle diameter was measured at a low tissue sensitivity of 60 Decibel, which was maintained throughout the study. The ''Narrow Scanning Field'' of 35° was used to image the extraocular muscle. This narrow scanning angle maintains the same number of scanning lines which are packed at a narrower scanning angle over ''Wide Scanning Field'' of 50° and therefore it provides a higher lateral resolution of each image. Measurements were taken using in-built calipers in the instruments.

The examination techniques used in measuring the extraocular muscles with standardized echography were the same as described by McNutt[4] *and Ossoining.*[5] This includes evaluation of the Inferior rectus, medial rectus and the superior rectus muscles and levator palpebrae muscle in the primary gaze position and lateral rectus muscle in the 10 degrees abducted eye position.

Both transverse and longitudinal approaches were used for morphological evaluation of the muscles. Transverse orientation provides cross sectional view and the muscle appears rectangular or oval shaped. Longitudinal orientation provides a long-axis (anteroposterior) view and the muscle appears fusiform in shape. The echographic probe located in the transbulbar position was aimed at the equator. Measurements in both longitudinal and transverse scans were taken at the level where distance between the globe and the muscle was 4 mm. A perpendicular line was drawn on the globe to the muscle belly and measurements were taken at 4 mm distance from the globe plane for all subjects at the muscle belly in all images (Figure 1).

The longitudinal scan provided the horizontal diameter for the medial and the lateral rectus. Transverse scan provided both the vertical and the horizontal diameter of all recti. The vertical diameters of the inferior, superior rectus and levator palpebrae muscle complex were obtained in the longitudinal scan.

The levator palpebrae muscle appears as a thin, umbrella shaped less echo lucent area above the superior rectus in echography, which is quite difficult to measure virtually.[3,4] Hence, first the superior rectus and the levator palpebrae muscles were measured together in the longitudinal scan as a combined or complex structure. Next the superior rectus muscle thickness was evaluated separately using a transverse scan. Finally these two values were deducted from each other to find out the levator muscle thickness.

Statistical analysis

The distribution of muscle diameters was tested for deviation from a Gaussian distribution using the Shapiro–Wilks test. However, the absolute values often do not follow a Gaussian distribution. The effect of demographic variables like gender, the contralateral difference of muscle measurement, and the thickness values obtained from two different orientations of each muscle were evaluated using a non-parametric Mann Whitney test. Pearson's correlation was used to evaluate correlations between muscle thicknesses with continuous demographic variable. The muscle thickness values were statistically elaborated; the mean, median, range, the standard deviation and the 5th and 95th percentiles were calculated. A *p*-value of less than 0.05 was considered statistically significant. All statistics in the present study were done using version SPSS 15.0 (SPSS Inc., Delaware).

Results

Two-hundred eyes of 100 subjects were enrolled in the study of which 50 were female. Subjects were divided into 5 groups based on their age starting from 10 to 60 years at 10 year interval and each group contained 10 males and 10

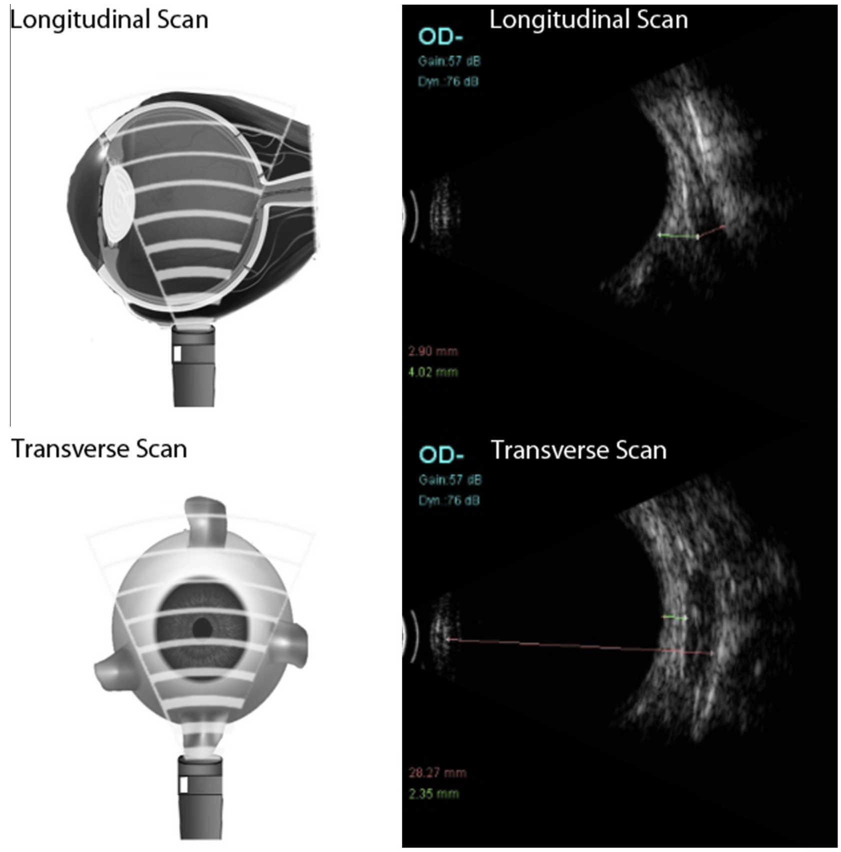

Figure 1. Ultrasonic images of extraocular muscles in two different probe orientations. Muscle appears fusiform shaped when the probe is directly perpendicular to the muscle in longitudinal scan (top) and muscle looks oval shaped in transverse orientation when probe is parallel to the muscle (bottom). A perpendicular line (green line) was drawn on the globe to the muscle belly and measurements were taken at 4 mm distance from the globe plane at the muscle belly before muscle thickness measurement.

females. *Seven males and five females came from North India; the rest were from South India.*

The intraobserver agreement for muscle thickness measurement was measured in first 30 eyes for measurement for all muscles and was found to be 0.995. Coefficient of reproducibility for muscle thickness measurement was 0.61 mm (95% confidence interval 0.56–1.16 mm).

The sample distributions of muscle sizes were found non-Gaussian. The difference between two values obtained from two different orientations for inferior, medial and lateral rectus muscles was found to be statistically not significant ($p < 0.05$) in the Mann Whitney test ($p > 0.1$ for Medial rectus, $p > 0.7$ for lateral rectus, $p > 0.6$ for inferior rectus, respectively). So the average values of two measurements from two different probe orientations were taken for further analysis. The muscle diameter measurement data derived from this, were analyzed.

The Mean width of each muscle is horizontally and vertically distributed by age, and the overall mean thickness along with standard deviation is shown in Table 1. The mean diameters of the extraocular muscles in male and female subjects are shown in Table 2. The extra ocular muscle thickness was higher in males than in females, however, there was no statistically significant difference between male and female patients ($p > 0.05$) (Table 2). The analyzed data provided a range of normal diameters for each of the four muscles both vertically and horizontally and a combined thickness of all muscles as a numerical index for all muscles. No significant inter-ocular differences in diameter between contralateral fellow muscles were found (Table 3). The coefficient of variation in thickness is summarized in Table 4. Though the muscle thickness reduced in the late decade of life, no statistical significant changes exist among the mean diameters of the each extraocular muscle in relation to age shown in Figure 2.

Discussion

It is possible that normal muscle values may vary with different examination techniques, different instrumentations and so by different observers. Therefore, Demer and Kerman[7] recommended that every echographic center should have its own range of normal values. The standardized echographic technique for measurements has been established long back. Our study describes a new technique of measuring the distance from the globe to the muscle belly prior to every measurement, which was found to be highly reproducible. This may help to acquire more precise measurements and during follow up examinations.

This study provides the normal range of muscle thickness values in both genders of various age groups using the standardized technique. Normative values of extraocular muscle dimensions have been reported first by McNutt et al.[4] in 1977 using A scan and in 1991 by Byrne et al.[8] using B scan.

Table 1. Mean muscle thickness (mm) in different age groups.

Muscle		10–20 years	21–30 years	31–40 years	41–50 years	51–60 years	Mean (mm) ± SD
Superior rectus/levator complex		4.38	4.36	4.91	4.71	4.49	4.56 ± 0.47
Levator palpebral superioris		1.31	1.38	1.62	1.49	1.48	1.45 ± 0.32
Superior rectus	(V)	3.06	2.98	3.31	3.22	3.01	3.11 ± 0.31
	(H)	7.81	7.61	7.71	8.09	8.22	7.92 ± 0.68
Medial rectus	(H)	3.03	3	3.23	3.21	2.8	3.06 ± 0.32
	(V)	8.23	8.35	8.12	8.57	8.68	8.370.76
Lateral rectus	(H)	2.96	2.96	3.19	3.14	2.74	2.99 ± 0.32
	(V)	8.52	8.64	8.36	8.83	8.62	8.6 ± 0.91
Inferior rectus	(V)	3.11	3.08	3.3	3.25	3	3.15 ± 0.32
	(H)	8.09	7.91	7.99	8.47	8.2	8.15 ± 0.76

V = Vertical, H = Horizontal, SD = Standard deviation.

Table 2. Normal diameter of extraocular muscles according the gender.

Muscle		Male Mean ± SD (mm)	Female Mean ± SD (mm)	*p* Value
Superior rectus/levator palpebral superioris complex		4.57 ± 0.5	4.45 ± 0.43	0.62
Levator palpebral superioris		1.46 ± 0.33	1.41 ± 0.3	0.94
Superior rectus	(V)	3.2 ± 0.34	3.12 ± 0.28	0.7
	(H)	8 ± 0.64	7.83 ± 0.7	0.72
Medial rectus	(H)	3.08 ± 0.34	3.04 ± 0.3	0.66
	(V)	8.62 ± 0.76	8.13 ± 0.68	0.45
Lateral rectus	(H)	3.02 ± 0.3	2.98 ± 0.34	0.58
	(V)	8.72 ± 0.94	8.49 ± 0.86	0.08
Inferior rectus	(V)	3.17 ± 0.36	3.13 ± 0.31	0.27
	(H)	8.32 ± 0.74	7.98 ± 0.74	0.8

V = Vertical, H = Horizontal, SD = Standard deviation.

Table 3. Range of maximum and minimum diameters of healthy extraocular muscles along with diameter difference from the contralateral eye muscles.

Muscle		Range (mm) *n* = 200	Difference from contralateral eye (mm)	*p* Value
Superior rectus/levator complex		3.47–5.93	0.5	0.87
Levator palpebral superioris		0.75–2.51	0.1	0.96
Superior rectus	(V)	2.3–4.02	0.4	0.51
	(H)	6–10	0.6	0.62
Medial rectus	(H)	2.02–3.8	0.1	0.28
	(V)	6.85–10.3	0.7	0.92
Lateral rectus	(H)	2.07–3.68	0.1	0.82
	(V)	6.24–11	0.8	0.31
Inferior rectus	(V)	1.89–3.89	0.5	0.37
	(H)	6.05–10.78	0.9	0.83
Sum of minimum diameter		12.17–15.35		
Sum of maximum diameter		29.04–36.15		

V = Vertical, H = Horizontal, SD = Standard deviation.

Table 4. Median and 5th, 50th and 95th percentile range of extraocular muscle thickness.

Muscle		Median	5th percentile	50th percentile	95th percentile	Range
Superior rectus/levator complex		4.46	3.89	4.46	5.38	0.64
Levator palpebral superioris		3.13	2.57	3.13	3.63	0.41
Superior rectus	(V)	7.91	6.84	7.91	9.1	0.87
	(H)	1.4	1.01	1.4	9.1	0.48
Medial rectus	(H)	3.1	2.49	3.1	1.99	0.39
	(V)	8.32	7.27	8.32	9.7	1.12
Lateral rectus	(H)	3.03	2.35	3.03	3.48	0.47
	(V)	8.6	7.17	8.6	10.02	1.25
Inferior rectus	(V)	3.19	2.61	3.19	3.63	0.46
	(H)	8.05	7.01	8.05	9.64	0.97

V = Vertical, H = Horizontal, SD = Standard deviation.

Byrne et al. measured either horizontal or vertical diameters in a small sample size with an age-wise distribution.[8] In the present study, each muscle thickness was measured both vertically and horizontally in each decade. Sacca et al. in 2000 reported varying extraocular muscle thickness with increasing age using ultrasound in 76 subjects.[9] However, the age distribution was heterogeneous (5–10 years, 11–15 years and 28–37 years), therefore, any conclusion cannot be drawn to establish the relation between the age and change in thickness. Arora et al. reported extraocular muscle thickness

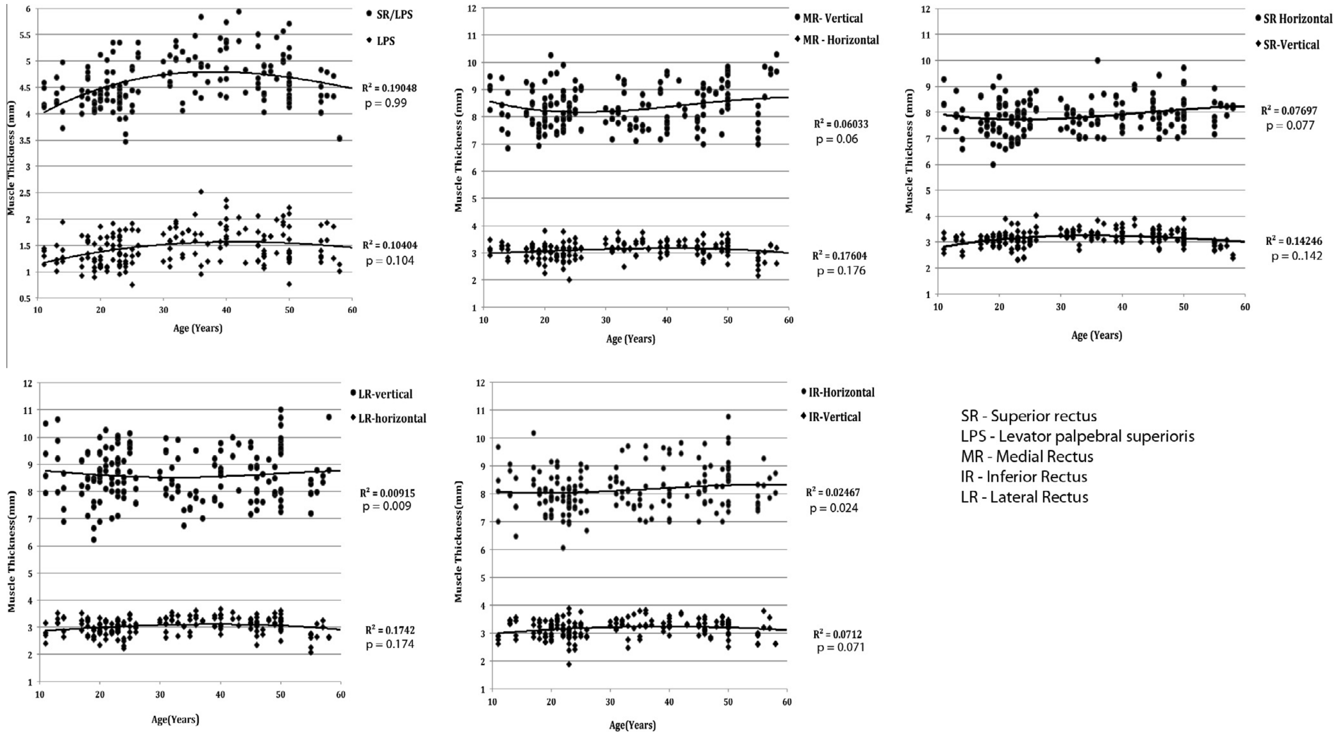

Figure 2. The regression analysis plot of muscle thickness as a function of age, shows that the muscle thickness of any of the extraocular muscles does not change significantly with age.

in Indian population however, the sample size was small (40 eyes) without any age-wise distribution.[6] Table 5 shows comparison of the present study with the published literature.[3,6,8,10] *Noteworthy is the fact that most subjects were from Southern India, and the study would be more directly applicable to the said region.*

The superior rectus and the levator palpebrae superioris are traditionally imaged and measured as a unit complex called ''SR–LPS complex'' in the longitudinal orientation. Superior rectus and levator palpebrae superioris muscles were measured both as a group as well as separately, which to the best of our knowledge has not been reported previously. It is important to include measurement of the levator muscle separately in routine extraocular muscle evaluation of patients with orbital disease such as in Graves' ophthalmopathy.[11] A study by Small[12] already demonstrated enlargement of LPS in Graves' ophthalmology using magnetic resonance imaging (MRI), which is likely to be a cause of upper lid retraction. They reported LPS thickness to be 1.72 ± 0.25 mm using MRI technique in healthy subjects, which is consistent with our study results (1.46 ± 0.33 mm).

CT and MRI are easier to interpret as compared to echography. Also images of both orbits may be viewed simultaneously and can be compared in these imaging procedures. Demer and Kerman[7] demonstrated that the average size for each rectus muscle was similar for the echographic and magnetic resonance imaging techniques. However, occasionally a slight oblique section on CT or MRI can result in misinterpretation of muscle enlargement. During echography the examiner can adjust the probe position in order to prevent oblique section scanning. Echography can be performed in the specific direction to look for the specific lesion.[8] Easy availability, no prerequisites; easy repetition and less expense make ultrasound a preferred technique over CT and MRI for extraocular muscle assessment. Echography has no contraindications like CT/MRI, and can be performed in children and claustrophobic subjects.

There was no statistically significant difference found in any of the muscles either between two eyes or between the two genders. The linear regression analysis of individual muscle thickness shows that the muscle thickness increases with growing age up to the middle age (31–40 years) and then decreases gradually, though the trend is not statistically significant. This change is probably due to biological growth of the muscle as well as the 'functional' activity.[9] Similar to previous report by Arora et al.[6] our study also reports slightly

Table 5. Comparison with the previously published literature.

Author	Sample size	MR(H)	LR(H)	IR(V)	SR–LPS complex (V)	Muscle index	Procedure
Byrne et al.[8]	38	3.5 ± 0.637	3.0 ± 0.4	2.6 ± 0.5	5.3 ± 0.7	14.4 ± 1.3	Ultrasound B scan
Suna Tian et al.[10]	21	3.5 ± 0.47	3.2 ± 0.49	4.4 ± 0.55	4.0 ± 0.72	–	MRI
Lerdlum et al.[3]	200	3.7 ± 0.9	3.6 ± 1.2	4.0 ± 1.4	3.8 ± 1.4	15.0 ± 3.6	MRI
Arora et al.[6]	20	4.02 ± 0.76	3.54 ± 0.36	3.18 ± 0.66	3.75 ± 0.65	–	Ultrasound B scan
Current study	100	3.06 ± 0.32	2.99 ± 0.32	3.15 ± 0.32	4.56 ± 0.47	13.77 ± 1.6	Ultrasound B scan

V = Vertical, H = Horizontal.

thicker muscles in males compared to females; however, this difference was not statistically significant. This may be due to a larger head size in male subjects.[4]

There was no significant correlation between thickness of four rectus muscles and age. Similar to the study by Lerdlum et al.[3], the present study also showed a definite ranking of extraocular muscles thickness as inferior rectus > superior rectus > medial rectus > lateral rectus based on the minimal diameter (Table 1). In contrast, for the maximum diameter the ranking was lateral rectus > medial rectus > inferior rectus > superior rectus (Table 1). Inferior rectus muscle showed a wide range of diameter variations among different age groups in both vertical and horizontal scans compared to other rectus muscles (Table 3).

In conclusion, this prospective observational study provides a normative database for muscle dimensions in both genders across various age groups in Indian population. This is the only study, which describes LPS and SR muscle dimensions separately. Our study shows that the diameter of the extraocular muscles increases up to the middle age, then it starts decreasing. There was no difference between the genders and the eyes of same subject. Our study results could be useful to diagnose and follow up changes in extraocular muscles in various orbital and systemic diseases.

Conflict of interest

The authors declared that there is no conflict of interest.

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