

Reference Values of the Central Corneal Thickness with Different Refractive Errors for the Adult Egyptian Population

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Aim: To generate reference values of the central corneal thickness (CCT) with different refractive errors for the adult eastern Egyptian population.

Subjects and Methods: This study was a retrospective, observational, and cross-sectional study. It included 1166 eyes (1166 subjects) scheduled for LASIK, who came to private refractive eye centre, Ismailia, Egypt. The study period was from January 2018 to January 2020. The subjects were divided into a broad range of myopia with spherical equivalent (SE) $\leq -0.5D$ and hyperopia (SE) $\geq +0.5D$. Then, the myopic eyes divided into low (SE $> -3.0D$), moderate (SE $-3.0D$ to $> -6.0D$), and high (SE $\leq -6.0D$). Similarly, the hyperopic eyes were divided into low (SE $< +3.0D$) and moderate (SE $+3.0D$ to $< +6.0D$) and high $\geq +6.0D$. The refractive error was measured by an auto-refractometer, and CCT was measured using ultrasonic pachymetry.

Results: The data of 556 myopic eyes in 556 subjects (31.1% males and 68.9% females) and 610 hyperopic subjects (34.4% males and 65.6% females) were included in this study. The mean \pm SD of CCT for the total myopic subjects was $532.8 \pm 32.6 \mu\text{m}$, range (470 to $627 \mu\text{m}$). The mean \pm SD of SE was $-4.06 \pm 2.50D$, range (-0.50 to $-14.00D$). The mean \pm SD of CCT for the total hyperopic subjects was $530.8 \pm 37.2 \mu\text{m}$, range (471 to $616 \mu\text{m}$). The mean \pm SD of SE was $+3.57 \pm 1.98D$, range ($+0.50$ to $+8.50D$). About 16.2% of the myopic eyes and 12.7% of the hyperopic eyes have CCT less than $500 \mu\text{m}$.

Conclusion: The mean of the central corneal thickness of the eastern Egyptian population was $532.8 \mu\text{m}$ for myopic and $530.8 \mu\text{m}$ for hyperopic subjects, respectively. The myopic and hyperopic subjects show a reduction in CCT with age. Females have a thinner cornea than males, 16.2% of the myopic eyes and 12.7% of the hyperopic eyes have CCT less than $500 \mu\text{m}$.

Keywords: central corneal thickness, myopia, hyperopia, refractive errors

Introduction

Central corneal thickness (CCT) is a crucial indicator of a healthy cornea; it helps to evaluate corneal diseases. Average ordinary CCT is around $540 \mu\text{m}$ most part, consists of the corneal stroma which is estimated to be $450 \mu\text{m}$ in the centre. This stroma gives essential structural integrity and plays a significant function in keeping up corneal transparency.¹

CCT usually is measured by ultrasonic pachymeter.² It is an essential factor to assess the suitability in refractive surgeries as it is used to exclude patients at risk of postoperative corneal ectasia.³ It is also a measure of the rigidity of the cornea and

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has an influence on the precision of intraocular pressure (IOP) estimation by Goldman applanation tonometry (thick corneas offer resistance to it, causing a falsely higher IOP).^{4,5} Also, many studies have revealed that the differences in mean CCT and IOP among sub-groups may display the hypothesis of the presence of anatomical and morphological disparities among ethnicities.^{6,7}

The increasing popularity of refractive surgeries brings significance to accurate and consistent data regarding the corneal thickness.⁸ Gathering this data from different population samples can aid the differentiation of healthy corneas from unhealthy corneas.⁹ The moment that normal range of the CCT is specified in a particular population, applicable studies can be done without the need for a control group. Moreover, patients' CCT records can be refereed with more dependability.¹⁰ The racial and environmental differences in corneal thickness makes it essential to get normative and reference data for each population to define this range.^{11,12}

Current studies have showed that age, sex, race, and ethnicity may affect CCT. It is reported to be thinner in elders and African-Americans than in whites.^{8,13} Some studies showed that men had thicker corneas than women.^{14,15}

In Egypt, there are few published articles that record CCT of the Egyptian population as a unique racial background and geographical location. So, this study aimed to give reference values of the CCT with different refractive errors for the adult eastern Egyptian population.

Subjects and Methods

All the subjects experienced comprehensive ocular examinations, including slit-lamp (Topcon, Tokyo, Japan) examination, IOP by Goldmann applanation tonometry (Shin-Nippon, Tokyo, Japan) direct and indirect ophthalmoscopy (Topcon, Tokyo, Japan), both cycloplegic (cyclopentolate HCL1%, Plegica, Hikma pharmaceuticals) and subjective refractive error presented in spherical equivalent with auto-refractometer (Topcon KR 8900, Tokyo, Japan), keratometry and corneal topography by Sirius (CSO, Florence, Italy). Schirmer's testing (Hagg-Streit, Edinburgh, UK) without anaesthesia was used to exclude dry eyes.

Corneal thickness measurement was by ultrasonic pachymetry (Tomy, Tokyo, Japan). Five corneal thickness measurements were taken, and the average was used for analysis. All the measurement was between 9.00 and 10.00 am.

The eligibility criteria included myopia and hyperopia, a minimum age of 21 years, a regular corneal topography pattern, both sex and free of any existing systemic pathology. All female subjects were non-pregnant or breastfeeding. The exclusion criteria included subjects with a history of current or recent contact lens wear (not worn contact lenses two weeks before examination), ocular trauma, ocular surgeries, keratoconus, and glaucoma. None of the subjects was utilising any topical ophthalmic medications.

The subjects were divided¹⁶ into a broad range of myopia ($SE \leq -0.5$ D) and hyperopia ($SE \geq +0.5$ D). Then, the myopic eyes divided into low ($SE > -3.0$ D), moderate ($SE -3.0$ to > -6.0 D), and high ($SE \leq -6$ D). Similarly, the hyperopic eyes were divided into low ($SE < +3.0$ D) and moderate ($SE +3.0$ to $< +6.0$ D) and high ($\geq +6.0$ D).

This study follows the Declaration of Helsinki. It was reviewed and approved (approval No. 4182) by the research ethics committee of the Faculty of Medicine, Suez Canal University. No informed consent was required to review the medical records of the subjects due to the large number of the study sample and the retrospective nature of the study design. The confidentiality of the patients' data was guaranteed.

Statistical Analysis

All data manipulation and statistical analysis were performed by Statistical Package for the Social Sciences (SPSS version 25.0; IBM Corporation, Armonk, NY, USA). Baseline characteristics of the study population were presented as frequencies and percentages (%) or mean values and standard deviations (SDs). Differences between frequencies in the groups were compared by Chi-square test. Kolmogorov–Smirnov test was used to test for data normality. Differences between means in the groups were compared by Student's *t*-test or Mann–Whitney test if data were not normal. To compare the difference in the mean measurements between the sub-groups of myopia and hyperopia, one-way ANOVA was performed, or Kruskal–Wallis tests if data were not normal. A *P*-value < 0.05 was considered statistically significant.

Results

This study included 556 myopic subjects (31.1% males and 68.9% females) and 610 hyperopic subjects (34.4% males and 65.6% females) who came to private eye centre, Ismailia, Egypt for refractive surgery. Data included in the statistical analyses were obtained from a randomly selected eye of each subject (ie, each subject gave only one randomly selected eye), [Table 1](#).

Table 1 General Characteristics of All Subjects

Characteristics	Myopic Subjects	Hyperopic Subjects	P-value
Eyes, n	556	610	—
Age (yrs): Mean±SD Range	27.3 ± 7.0 (21–60)	35.1 ± 10.7 (21–60)	<0.001*
Age group (yrs), n (%): < 30 30–39 ≥40	390 (70.1%) 134 (24.1%) 32 (5.8%)	230 (37.7%) 170 (27.9%) 210 (34.4%)	<0.001*
Sex: Male, n (%) Female, n (%)	173 (31.1%) 383 (68.9%)	210 (34.4%) 400 (65.6%)	0.035*
Laterality: Right, n (%) Left, n (%)	288 (51.8%) 268 (48.2%)	300 (49.2%) 310 (50.8%)	0.026*

Note: * Statistical significance (P-value <0.05).

Abbreviations: SD, standard deviation; n, number; yrs, years.

Myopic Subjects

Mean±SD of CCT for the total myopic subjects was 532.8 ±32.6µm range (470 to 627µm). Mean±SD of spherical equivalent (SE) was -4.06±2.5D range (-0.50to-14.00D).

The subjects with CCT<500µm were 16.2% of the total myopic subjects. The mean±SD of the CCT, according to the different age groups, eye laterality, and sex, are presented in [Table 2](#). When further sub-classified the myopic subjects, those with low myopia>-3.0D the mean±SD of the CCT was 532.7±33.5µm, range (470 to 615µm). Moderate myopia -3.0 to> -6.0D the mean±SD of the CCT was 532.8±31.81µm, range (471 to 627µm). Those with high myopia ≤-6.0D the mean±SD of the CCT was 533.2±31.83µm, range (472 to 610µm). There were no statistically significant differences between myopic sub-groups regarding CCT (P=0.897). [Table 2](#), [Figure 1](#). The range of distribution of the CCT in myopic adult Egyptian subjects is presented in [Figure 2](#).

Hyperopic Subjects

Mean±SD of CCT for the total hyperopic subjects was 530.8 ± 37.2µm range (471 to 616µm). Mean±SD of the refraction error was +3.57±1.98 D range (+0.50 to +8.5D). The subjects with CCT<500µm were 12.7% of the total hyperopic subjects. The mean±SD of the CCT, according to the different age groups, eye laterality, and sex, are presented in [Table 3](#). When further sub-classified the hyperopic subjects, those with low hyperopia<+3.0D the mean±SD of the CCT was

Table 2 General Characteristics of Myopia Sub-Groups

	Myopia Total Subjects	Myopia Sub-Groups n (Column %)			P-value
		Low >-3.0D	Moderate -3.0 to >-6.0D	High ≤-6.0D	
Number (%)	556(100%)	263(47.3%)	207(37.2%)	86(15.5%)	—
Age (yrs): Mean±SD Range	27.3 ± 7.0 (21–60)	27.5 ± 6.3 (21 to 60)	27.1 ± 7.1 (21 to 60)	27.3 ± 8.7 (21 to 60)	0.106
Sex, n (%): Male Female	173 (31.1%) 383 (68.9%)	99 (37.6%) 164 (62.4%)	53 (25.6%) 154 (74.4%)	21 (24.4%) 65 (75.6%)	0.007*
Eye, n (%): Right Left	288 (51.8%) 268 (48.2%)	140 (53.2%) 123 (46.8%)	100 (48.3%) 107 (51.7%)	48 (55.8%) 38 (44.2%)	0.410
SE (D): Mean±SD Range	-4.06±2.50 (-0.50 to -14.00)	-2.14±0.77 (-0.50 to -4.75)	-4.62±1.05 (-3.0 to -8.50)	-8.62±1.76 (-6.0 to -14.25)	<0.001*
CCT (µm): Mean±SD Range	532.8±32.6 (470 to 627)	532.7±33.5 (470 to 615)	532.8±31.81 (471 to 627)	533.2±31.83 (472 to 610)	0.897

Note: * Statistically significant (P-value <0.05).

Abbreviations: SE, spherical equivalent; n, number; yrs, years; µm, micrometre; SD, standard deviation; D, dioptre.

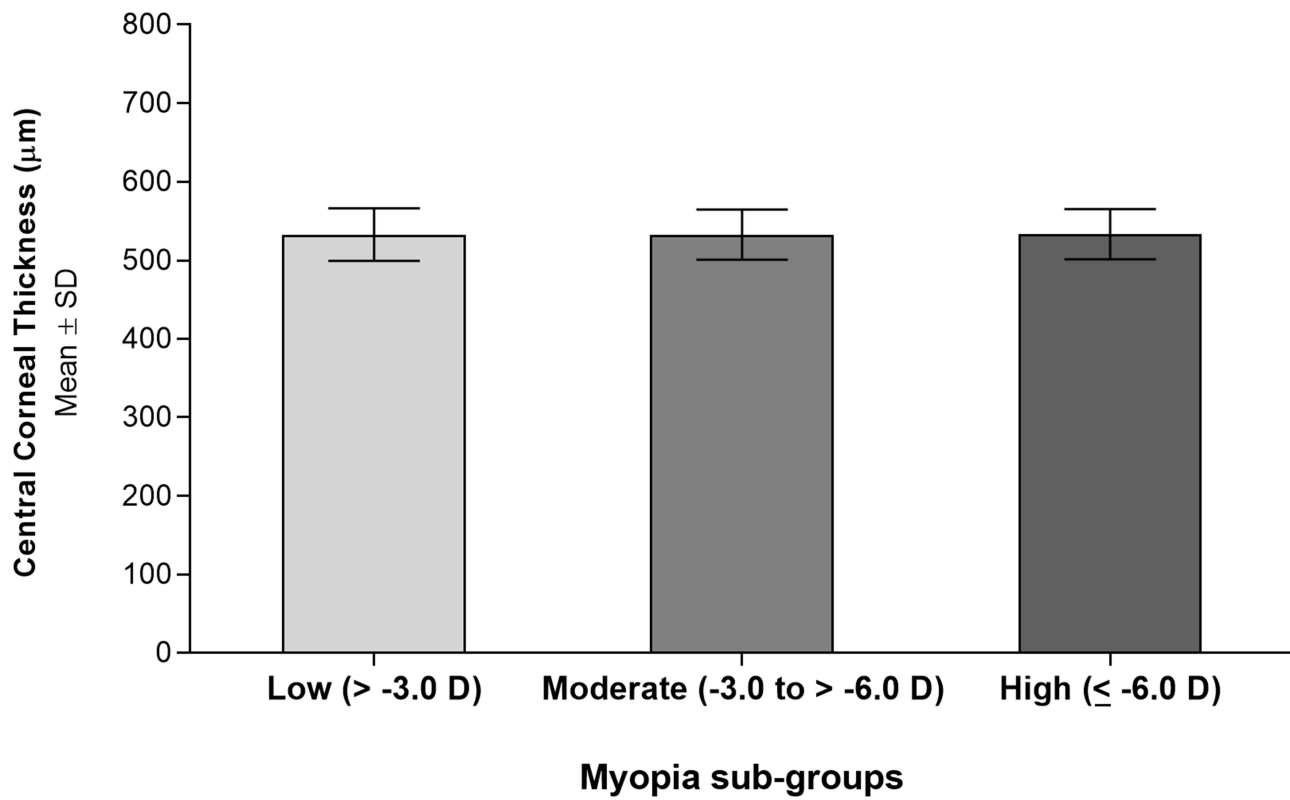


Figure 1 Mean±standard deviation (SD) of the central corneal thickness of myopia sub-groups.

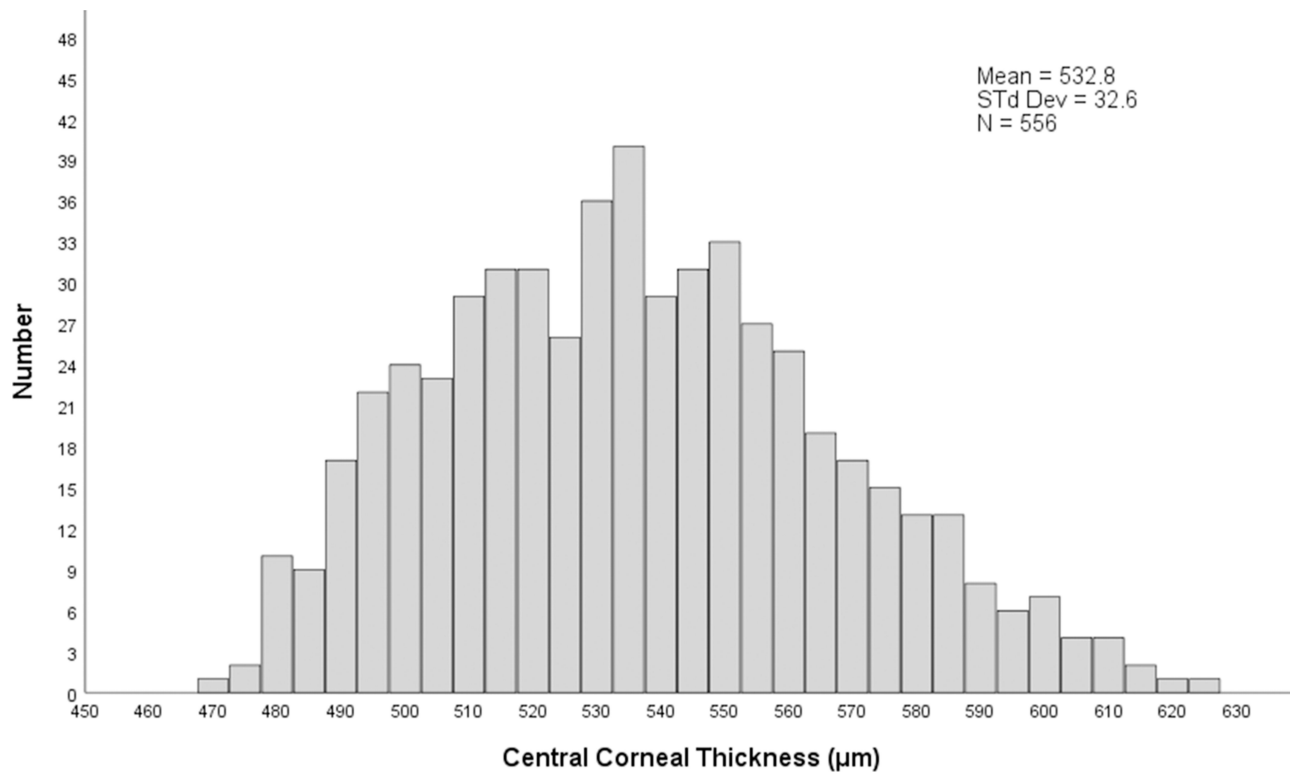


Figure 2 Histogram showing the distribution of central corneal thickness values in myopic adult Egyptian subjects (Std. Dev. = Standard Deviation).

Table 3 General Characteristics of Hyperopia Sub-Groups

	Hyperopia Total Subjects	Hyperopia Sub-Groups n (Column %)			P-value
		Low <+3.0D	Moderate +3.0 to <+6.0D	High ≥+6.0D	
Number (%)	610 (100%)	290 (47.5%)	190 (31.1%)	130 (21.3%)	—
Age (yrs): Mean±SD Range	35.1±10.7 (21 to 60)	35.5 ± 10.6 (21 to 60)	39.0 ± 11.5 (21 to 54)	28.6 ± 6.1 (21 to 42)	0.022*
Sex, n (%): Male Female	210 (34.4%) 400 (65.6%)	100 (34.5%) 190 (65.5%)	60 (31.6%) 130 (68.4%)	50 (38.5%) 80 (61.5%)	0.922
Eye, n (%): Right Left	300 (49.2%) 310 (50.8%)	90 (31.0%) 200 (69.0%)	120 (63.2%) 70 (36.8%)	90 (69.2%) 40 (30.8%)	0.025*
SE(D): Mean±SD Range	+3.57±1.98 (+0.50 to +8.50)	+1.85±0.61 (+0.5 to +2.75)	+4.14±0.60 (+3.0 to +5.25)	+6.58±0.82 (+6.0 to +8.50)	<0.001*
CCT(µm): Mean±SD Range	530.8±37.2 (471 to 616)	527.5±38.0 (471 to 616)	524.7±36.3 (478 to 588)	547.2±34.7 (491 to 606)	0.197

Note: *Statistically significant (P-value <0.05).

Abbreviations: SE, spherical equivalent; n, number; yrs, years; µm, micrometre; SD, standard deviation; D, dioptre.

527.5±38.0µm, range (471 to 616µm). Moderate hyperopia +3.0 to <+6.0D the mean±SD of the CCT was 524.7±36.3µm, range (478 to 588µm). Those with high hyperopia ≥ +6.0D the mean±SD of the CCT was 547.2±34.7µm, range (491 to 606µm). There are also no statistical significance differences between hyperopic sub-groups as regarding CCT (P=0.197), [Table 3](#), [Figure 3](#). The range of distribution of the CCT in hyperopic adult Egyptian subjects is presented in [Figure 4](#).

Age, Sex, and Eye Laterality

The subjects were divided into three age sub-groups <30years, 30 to 39years, and ≥40years. The mean ±SD of CCT of these sub-groups found to be thinner with age, but the differences were statistically not significant in both myopic subjects (P2=0.430) and hyperopic subjects (P2=0.898). Male has thicker cornea than females with statistically insignificant differences (P4=0.473 and P=0.395) for the myopic and hyperopic subjects, respectively [Table 4](#).

Discussion

Reference values are a significant base for clinical decisions during patient examinations and diagnosis of different ocular diseases. The diagnostic criteria for those

diseases depended on the differences between those reference values and clinical observations.⁶ Reference values for CCT in the eastern Egyptian population with myopia and hyperopia were measured, quantified, and presented in this study. These values offer tools for interpreting many clinical situations and evaluating changes in physiology and corneal biology in response to systemic diseases among the Egyptians. This also will help for accurate diagnoses of suspected keratoconus, early keratoconus, and other corneal diseases. The mean reference values for the CCT of the eastern Egyptian population aged from 21 to 60 years with different refractive errors measured by ultrasonic pachymetry were 532.8µm for myopic and 530.8µm for hyperopic subjects, respectively. These values are relatively higher compared to that recorded in other studies (other ethnic groups).^{6,16–20} Values of the CCT of different ethnical groups vary and are summarised in [Table 5](#). Also, it reports that myopic and hyperopic subjects show a statistically non-significant reduction in CCT with ageing, females have thinner corneas than males, with no significant differences as recorded in other studies.^{18,21,22} Also, about 16.2% of the myopic eyes and 12.7% of the hyperopic eyes (in the investigated sample) have CCT less than 500µm, and this

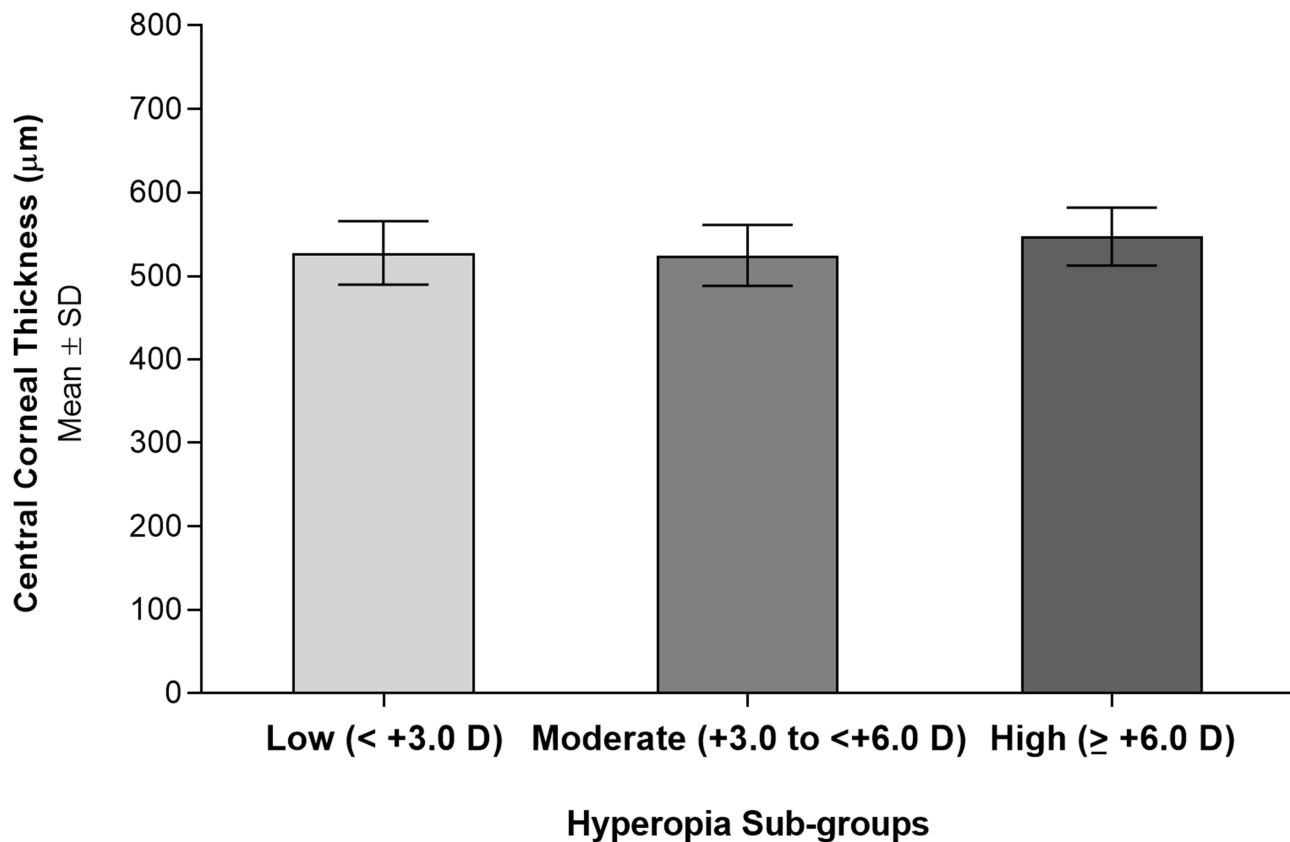


Figure 3 Mean±standard deviation (SD) of the central corneal thickness of hyperopia sub-groups.

means that those patients are not suitable for LASIK. A remarkable previous study by Mostafa²³ recorded mean CCT in a southern Egyptian population by ultrasonic pachymetry in emmetropic, myopic, and hyperopic subjects aged from 16 to 70 years. The recorded mean CCT was 532.6μm in emmetropic, 531.5μm in myopic <6.0D, 531.1μm in myopic >6.0D and 533μm in hyperopic. The percentage of patients with a CCT≤500 μm was 31.9% in the emmetropic, 37.9% in myopic and 22.9% in hyperopic subjects.

Normal reference values represent an essential base of clinical judgment for the patients. Once the normal range of CCT is specified in a population, applicable studies can be completed without the necessity for a control group, and patients' pachymetry analyses can be adjudicated with more certainty.^{36–39}

Still, most ophthalmic diagnostic instruments produced in America and Europe use normal reference values of their populations. In this manner, it may not be useful to assess the Egyptian population utilising normal values from Americans and Europeans. Gathering reference values of the corneal thickness in a large population of

adult Egyptians will help in precise diagnoses of keratoconus and keratoconus suspect, besides other corneal diseases, where these reference values of Egyptians CCT are essential also in glaucoma diagnosis and treatment.

Principally in successful corneal refractive surgery, corneal thickness is an essential factor for the preoperative screening of keratoconus and for pre-surgical assessment of the precise ablation profile to maintain post-surgical corneal stability. This reduces the incidence of post-LASIK corneal ectasia.⁴⁰

Increased care on the corneal thickness has brought about its description in a considerable number of studies from different regions and countries.^{21–23,36–48} For the contrasts in ethnicity, geography, and other environmental variables, there is a wide-extending variety within these records; in this way, reference values of the corneal thickness-related parameters should not be utilised imprecisely and should be sensitive to variations within each population.

Some limitations should be considered while reading this study. First, it is a retrospective study, and in this way, all related restrictions must be thought of. Second, factors affecting female central corneal thickness, like the menstrual cycle,

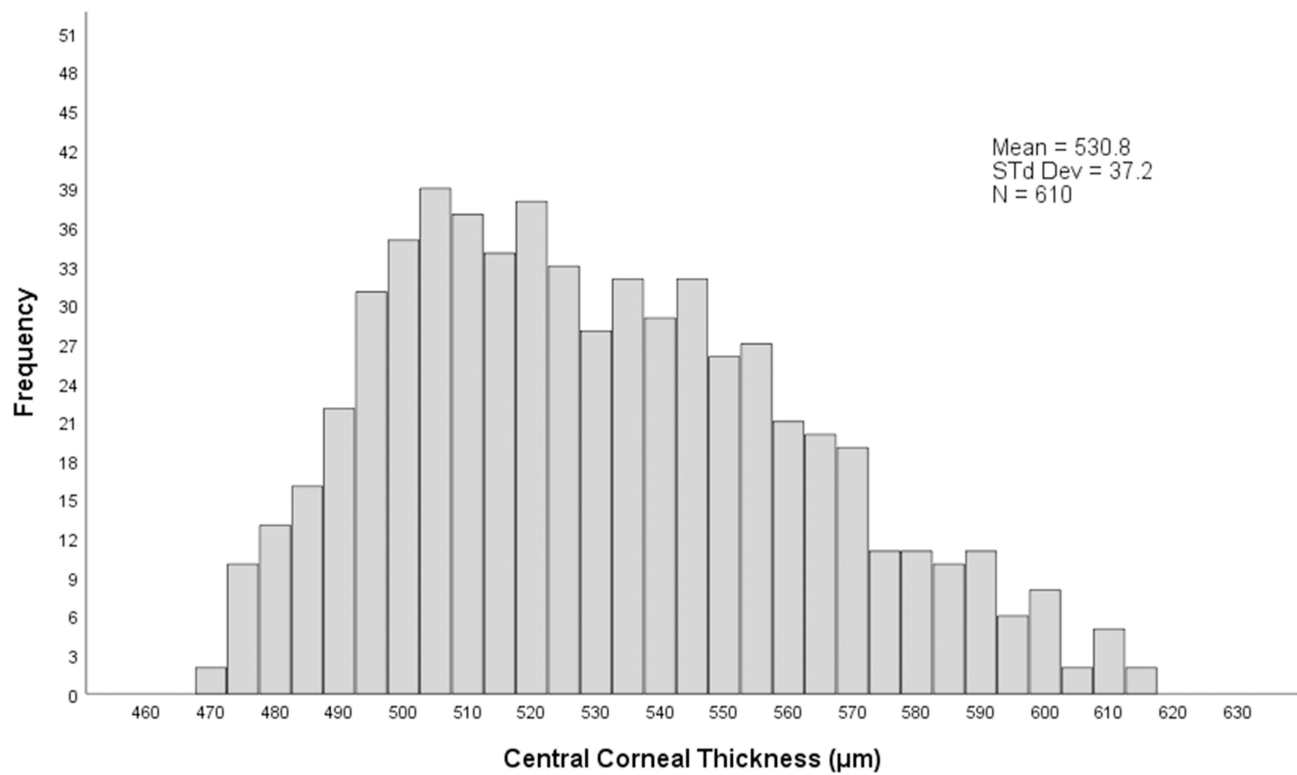


Figure 4 Histogram showing the distribution of central corneal thickness values in hyperopic adult Egyptian subjects (Std. Dev. = Standard Deviation).

lactation, oral contraceptive pills, and hormonal therapy, were not associated. Third, although ultrasonic pachymetry is considered the gold standard for the measurement of CCT, it is operator dependent and can modify its results if the cornea is indented during the measurement or non-

perpendicular alignment of the ultrasound probe. Fourth, the unequal distribution of age groups between the myopic and hyperopic subjects.

In conclusion, the mean of the CCT of the eastern Egyptian population was 532.8µm for myopic and 530.8µm

Table 4 Central Corneal Thickness by Age Groups, Eye Laterality and Sex in Myopic and Hyperopic Subjects

		Central Corneal Thickness Mean±SD Range		P1-value
		Myopia	Hyperopia	
Age groups (yrs):	<30	539.5 ± 34.7 (477 to 617)	535.7 ± 41.5 (473 to 616)	0.092
	30-39	533.7 ± 31.8 (471 to 621)	532.1 ± 29.4 (495 to 591)	0.372
	≥40	532.0 ± 32.6 (470 to 627)	524.4 ± 38.7 (471 to 589)	0.0003*
	P2-Value	0.430	0.898	
Sex	Male	534.3 ± 31.8 (471 to 615)	536.5 ± 36.6 (478 to 606)	0.276
	Female	532.2 ± 32.9 (470 to 627)	527.9 ± 37.7 (471 to 616)	0.039*
	P3-value	0.473	0.395	

Note: *Statistically significant (P-value <0.05).

Abbreviations: SD, standard deviation; yrs, years.

Table 5 Summary of Mean Central Corneal Thickness in Different Ethnic Groups

Ethnic Groups	Age Group (yrs)	CCT (μm)	Measured by	Study Type
Australian ¹⁹	14–51	508	Ultrasound	Case-control
Japanese ²⁴	40–80	514.5	Specular microscope	Cross-sectional
Japanese ¹⁸	≤ 40	517.5	Specular microscope	Cross-sectional
African American ²⁵	$67.3 \pm 15.9^*$	521.0	Ultrasound	Retrospective
Ghana ²⁶	40–98	525.3	Ultrasound	Prospective
Reykjavik ²⁷	< 50	527.0	Scheimpflug anterior segment photography	Cross-sectional
European ²⁸	5–15	529.0	Ultrasound	Cross-sectional
European ²⁸	32–60	533.0	Ultrasound	Clinical
Thai ²⁹	12–60	535.2	Ultrasound	NA
Australian ¹⁹	15–56	541	Ultrasound	Case-control
Singapore ³⁰	40–80	541.2	Ultrasound	Cross-sectional
Bridlington ³¹	< 65	544.1	Ultrasound	Population screened
South Australia ³²	$44.8 \pm 14.5^*$	544.6	Ultrasound	Cross-sectional
Latinos ³³	40	546.9	Ultrasound	Population-based cohort
Hispanic ²⁵	$67.3 \pm 15.9^*$	548.1	Ultrasound	Retrospective
Filipino ²⁵	$67.3 \pm 15.9^*$	550.6	Ultrasound	Retrospective
Turkish ³⁴	6–88	552.2	NA	Clinical
Chinese ²⁵	$67.3 \pm 15.9^*$	555.6	Ultrasound	Retrospective
Iranian ⁴²	14–81	555.6	Orbscan	Cross-sectional
Beijing ³⁵	< 45	556.2	Ultrasound	Cross-sectional
German ⁴¹	$60.2 \pm 15.0^*$	616.6	NA	Histomorphometric

Note: *mean \pm SD.

Abbreviations: NA, not applicable; yrs, years; μm , micrometre.

for hyperopic subjects, respectively. The myopic and hyperopic subjects show a reduction in CCT with age. Females have a thinner cornea than males, 16.2% of the myopic eyes and 12.7% of the hyperopic eyes have CCT less than 500 μm .

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Disclosure

The author reports no conflicts of interest in this work.

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