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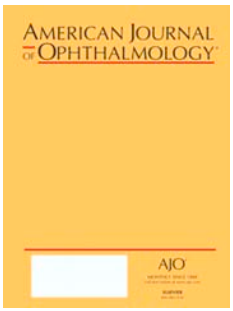


Choroidal Thickness And Volume In Healthy Young Whites And Their Relationship With Axial Length, Ammetropy And Sex

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**PURPOSE:** To evaluate choroidal thickness in young subjects using Enhanced Depth Imaging Spectral Domain Optical Coherence Tomography (EDI SD-OCT) describing volume differences between all the defined areas of the Early Treatment Diabetic Retinopathy Study (ETDRS).

**DESIGN:** Prospective, clinical study.

**METHODS:** Seventy-nine eyes of 95 healthy, young (23.8±3.2years), adult volunteers were prospectively enrolled. Manual choroidal segmentation on a 25-raster horizontal scan protocol was performed. The measurements of the nine subfields defined by the ETDRS were evaluated.

**RESULTS:** Mean subfoveal choroidal thickness was 345.67±81.80μm and mean total choroidal volume was 8.99±1.88mm$^3$. Choroidal thickness and volume were higher at the superior and temporal areas compared to inferior and nasal sectors of the same diameter respectively. Strong correlations between subfoveal choroidal thickness and axial length (AL) and myopic refractive error were obtained, $r = -0.649$, $p<0.001$ and $r = 0.473$, $p<0.001$ respectively. Emmetropic eyes tended to have thicker subfoveal choroidal thickness (381.94±79.88μm versus 307.04±64.91μm) and higher total choroidal volume than myopic eyes (9.80± 1.87mm3 versus 8.14±1.48mm3). The estimation of the variation of the subfoveal choroidal thickness with the AL was -43.84μm/mm. In the myopic group, the variation of the subfoveal choroidal thickness with the myopic refractive error was -10.45μm/D.

**CONCLUSIONS:** This study establishes for the first time a normal database for choroidal thickness and volume in young adults. Axial length, and myopic ammetropy are highly associated with choroidal parameters in healthy subjects. EDI SD-OCT exhibited a high degree of intraobserver and interobserver repeatability.

# Choroidal Thickness And Volume In Healthy Young Whites And Their Relationship With Axial Length, Ammetropy And Sex

Short Title: Choroidal Thickness And Volume In Healthy Young Whites

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## INTRODUCTION

The development of optical coherence tomography (OCT) technology has revolutionized the diagnostic, monitoring and therapeutic approaches to many retinal diseases. Spectral domain OCT (SD-OCT) offers improved axial resolution (3 µm); by providing 19,000 A-scans per second, it shortens examination times, reducing the eye exposure as well as artifacts[1]. The latest development in OCT technology, swept-source longer-wavelength OCT (SS-OCT), has a longer-band light source than does the conventional instrumentation (1 µm band light source), providing higher penetration through the retinal pigment epithelium (RPE) and allowing for better visualization of the choroid; however, at the present time, SS-OCT use is limited to research.

The role of the choroid in a number of diseases, including central serous chorioretinopathy, high myopia, age-related macular degeneration, choroidal melanoma, and polypoidal choroidal vasculopathy, emphasizes the importance of understanding choroidal structure in ocular disease[2-5]. Indocyanine green has been the best tool for studying choroidal vasculature; however, it does not provide a quantitative evaluation of the layer; other imaging methods such as echography aid in evaluating the layer, and MRI could provide limited imaging of it. Until recently, accurate morphologic study of the choroid using SD-OCT was not possible owing to its posterior location and the scattering of light caused by the pigmented RPE cells. Both the recently introduced enhanced depth imaging (EDI) system by Spaide et al.[6] and SS-OCT provide higher penetration through the RPE, allowing for accurate *in vivo* deep choroidal imaging and measurement[7].

Changes in choroidal thickness have been described as being related to smoking, changes in arterial pressure, daylight/daytime, age and axial length[8-12]. It is important to have a normative base of choroidal thickness at different ages to compare values with aging. Measurement of choroidal thickness in young adults is required to create this normative base. Choroidal thickness is greater in children than in adults at different ages because choroidal layer thickness diminishes with age, mainly in the temporal area[13]. Although young adult choroidal thickness has been described in previous work using SS-OCT, these studies only focused on thickness at the horizontal and vertical levels that cut the fovea because automated choroidal segmentation software was unavailable and measurement could only take place manually. Measurements of a small number of points can be influenced by local changes in choroidal thickness or irregularities in the choroidoscleral border[5, 14, 15].

In the present study, we evaluated choroidal thickness and 3D reconstruction in young subjects using EDI SD-OCT to describe volume differences between all of the defined areas of the Early Treatment Diabetic Retinopathy Study (ETDRS).

## MATERIAL AND METHODS

This prospective study was performed between February 1 and June 30, 2013, with healthy volunteers aged 19–32 years. The subjects were recruited from students of the optometry school and evaluated in this cross-sectional observational study at the Ophthalmology Department of the Lozano Blesa University Hospital, Zaragoza, Spain. All of the subjects referred to themselves as healthy. Written consent was obtained from each participant before enrollment. The study was performed in accordance with the tenets of the Declaration of Helsinki.

The inclusion criteria were: best corrected visual acuity (BCVA) over 0.8 on the Snellen scale; refractive spherical equivalent ≤ 8.0 diopters (D); or astigmatism <3D with no retinal or optic disc alteration as determined by mydriatic funduscopic examination. Exclusion criteria were: history of amblyopia, strabismus, systemic diseases (no

findings during medical exam prior to university enrollment) or intraocular pressure (IOP) measured by Goldmann tonometry as over 21 mmHg.

All subjects underwent a complete ophthalmologic examination including BCVA, assessment of ocular motility and alignment and evaluation of the anterior and posterior poles. A biometer (IOLMaster; Carl Zeiss Meditec, Dublin, CA) was used to explore each subject's axial length (AL); an open-view autorefractometer (autokerato/refractometer WAM-5500®, Grand Seiko Co. Ltd, Japan) and an aberrometer (Wavefront Supported Custom Ablation (WASCA); Carl Zeiss Meditec AG, Jena, Germany) were used to establish each participant's refractive status. The average of three measurements was recorded without pupillary dilatation. Then, SD-OCT was performed using Spectralis OCT (Spectralis; Heidelberg Engineering GmbH, Heidelberg, Germany). Each eye was considered separately, and only one random eye from each subject was included in the study.

All subjects underwent choroidal segmentation on a 25-raster horizontal scan protocol. Volume fast macular scans and three additional scans with the same protocol using EDI were performed. Each subject's refractive errors were corrected to improve retinal image quality. The peripapillar retinal nerve fiber layer was also evaluated to identify any optic nerve pathology. This sequence was performed using *TruTrack* eye-tracking technology (Heidelberg Engineering GmbH, Heidelberg, Germany), which recognizes, locks onto and follows the patient's retina during scanning; the tracker also automatically takes follow-up scans to ensure accurate monitoring of disease progression. The Spectralis software version used was 5.6b. The quality of the scans was assessed prior to the analysis, and poor-quality scans were rejected; only images with a score higher than 28 dB over 40 dB were used. All scans were performed by the same experienced operator. Between scan acquisitions, there was a time delay, and subject position and focus were randomly disrupted, meaning that alignment parameters had to be newly adjusted at the start of each image acquisition. No manual correction was applied to the OCT output. An internal fixation target was used because it has previously been shown to give the highest reproducibility[16].

We selected the retinal thickness map analysis protocol to display the numeric averages of the measurements for each of the nine subfields defined by the ETDRS, with three concentric circles defining ninemacular sectors (1 mm, 3 mm and 6 mm, nasal, temporal, superior and inferior to the fovea). The average of all points within the inner circle of 1 mm radius was defined as the subfoveal choroidal thickness. All nine areas were considered for analysis.
To assess choroidal thickness, segmentation lines were manually changed (Figure 1). The internal limiting membrane layer was moved to the outer part of the RPE level and the Bruch membrane segmentation line was moved to the division between the choroid and the sclera. Moving both segmentation lines limits the choroid, and the values that appeared in the described macular areas were the true choroidal thickness values[17]. Segmentation was performed by the same observer, and one of the three choroidal maps was also segmented by another observer to ensure interobserver reproducibility.

Statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS 20.0, SPSS Inc., Chicago, IL, USA). A parametric test (Kolmogorov-Smirnov test) was used because of the normal distribution of the results, and paired t-tests were subsequently performed to compare means between areas. To calculate the degree of correlation between the study values, Pearson correlation coefficients were calculated. Choroidal thicknesses were compared between AL, sex and age using Student's t-test. Choroidal values for the nine areas defined in the ETDRS were compared to assess the differences in the different areas. Values of $p<0.05$ were considered to be indicative of statistically significant differences.

To assess the repeatability of repeated measurements, intraclass correlation coefficients (ICC) were calculated[18]. The ICC was defined as the ratio of the between-subject variance to the sum of the pooled within-subject ($S_w$) and between-subject variances. The study's ICC interpretation considered values between 0 and 0.2 to have slight reliability, and those from 0.21 to 0.4 had fair reliability. Reliability was moderate if the ICC value was between 0.41 and 0.6, substantial if the ICCs were between 0.61 and 0.8 and nearly perfect when the ICC exceeded 0.81. The coefficient of variation (COV) was calculated as the $S_w$ divided by the mean of the measurements and expressed as a percentage; the lower the COV, the higher the repeatability. The Bland-Altman method was used to analyze the intra-observer and interobserver agreement among measurements and between observers, respectively[19].

## RESULTS

### Choroidal thickness and volume

The choroidal thickness and volume values shown on the ETDRS grid were evaluated in a total of 95 healthy eyes, as shown in Figure 2. The choroidal limits were delimited without difficulty in all subjects except one; one eye was excluded because of ocular traumatism during childhood with surgical aphakia and retinal detachment. A total of 95 measured eyes were used for our study, of which 30 were male (31.58%) and 65 were female (68.42%). The mean age was 23.8 ± 3.2 years (range, 19-32). All studied eyes had a BCVA of 0.8 or better as was set in the inclusion criteria, and all of the subjects were white. Mean spherical equivalent (D) was -1.50 ± 2.32D (range, -11.25D to 0D), and mean AL was 24.04 ± 1.21 mm (range, 22.05 to 28.72 mm). Mean choroidal thicknesses and volumes in the different areas are displayed in Table 1. Mean subfoveal choroidal thickness was 345.67±81.80μm, and mean volume in the same area was 0.27±0.06 $mm^3$. Choroidal thickness and volume were higher in the superior and temporal areas (3 and 6 mm) compared with inferior and nasal sectors of the same diameter. Table 2 shows statistically significant differences ($p<0.05$) between these zones.

### Variation of choroidal thickness with axial length, refractive error and sex

Strong correlations between subfoveal choroidal thickness and AL (Figure 3) and refractive error were obtained ($r=-0.649$, $p<0.001$ and $r=0.473$, $p<0.001$, respectively). For the refractive error values, two groups were defined, emmetropic eyes (n=49) with no spherical equivalent and myopic eyes with any negative spherical equivalent (n=46); values ranged from -0.39D to -11.25D, and the choroidal values for both groups are shown in Table 3. Differences ($p<0.05$) were found between the thicknesses and volumes of the two groups, with a negative correlation between mean choroidal characteristics and AL: emmetropic eyes tended to have thicker choroids and higher choroidal volume than did myopic eyes. In the myopic group, an estimate of the subfoveal choroidal thickness variation with myopic refractive error was calculated (Figure 4).

Differences between the sexes were also evaluated; males (n=30) tended to have more similar choroidal thicknesses than did females (n= 65) in addition to comparable choroidal volumes. Table 4 shows that no statistically significant differences ($p>0.05$) found between the sexes in certain zones.

### Intra-observer and interobserver repeatability of choroidal thickness and volume with EDI-OCT

To evaluate the intra-observer repeatability, the choroidal membranes of 30 eyes were delimited by the same operator three times. ICCs were calculated for each area in the

ETDRS grid. Choroidal thickness ICCs varied from 0.974 to 0.995, and no statistically significant differences were found among the three measurements taken by the same examiner. Choroidal volume ICCs ranged from 0.975 to 0.995, with similar statistical results (Table 5). Interobserver reproducibility was additionally evaluated (Table 5), with the limits of the choroids of 30 eyes being independently defined by two operators. Although the ICC results indicated perfect reliability in choroidal thickness (0.896 to 0.980) and volume (0.894 to 0.980), there were statistically significant differences between the two observers in some parameters ($p<0.05$). Intra-observer COV (thickness and volume) varied from 14% to 24% and interobserver COV varied from 14% to 23%.

## DISCUSSION

Previous studies have measured choroidal thickness in both normal subjects and those with ocular disease using EDI-OCT and SS-OCT[2, 7, 9, 13, 20-24]. Retinal studies are typically performed with specific software provided by the different OCT manufacturers; however, manual segmentation is required in all cases in which choroidal thickness or volume are measured. The resolution of the choroidal images taken with EDI SD-OCT is worse than that of the retinal images, and obtaining high resolution can be difficult, such as when the long posterior ciliary arteries enter the eye. It is crucial to study repeatability and reproducibility because of the manual segmentation and the other mentioned parameters. Comparison with previous studies is difficult because of the different line scans performed with various instruments, variability in the ages and sexes of the populations being evaluated or the different statistical methodologies used.

A number of studies have characterized healthy choroidal thickness, one of the most studied parameters, as having mean subfoveal choroidal thickness values lower than 300μm[7, 9, 10, 20, 23, 25] or higher that 300μm[6, 8, 13, 24, 26-28], with a range from 202.6±83.5μm[9] to 355±73μm[8] or 354±111μm [27]. Our mean subfoveal choroidal thickness result, 345.67±81.80μm, is closer to these last values because the mean age of our population was 24 years and the earlier studies were conducted with subjects 65, 33 and 39 years old. Ruiz Moreno et al.,[13] in a pediatric population, used SS-OCT to establish a mean subfoveal choroidal thickness value of 312±65.3μm, which diminished in the adult group (mean age 53.2 years). These changes in choroidal thickness can be explained by differences in age distribution (negative correlation), as the literature reflects[7-10, 13, 22-25, 28]. Additional studies on choroidal thickness and profile may clarify the influence of normal eyeball development on the choroid and on changes related to aging. Our study suggests that the choroid is thickest in the superior and temporal areas, similar to the findings of Ouyang et al.[10] and Hirata et al.[9]; choroidal thickness decreases in the nasal direction,[7-10, 13, 20, 22-25] and the temporal choroid is significantly thicker than the nasal choroid[9, 22, 24, 28]. The choroid immediately adjacent (3 mm) to the subfoveal area (1 mm) remained without changes in thickness in the temporal and superior areas, decreased slightly in the inferior zone and reflected significant changes in the nasal region ($p<0.001$). Although differences between temporal and nasal thickness can be observed in a circle of 3 mm, an area of 6 mm is required to identify differences between the superior and inferior thicknesses. This tendency was described by Hirata et al.,[9] although our absolute values for the different areas are higher than those found in their study. These differences could again be attributable to the ages of the studied groups; the mean age in our study was 24 years, and in their study, it was 65 years with a range between 21 and 87. Despite these changes in choroidal thickness, significant variations in choroidal volume can be observed in all studied areas except in the 3 mm superior/inferior. In adults over a mean age of 45 years old, Hirata et al.[9] found a total volume of 5.411±2.097 $mm^3$ (mean age 65 years); Shin et al.[28] reported a total volume of 7.72±1.2 $mm^3$ (mean age

46.2 years); and Barteselli et al.[29] reported 7.374±2.181 $mm^3$ (mean age 50 years); all of these values were lower than our results. Barteselli et al.[29] reported 8.311±2.199 $mm^3$ in subject aged 40 or younger, similar to our results—8.99±1.88 $mm^3$—and comparable in ages. We found significant differences in volume between emmetropic and myopic eyes, as shown in Table 3. The same tendency was described by Barteselli et al.,[29] with values of 7.645±2.186 $mm^3$ and 6.761±2.005 $mm^3$, respectively. Differences in choroidal volume between the sexes were reported by these same authors,[29] with the values for males being 7.37% greater than those for females. We found similar total volumes for both females and males, as shown in Table 4, with no significant differences in certain areas. Other authors, including Park et al.,[24] found that subfoveal choroidal thickness was not significantly different between the sexes, and a borderline correlation between subfoveal choroidal thickness and sex was found by Manjunath et al.[25] with slightly greater thickness in males than in females. It is possible that ethnic, age and axial length differences influenced these contradictory conclusions, and thus, additional clinical studies with larger populations are required to evaluate the sex-dependence of these findings.

We found a moderate linear correlation (r=0.473) between subfoveal choroidal thickness and refractive error (Figure 4), as did Ouyang et al. [10], Ruiz-Moreno et al. [13] and Hirata et al.[9] Although Park et al.[24] reported no significant correlations, other authors have obtained choroidal thickness declines in myopic eyes that varied from -9.3μm/D (Ikuno et al.[22]) to -10.87μm/D (Ding et al.[20]). In our population, we found that the subfoveal choroidal thickness was in the range of -10.45μm/D, a similar value to those found by previous authors including Shin et al.[28] (-9.55μm/D) and Flores-Moreno et al.[23] (-9.4μm/myopic diopter (only in high myopia)). Analysis is clearer when refractive error is substituted by AL—there was a significant negative correlation between foveal choroidal thickness and AL[8-10]. We identified a -43.84μm/mm factor, lower than that found by Li et al.,[26] who found a value of -58.2μm/mm, but higher than the -22.4μm/mm found by Ikuno et al.[22] and the -31.96μm/mm of Ouyang et al.[10] Additionally, Flores-Moreno et al.[23] found -26μm/mm in highly myopic subjects but no correlation in healthy eyes. We found that the choroid is thinner in myopic eyes than in normal eyes and that there are great differences in volume. Histologically, the choroid is formed mainly by blood vessels, and thus, reduced thickness and volume in this structure represent diminished blood supply. The axial length-dependent decrease in the choroidal thickness and volume may be related to the progressive disease of degenerative myopia and the loss of choroidal tissue in the nasal area to peripapillar atrophy.

Our ICC for foveal measurements reached 0.979, in accordance with previous studies[30]; estimated correlations among thickness and volume measurements performed by the same operator were nearly perfect in reliability (Table 5). The Bland-Altman analysis found that only 10% (3/30) of the differences were located outside of the 95% of agreement. Mean value ± standard deviation was -3.87±22.06μm, higher than the value previously reported by Rahman et al.[31] but of the same order of magnitude. subfoveal choroidal thickness was the only comparable value, owing to the different methods used to acquire images.

Yamashita et al.[32] reported nasal, subfoveal and temporal ICC values of 0.978, 0.976 and 0.904, respectively, similar to our results. The authors calculated subfoveal and temporal COVs of 23%, with a nasal value of 27%. Our COVs varied from 14% to 24% in thickness but were always lower values than those of Yamashita et al.[32] The different measurement protocol may be the reason for the reduced variations in our final results; the more line scans you take, the more precise the measurement. Yamashita et al.[32] used a protocol of 30º cross lines, and the thickness of the choroid in the different areas was defined; the authors examined 750μm temporal to the fovea and 750μm

nasal to the fovea. Hirata et al.[9] described the behavior of the SS-OCT, and they found high ICC values, similar to our results (>0.9) despite the differences in data acquisition.

Our data show that variability in measuring the same choroidal thickness between two examiners is low. Our Bland-Altman result showed that the mean difference between the two was -11.33±48.64μm, and only 6.67% (2/30) of the measurement points were located outside of the 95% limit of agreement. Previous results by Spaide et al.[6], Rahman et al. [31] and Shao et al. [30] found better interobserver repeatability than we did. This can be explained by our protocol; our results were calculated with 25 horizontal line scans, whereas these other authors only studied subfoveal choroidal thickness. To do this, Spaide evaluated one horizontal line scan, Rahman two line scans through the fovea, and Shao seven sections. Rahman et al. [31] found that changes over 32 microns were likely to exceed interobserver subfoveal choroidal thickness variability in healthy eyes. Very high inter-examiner ICCs for subfoveal choroidal thickness were found in previous studies; Ikuno et al.[22] reported 0.97 and Shao et al.[30] reported 0.96. Our results were 0.961 for foveal thickness, in accord with these previous authors, but we conducted the broadest study of different foveal sections (thickness and volume), as shown in Table 5.

Regarding extreme areas, fewer papers can be found. Branchini et al. [33] described nasal and subfoveal interobserver correlations of 0.96 and a 0.93 value for the temporal area; the values from Manjunath et al. [25] varied from 0.88 to 0.95. Yamashita et al. [32] reported subfoveal and temporal COVs of 23% and 27% in the nasal area with 0.944, 0.917 and 0.989 ICC, respectively. Our COVs, although high (Table 5), were lower than those previously mentioned; therefore, the lower the COV, the higher the repeatability.

All subjects were healthy, with no systemic medication that could have modified choroidal thickness. One of our study's limitations is the hyperopic refraction. There were insufficient hyperopic eyes for identifying any changes that could be comparable with the emmetropic or myopic groups, which should be evaluated in additional studies.

In conclusion, we propose that a 25-raster horizontal scan mapping procedure on a commercially available SD-OCT provides accurate measurements of the central and peripheral regions. Although other scan protocols are used clinically to evaluate choroidal thickness and volume, interpolation errors are present. ETDRS-style choroidal maps have high repeatability and reproducibility using EDI SD-OCT despite the manual choroidal segmentation. Software to determinate choroidal limits is essential to standardizing the evaluation and because of the increased importance of choroidal studies. Our study provides a normal database for choroidal thickness and volume in young adults. Axial length and myopic ammetropy are highly associated with choroidal parameters in healthy subjects.

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FIGURE CAPTIONS

Figure 1. This image shows an example of how both reference lines were moved to evaluate choroidal thickness. Left original reference lines and Right moved lines.

Figure 2. Example of choroidal map of an emmetropic eye. Average thickness and volume values are shown for the Early Treatment Diabetic Retinopathy Study areas.

Figure 3. Scatterplot of subfoveal choroidal thickness and axial length in healthy young withes. Subfoveal choroidal thickness= -43.84*axial length + 1399.7; $R^2 = 0.421$

Figure 4. Scatterplot of subfoveal choroidal thickness and myopic ammetropy in healthy young withes. Subfoveal choroidal thickness= 10.45*myopic ammetropy + 339.5; $R^2 = 0.223$

Table 1. Mean choroidal thickness and volume in healthy young whites evaluated with the Early Treatment Diabetic Retinopathy Study grid, all the areas were independently measured.

| | | Thickness (µm) | | | Volume ($mm^3$) | | |
|---|---|---|---|---|---|---|---|
| Ring | Area | Mean ± SD | Minimum | Maximum | Mean ± SD | Minimum | Maximum |
| 6 mm | Temporal | 326.33 ± 59.25 | 181 | 491 | 1.73± 0.31 | 0.96 | 2.60 |
| | Inferior | 326.04± 74.62 | 175 | 532 | 1.73± 0.40 | 0.93 | 2.82 |
| | Nasal | 249.76± 70.23 | 109 | 456 | 1.31± 0.38 | 0.56 | 2.42 |
| | Superior | 341.89± 69.64 | 208 | 514 | 1.81± 0.37 | 1.10 | 2.72 |
| 3 mm | Temporal | 347.97± 73.02 | 164 | 518 | 0.55± 0.11 | 0.26 | 0.81 |
| | Inferior | 342.74± 84.45 | 157 | 562 | 0.54± 0.14 | 0.25 | 0.88 |
| | Nasal | 316.27± 82.40 | 131 | 525 | 0.51± 0.17 | 0.21 | 1.61 |
| | Superior | 349.83± 76.24 | 164 | 569 | 0.55± 0.12 | 0.26 | 0.89 |
| 1 mm | Fovea | 345.67± 81.80 | 152 | 519 | 0.27± 0.06 | 0.12 | 0.41 |
| | Total | --- | --- | --- | 8.99± 1.88 | 4.75 | 14.29 |

Table 2. Mean thickness and volume of the different areas evaluated and statistical comparison of the results. Comparison of the symmetric areas of the outer ring (6 mm) and the inner ring (3 mm), and the inner ring (3mm) with the subfoveal area (1 mm).

| | Thickness (μm) | | Volume ($mm^3$) | |
|---|---|---|---|---|
| Areas | Mean ± SD | p | Mean ± SD | p |
| Temporal (6 mm) - Nasal (6 mm) | 76.57± 43.78 | <0.001 | 0.42± 0.25 | <0.001 |
| Superior (6 mm) - Inferior (6 mm) | 15.85± 48.76 | 0.002 | 0.09± 0.26 | 0.002 |
| Temporal (3 mm) - Nasal (3 mm) | 31.69± 31.23 | <0.001 | 0.04± 0.12 | 0.003 |
| Superior (3 mm) - Inferior (3 mm) | 7.09± 44.01 | 0.120 | 0.01 ± 0.07 | 0.077 |
| Temporal (3 mm) – Center (1 mm) | 2.29± 22.64 | 0.326 | 0.27 0.06 | <0.001 |
| Nasal (3 mm) – Center (1 mm) | -29.40± 18.57 | <0.001 | 0.24± 0.13 | <0.001 |
| Superior (3 mm) – Center (1 mm) | 4.16± 31.37 | 0.200 | 0.28± 0.07 | <0.001 |
| Inferior (3 mm) – Center (1 mm) | -2.94± 27.24 | 0.296 | 0.26± 0.08 | <0.001 |

Table 3. Mean choroidal thickness and volume ± standard deviation of emmetropic and myopic healthy young whites groups. Statistically significant differences were found in all described parameters (p<0.05). Mean axial lengths were 23.35±0.74 mm and 24.77±1.19 mm (p<0.001) in the emmetropic and myopic groups, respectively.

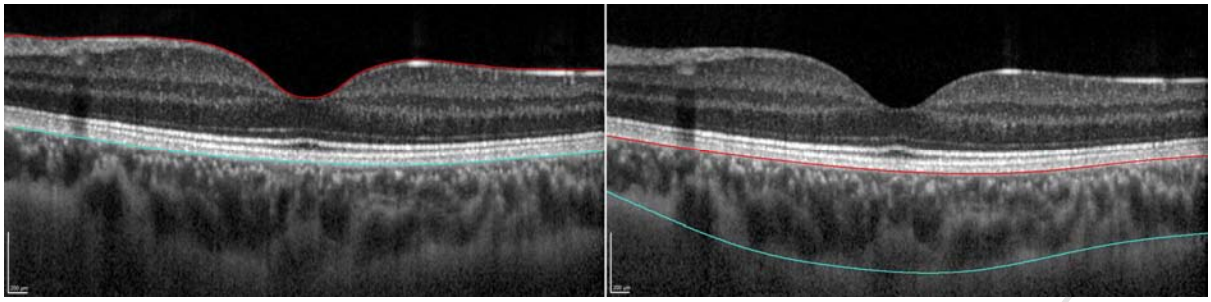
| | | Thickness (µm) | | | Volume ($mm^3$) | | |
|---|---|---|---|---|---|---|---|
| | | Emmetropic | Myopic | | Emmetropic | Myopic | |
| Ring | Area | Mean ± SD | Mean ± SD | p | Mean ± SD | Mean ± SD | p |
| 6 mm | Temporal | 351.31± 57.70 | 299.72 ± 48.78 | <0.001 | 1.86± 0.31 | 1.59± 0.26 | <0.001 |
| | Inferior | 359.29± 70.21 | 290.63± 62.36 | <0.001 | 1.90± 0.37 | 1.54± 0.33 | <0.001 |
| | Nasal | 277.82± 69.87 | 219.87± 57.67 | <0.001 | 1.47± 0.37 | 1.14± 0.30 | <0.001 |
| | Superior | 361.20± 75.21 | 321.33± 57.07 | 0.022 | 1.92± 0.40 | 1.70± 0.30 | 0.022 |
| 3 mm | Temporal | 380.47 ± 70.79 | 313.35± 58.46 | <0.001 | 0.60± 0.11 | 0.49 ± 0.09 | <0.001 |
| | Inferior | 381.69± 79.39 | 301.24± 69.02 | <0.001 | 0.60± 0.12 | 0.47± 0.11 | <0.001 |
| | Nasal | 352.61± 81.11 | 277.57± 64.79 | <0.001 | 0.55± 0.13 | 0.46± 0.20 | <0.001 |
| | Superior | 377.61± 78.01 | 320.24± 62.56 | 0.001 | 0.59± 0.12 | 0.50± 0.10 | 0.001 |
| 1 mm | Fovea | 381.94± 79.88 | 307.04± 64.91 | <0.001 | 0.30± 0.06 | 0.24± 0.05 | <0.001 |
| | Total | --- | --- | --- | 9.80± 1.87 | 8.14± 1.48 | <0.001 |

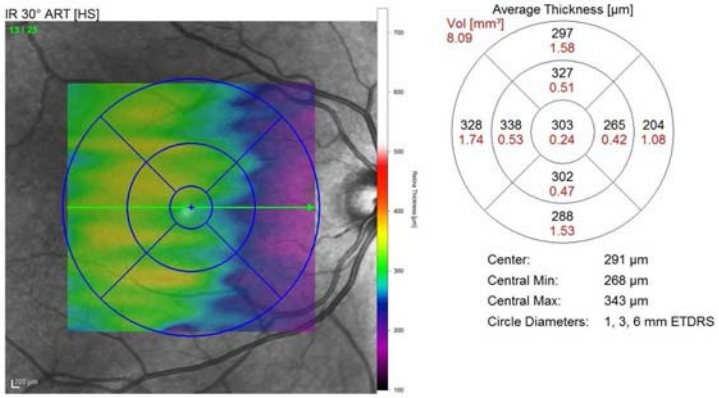
Table 4. Mean choroidal thickness and volume ± standard deviation of male and female healthy young whites groups. Statistically significant differences were found in all described parameters ($p<0.05$). Male axial length was 24.25 ± 0.99 mm and female axial length was 23.95 ± 1.30 mm ($p=0.105$).

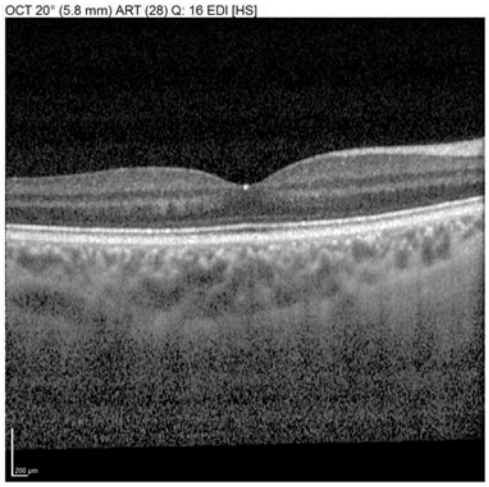
| | | Thickness (μm) | | | Volume ($mm^3$) | | |
|---|---|---|---|---|---|---|---|
| | | Male | Female | | Male | Female | |
| Ring | Area | Mean ± SD | Mean ± SD | p | Mean ± SD | Mean ± SD | p |
| 6 mm | Temporal | 314.47± 47.74 | 331.80± 63.46 | 0.126 | 1.67± 0.25 | 1.76± 0.34 | 0.129 |
| | Inferior | 320.97± 66.84 | 328.38± 78.34 | 0.642 | 1.70± 0.35 | 1.74± 0.42 | 0.642 |
| | Nasal | 247.03± 69.95 | 251.02± 70.87 | 0.740 | 1.27± 0.38 | 1.33± 0.38 | 0.412 |
| | Superior | 337.10± 61.58 | 344.11± 73.40 | 0.327 | 1.79± 0.33 | 1.83± 0.39 | 0.311 |
| 3 mm | Temporal | 339.13± 62.03 | 352.05± 77.68 | 0.321 | 0.53± 0.10 | 0.55± 0.12 | 0.334 |
| | Inferior | 332.87± 76.25 | 347.29± 88.17 | 0.374 | 0.52± 0.13 | 0.55± 0.14 | 0.336 |
| | Nasal | 305.90± 75.57 | 321.06± 85.51 | 0.339 | 0.52± 0.24 | 0.50± 0.14 | 0.506 |
| | Superior | 339.50± 65.33 | 354.60± 80.80 | 0.207 | 0.53± 0.10 | 0.56 ± 0.13 | 0.226 |
| 1 mm | Fovea | 337.63± 73.49 | 349.38± 85.65 | 0.385 | 0.27± 0.06 | 0.27± 0.07 | 0.448 |
| | Total | --- | --- | --- | 8.79± 1.61 | 9.09± 1.99 | 0.296 |

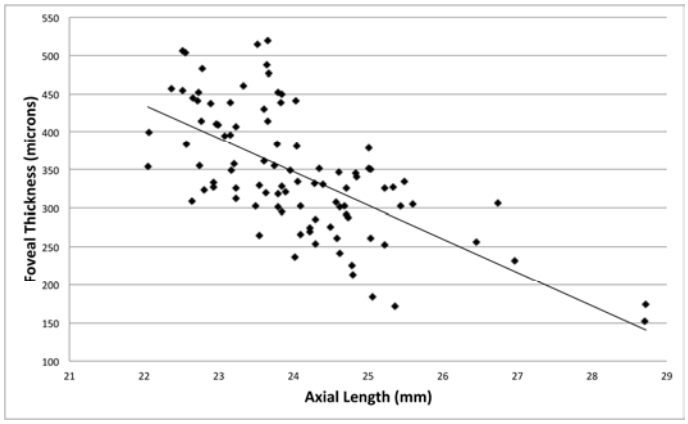
Table 5. Intraclass correlation coefficients and coefficients of variation in choroidal thickness and volume in healthy young whites measured three times by one observer (intraobserver) and by two observers (interobserver). All areas were independently evaluated.

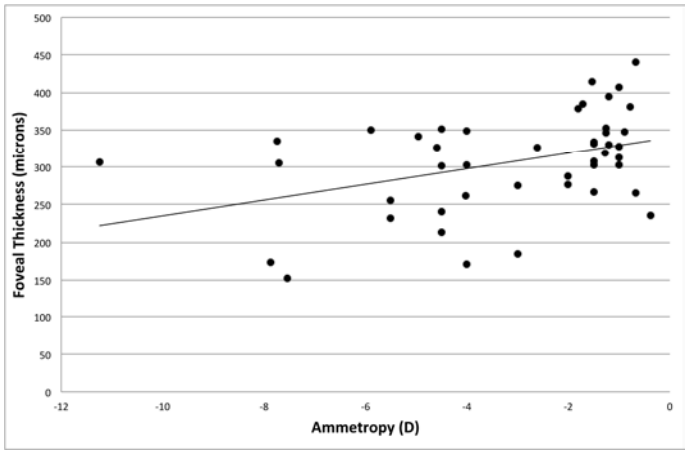
| | | Intraobserver | | | | | | Interobserver | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Thickness | | | Volume | | | Thickness | | | Volume | | |
| Ring | Area | ICC | p Value | COV(%) | ICC | p Value | COV(%) | ICC | p Value | COV(%) | ICC | p Value | COV(%) |
| 6 mm | Temporal | 0.978 | 0.389 | 13.64 | 0.977 | 0.413 | 13.66 | 0.896 | 0.061 | 14.07 | 0.894 | 0.060 | 14.08 |
| | Inferior | 0.995 | 0.119 | 18.93 | 0.995 | 0.127 | 18.92 | 0.976 | 0.001 | 18.66 | 0.977 | 0.001 | 18.64 |
| | Nasal | 0.990 | 0.150 | 23.65 | 0.990 | 0.114 | 23.57 | 0.973 | 0.059 | 23.28 | 0.973 | 0.063 | 23.27 |
| | Superior | 0.985 | 0.837 | 16.12 | 0.985 | 0.877 | 16.12 | 0.972 | <0.001 | 16.71 | 0.972 | <0.001 | 16.71 |
| 3 mm | Temporal | 0.984 | 0.499 | 15.70 | 0.983 | 0.488 | 15.71 | 0.938 | 0.007 | 15.70 | 0.938 | 0.005 | 15.70 |
| | Inferior | 0.993 | 0.542 | 21.17 | 0.993 | 0.600 | 21.29 | 0.980 | 0.006 | 19.68 | 0.980 | 0.006 | 19.74 |
| | Nasal | 0.987 | 0.111 | 21.39 | 0.987 | 0.136 | 21.41 | 0.979 | 0.012 | 21.27 | 0.979 | 0.013 | 21.18 |
| | Superior | 0.974 | 0.303 | 16.34 | 0.975 | 0.283 | 16.29 | 0.965 | 0.001 | 16.63 | 0.965 | 0.001 | 16.63 |
| 1 mm | Fovea | 0.979 | 0.195 | 19.44 | 0.981 | 0.141 | 19.16 | 0.961 | 0.018 | 18.49 | 0.961 | 0.022 | 18.55 |
| | Total | --- | --- | --- | 0.992 | 0.197 | 15.89 | --- | --- | --- | 0.976 | <0.001 | 16.04 |









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