Macular Thickness Assessment in Healthy Eyes Based on Ethnicity Using Stratus OCT Optical Coherence Tomography

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PURPOSE. To assess the variation in macular thickness measurements in healthy Caucasian and African American men and women through Stratus OCT optical coherence tomography (OCT-3).

METHODS. One hundred sixty-six eyes of 83 healthy patients underwent complete ophthalmologic examination in this prospective study. Exclusion criteria included a diagnosis of diabetes mellitus, hypertension, intraocular pressure (IOP) greater than 21 mm Hg, history of eye surgery or trauma, or evidence of eye disease. For analysis purposes, the authors excluded those participants in whom OCT signal strength was <7 in each eye. A fast macular thickness protocol consisting of a 6-mm radial scan centered on the fovea was used for the analysis, and the data were analyzed using the t-test for independence and linear regression. Both eyes of each patient were analyzed using the OCT-3, and analysis showed a statistically significant correlation between right and left eyes. Therefore, only one eye from each patient was randomly selected for final correlation and analysis.

RESULTS. Mean foveal thickness (MFT) for Caucasians was 32 μm greater than for African Americans (217 vs. 185 μm, respectively; P < 0.001). The MFT was significantly thicker in males than in females (220 vs. 197 μm, respectively; P < 0.001).

CONCLUSIONS. The fovea is significantly less thick in African Americans and females than in Caucasians and males. Racial and sexual differences should be considered when interpreting OCT scans. (Invest Ophthalmol Vis Sci. 2008;49:2668–2672) DOI:10.1167/ iovs.07-1000

Any pathologic processes involving the macula, such as glaucoma and diabetes mellitus, can cause changes in the retinal architecture that can subsequently lead to poor visual outcomes. Macular edema commonly results in vision loss and is often difficult to detect on slit lamp biomicroscopy. Optical coherence tomography (OCT) is a noninvasive imaging modality that provides high-resolution quantitative measurements of retinal thickness.1 Because of its high resolution and reliability, OCT has become an important tool for diagnosing and monitoring various macular diseases.2-6

In 2002, Carl Zeiss Meditec introduced the third generation of OCT (Stratus OCT [OCT-3]; Dublin, CA). The axial resolution of this model is <10 μm, and it is fourfold faster than previous versions.7 Two recent studies have used the Stratus OCT to assess macular thickness measurements in healthy patients.5,7 Interestingly, Chan et al.7 found that their mean foveal thickness (MFT) measurements were 38 to 62 μm thinner than previously reported values. It was hypothesized that this discrepancy might have been the direct result of the higher resolution and faster scanning time associated with the newer version of OCT. Although these studies are helpful in determining normal macular thickness measurements using the OCT-3 software, there is no mention of racial or sexual differences. The objective of this study is to provide normal macular thickness values according to race and sex and to determine whether there is any difference between the groups. To our knowledge, only one abstract published to date (Fraser-Bell S, et al. IOVS 2005;46:ARVO EAbstract 1542) was designed to assess macular thickness differences according to ethnicity.

SUBJECTS AND METHODS

This research adhered to the tenets of the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of the Medical University of South Carolina. All participants were informed of the goals and implications of the study in which they were taking part, and their signatures of consent were received. Healthy subjects were examined from February 17 to April 30, 2007. All subjects enrolled were self-described as either Caucasian or African American, and they had no history of diabetes, hypertension, any known eye pathology, or ocular trauma. Each patient underwent a complete ophthalmic examination, including a medical and family history, best-corrected visual acuity (BCVA) testing with manifest refraction, applanation tonometry, pachymetry, and slit lamp biomicroscopy. Axial length measurements using standard immersion A-scan ultrasound and optical coherence tomograms using the OCT-3 (Carl Zeiss Ophthalmic Systems, Inc., Humphrey Division, Dublin, Ireland) were obtained through a dilated pupil by a single, experienced technician.

Four patients (2 Caucasian [1 male, 1 female], 2 African American [0 males, 2 females]) were excluded because the OCT signal strength in each eye was <7. Twelve eyes had an OCT signal strength ≥6, but because the fellow eye had a higher signal strength, they were included. In these 12 eyes, the eye with the higher signal strength was used for data analysis.

The fast macular thickness (FastMac 128 A-scans/B-scan) protocol on the OCT-3 was used to obtain six consecutive macular scans, 6 mm in length, centered on the fovea, at equally spaced angular orientations. Cross-sectional images were analyzed using the OCT-3 mapping software. The retinal map analysis protocol on the OCT-3 was used to show the nine map sectors, as defined by the Early Treatment Diabetic Retinopathy Study.5 The inner and outer rings were segmented into...
Mean foveal thickness (m) 217 ± 25 μm vs. 185 ± 17 μm; P < 0.001). Males had significantly greater MFT than females (220 ± 26 μm vs. 197 ± 24 μm; P < 0.001). The sample size was insufficient to confound all variables of multivariate regression analysis. Linear regression analyses showed that age, IOP, spherical equivalent, or axial length did not significantly influence MFT.

The mean and SD of retinal thickness by sector for Caucasians (52 patients) and African Americans (31 patients) is shown in Figure 2, whereas Figure 3 shows the mean and SD for females (52 patients) and males (31 patients). In each group, the macular thickness was thinnest at the fovea and thickest within the 3-mm diameter ring around the center of the fovea. Outside this 3-mm ring, the retinal thickness thinned as it approached the periphery.

The MFT was thicker in the Caucasian population (P < 0.001), and there was a significant difference in several of the inner sectors. It should be noted that there was a trend toward statistical significance between the two racial groups for the right eye, inferior inner (P = 0.056) and temporal inner sectors (P = 0.075), and the left eye, temporal inner sector (P = 0.053).

The MFT in smokers was thinner (193 ± 16 μm) than in nonsmokers (207 ± 27 μm). However, further interpretation of this difference cannot be made because only 9 subjects had a history of smoking. Effects of smoking might have been confounded by the fact that 7 of 30 African American subjects were smokers but only 2 of 49 Caucasian subjects were smokers.

**RESULTS**

One hundred sixty-six eyes from 83 healthy subjects were analyzed. Patients ranged in age from 22 to 75 years (mean, 36.8 years; SD ± 12.1; median, 32 years), and the distribution is shown in Figure 1. Preliminary statistical analysis showed no difference in the retinal thickness measurements between right and left eyes for each patient (Pearson correlation coefficient, 0.904). Because of this congruity, and to avoid a correlation effect, one eye was randomly selected for each patient for data analysis, but the 12 eyes whose OCT signal strengths were <6 were omitted, though the fellow eye that met the criterion was included. The MFT was 205.4 μm for all included patients. Details of patient demographics according to racial categories are shown in Table 1.

Caucasians had greater MFT than African Americans (217 ± 25 μm vs. 185 ± 17 μm; P < 0.001). Males had significantly greater MFT than females (220 ± 26 μm vs. 197 ± 24 μm; P < 0.001). The sample size was insufficient to confound all variables of multivariate regression analysis. Linear regression analyses showed that age, IOP, spherical equivalent, or axial length did not significantly influence MFT.

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**DISCUSSION**

In the past two decades, OCT has provided clinically useful high-resolution images and quantitative data on a variety of ocular abnormalities.2–5 Many studies have demonstrated the reproducibility and reliability of its measurements.6–9–13 The third-generation Stratus OCT has an axial resolution of 8 to 10 μm, a greater sampling density, and a faster A-scan rate.6 Measurement of retinal thickness is dependent on definition of the anterior and posterior retinal surfaces. The Stratus OCT software has a predefined algorithm that defines the outer limit of the retina at the internal aspect of a highly reflective layer believed to correspond to the retinal pigment epithelium (RPE) and the choriocapillaris. Double laminae have been shown at this interface, with OCT-3 retinal thickness measurements including only the internal line and neglecting the additional

<table>
<thead>
<tr>
<th>Demographic Category</th>
<th>Caucasians ± SD (n = 52)</th>
<th>African Americans ± SD (n = 31)</th>
<th>All Patients ± SD (n = 83)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>36.2 ± 12.7</td>
<td>37.7 ± 11.2</td>
<td>36.8 ± 12.1</td>
</tr>
<tr>
<td>Females</td>
<td>30</td>
<td>22</td>
<td>52</td>
</tr>
<tr>
<td>Males</td>
<td>22</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>Mean BCVA</td>
<td>20/18</td>
<td>20/18</td>
<td>20/18</td>
</tr>
<tr>
<td>Mean spherical equivalent</td>
<td>−2.20 ± 2.8</td>
<td>−1.3 ± 2.0</td>
<td>−1.9 ± 2.5</td>
</tr>
<tr>
<td>Mean central corneal thickness (μm)</td>
<td>551 ± 37</td>
<td>537 ± 32</td>
<td>546 ± 36</td>
</tr>
<tr>
<td>Mean IOP (mm Hg)</td>
<td>14 ± 3</td>
<td>14 ± 3</td>
<td>14 ± 3</td>
</tr>
<tr>
<td>Mean cup-to-disc ratio</td>
<td>0.2 ± 0.1</td>
<td>0.4 ± 0.1</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>Mean axial length (mm)</td>
<td>24.1 ± 1.1</td>
<td>24.3 ± 0.9</td>
<td>24.2 ± 1.0</td>
</tr>
<tr>
<td>Range of axial length values (mm)</td>
<td>21.48–27.05</td>
<td>22.55–26.95</td>
<td>21.48–27.05</td>
</tr>
<tr>
<td>Mean foveal thickness (μm)</td>
<td>217 ± 25</td>
<td>185 ± 17</td>
<td>205 ± 27</td>
</tr>
<tr>
<td>Range of mean foveal thickness values (μm)</td>
<td>165–260</td>
<td>150–222</td>
<td>150–260</td>
</tr>
</tbody>
</table>
retinal space demarcated by an outer line. The internal line may represent a highly reflective part of the neurosensory retina made up of photoreceptor discs or interphotoreceptor matrix proteins, whereas the outer line is thought to correlate histologically with the RPE.

Paunescu et al. were the first to report normative retinal thickness measurements using the Stratus OCT. This report was followed in 2006 by a study by Chan et al. of 37 healthy patients. Neither of these studies mentioned racial or sexual differences as they relate to retinal thickness. To our knowledge, there is only one abstract that specifically addresses macular thickness differences according to racial differences. The data presented in that abstract show that the fovea is less thick in African Americans than it is in Caucasians (158 µm vs. 173 µm; $P < 0.001$). Surprisingly, the MFT for our African American population was 27 µm thicker than the reported

![Figure 2](https://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/932949/)

**Figure 2.** Mean retinal thickness measurements (µm) for Caucasian and African American participants.

![Figure 3](https://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/932949/)

**Figure 3.** Mean retinal thickness measurements (µm) for female and male participants.
abstract value, and the MFT for our Caucasian population was 44 μm thicker than that reported in the abstract. This is interesting because both studies used the Stratus OCT. Foveal thickness measurements in the present study are similar to those found by Paunescu et al. and Chan et al. 6,7

A racial difference in the peripapillary nerve fiber layer has been demonstrated using scanning laser polarimetry to study normal eyes. Adjusting for age, in more than half the age groups they found that on average Caucasian subjects had significantly thicker nerve fiber layers than did Afro-Caribbean subjects. The thinner nerve fiber layer in the African American may contribute to the higher prevalence of glaucoma and glaucomatous damage in this population. However, OCT analysis of nerve fiber layer thickness has shown the retinal nerve fiber layer of African Americans to be thicker than that of Caucasians, both superiorly and inferiorly. These racial differences may be attributed to differences in optic disc size because a larger disc is postulated to contain more nerve fibers. 

It is unclear why there is a racial difference in retinal thickness measurements; biochemical and histologic studies will likely be needed to answer this question. Chauhan and Marshall 15 explicate the interaction of melanin with the light beam of OCT optical radiation. They assert that melanin scatters, absorbs, and reflects light, thereby attenuating the light signal interpreted by OCT software. Higher concentrations of melanin in the apical RPE of African Americans may increase the attenuation of optical radiation interpreted by OCT, leading to a decreased signal of posterior retinal segments and concomitant underassessment of retinal thickness in darkly pigmented persons. Further research is necessary to elucidate the precise nature of the posterior retinal surface on OCT measurements and the cause of racial variation in retinal thickness. 

A 2005 study by Wong et al. 16 showed through multiple regression analysis that sex, body mass index, and axial length are significantly associated with central retinal thickness (P < 0.05). The mean thickness within the central 1000 μm was 203 μm for males and 189 μm for females. The same relationship for sex held true for our study. It should be noted that the Wong study was conducted using the OCT-2 model and that the participants were of Asian descent. Several other studies have shown that males have thicker foveae than females. 15,16,19

To our knowledge there have been no published reports on smoking status and retinal thickness measurements by OCT. A Japanese study in 1999 showed that smoking caused a transient increase in tissue blood velocity in the human optic nerve head and in the choroid of healthy young subjects. However, it remains unclear how the increased blood velocity in the retinal circulation in smokers could cause changes in retinal thickness. It has been hypothesized that certain biochemical modulators play a role in this process. 

Previous reports have hypothesized that highly myopic eyes would have thinner retinas than emmetropic eyes. 21,22 We found this not to be true because there was no statistical correlation between foveal thickness and axial length in our patients. The lack of this correlation between axial length and central retinal thickness is supported by several other studies. 23–25 The reason healthy myopic eyes do not have thinner retinas is yet to be determined. It should be noted that it can be difficult to measure foveal thickness accurately in eyes with pathologic myopia when using the OCT-3 because of the patient’s poor fixation. 

The OCT-3 differences in retinal thickness could impact our understanding of the difference in the prevalence of age-related macular degeneration between different ethnic groups. The nomograms for retinal thickness may also have to be adjusted when evaluating disorders affecting the macula, such as diabetic retinopathy. 

Limitations of the study include normative data heavily weighted with younger patients, relatively small sample size, lack of statistical power to evaluate the impact of parameters such as smoking on MFT, and use of self-reporting for the ethnicity assessment, though this is a common approach for determining ethnicity and is currently used by the US Census Bureau. This concept of race reflects self-identification by people according to the race or races with which they most closely identify; however, there is a potential for error in the case of subjects with parents of different ethnicities. 

In conclusion, healthy African Americans and females have thinner foveae than healthy Caucasians and males. Cigarette smoking may, in fact, play a role in retinal thickness because smokers tend to have thinner foveae. There was no correlation between foveal thickness and age, axial length, spherical equivalent, or IOP. We recommend that these differences in retinal thickness measurements be considered when interpreting OCT results.

References


