

# Macular Volume and Retinal Nerve Fiber Layer Thickness in Mild, Moderate, and High Myopia



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## ABSTRACT

**Purpose:** To compare macular volume and Retinal Nerve Fiber Layer (RNFL) thickness among individuals with mild, moderate, and high myopia and to evaluate association of these parameters with severity of myopia.

**Study Design:** Cross-sectional study.

**Place and Duration of Study:** Sehat Medical Complex from January 2025 to June 2025.

**Methods:** One hundred and twenty-four eyes were included in the study. Based on the spherical equivalent (SE) refractive error, participants were divided into three groups: moderate myopia (from -3.00 D to -6.00D), high myopia (<-6.00 D), and mild myopia (>-3.00 D and ≤ -0.50 D). Spectral-domain optical coherence tomography was used to evaluate thickness of RNFL and macular volume. For the statistical analysis one-way ANOVA and post-hoc Tukey HSD tests were employed.

**Results:** There were 69 males and 55 females. Age ranged between 18 and 45 years with average age of 30.96 years. The RNFL thickness varied significantly among myopia groups, as confirmed by the F-statistic (374.129) and p-value of < 0.001. There was significant thinning of RNFL with increase in myopia. Macular volume significantly differed among the three myopia groups as confirmed by the significant finding (F = 14.323, p < 0.001). Post-hoc analysis showed that there was significant difference between macular volume of mild and high myopia (p < 0.001). As the severity of myopia increased, macular volume gradually decreased.

**Conclusion:** Decrease in macular volume was a gradual structural alteration. Significant RNFL thinning was observed in cases of severe myopia.

**Keywords:** Myopia, Macula Lutea, Optical Coherence Tomography, Retinal Nerve Fiber Layer.

**How to Cite this Article:** Habib A, Saeedi MA, Farid A, Sabir SYA, Qasim MMA. Macular Volume and Retinal Nerve Fiber Layer Thickness in Mild, Moderate, and High Myopia. 2026;42(3):237-242.

**Doi:** 10.36351/pjo.v42i3.2326

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*Received: December 30, 2025*

*Revised: April 29, 2026*

*Accepted: May 15, 2026*

## INTRODUCTION

Myopia has become a serious public health concern as it is becoming increasingly prevalent globally, particularly in East and Southeast Asia. There were

around 1.4 billion people with myopia in 2000; by 2050, that number is predicted to rise to 4.8 billion.<sup>1</sup> According to prevalence estimates and related population figures globally, by 2050, 52% (4949 million) and 10.0% (925 million) of the world's population would suffer from myopia and high myopia, respectively. As a result, it is estimated that by 2050, 52% of people worldwide will have myopia, from 27% in 2010.<sup>2</sup>

The excessive axial elongation of the eyeball is the main anatomical change associated with myopia. The ocular tissues, particularly retina, retinal pigment

epithelium (RPE), choroid, and sclera, gradually stretch and weaken because of the biomechanical stress brought on by this elongation.<sup>3</sup> Macula is particularly susceptible to these alterations. Myopic eyes have structural changes in the macula, such as decreased macular thickness and volume leading to myopic maculopathy.<sup>4</sup>

The clinical diagnosis and tracking of glaucoma progression in myopic eyes are difficult due to the morphological appearance of the optic nerve head in myopia and concurrent visual field defects.<sup>5</sup> Critical gaps persist in our understanding of myopia-related structural changes, despite established associations with reduced macular thickness, macular volume, and retinal nerve fiber layer (RNFL) thickness. There is a need for a comprehensive evaluation of how these parameters vary across the full spectrum of myopia severity—from mild to moderate to too high. Most previous studies have either focused exclusively on high myopia or have primarily compared myopic with non-myopic eyes, limiting insight into the progressive structural alterations that occur with increasing myopic severity.<sup>6</sup>

Thinning of RNFL has been correlated with myopia, longer axial length, lower birth weight, and white race. Conversely, Asian or Hispanic race and optic disc tilting have been linked to a thicker RNFL.<sup>7</sup> Literature shows that persons with high myopia have reduced radial peripapillary capillary density and deep perifoveal artery density.<sup>8,9</sup>

OCT is a great tool to assess structural problems such as macular schisis, myopic traction maculopathy, dome-shaped macula, chorioretinal atrophy, and myopic neovascularization.<sup>10</sup> Using OCT, macular volume and RNFL thickness are found to be well-established biomarkers of retinal health in myopia.<sup>11</sup> The existing literature frequently concentrates on discrete parameters or limited severity ranges, resulting in gaps in our comprehension of the evolution of retinal structure with progressive myopia.

This study measures the differences in macular volume and RNFL thickness between groups with low, moderate, and high myopia, and patterns of variation in these parameters among myopic patients with different severity.

## METHODS

This cross-sectional, comparative study was conducted from January 2025 to June of 2025 at Sehat Medical

Complex. The study was approved by the Institutional review board/Ethical review board (**UOL-SMC/001-46/2025**). Based on their spherical equivalent (SE) refractive error, participants were divided into three groups: moderate myopia (SE  $>-6.00$  D to  $\leq -3.00$  D), high myopia ( $<-6.00$  D), and mild myopia ( $> -3.00$  D to  $\leq -0.50$  D).<sup>12</sup> A total of 124 participants were enrolled in this study. To avoid inter-eye correlation, only one eye was included from each participant (the eye with more severe myopia; if both eyes had the same severity, the right eye was chosen). G\*Power 3.1 was utilized to calculate the required sample size for a one-way ANOVA (fixed effects, omnibus) that assessed the RNFL thickness and macular volume across three myopia groups. The minimum sample size required was 120 individuals, based on an assumed medium effect size ( $f = 0.25$ ),  $\alpha = 0.05$ , and power = 0.80. After accounting for possible exclusions, 124 individuals were recorded.

Patients of 18-45 years of age, best-corrected visual acuity (BCVA) of 20/25 or above and refractive error falling into one of the predetermined myopia categories were included. High astigmatism ( $>2.50$  D), retinal pathology (e.g., diabetic retinopathy, epiretinal membrane, and macular hole), glaucoma or ocular hypertension, optic nerve abnormalities, systemic diseases known to affect the retina (e.g., uncontrolled diabetes, hypertension), and a history of ocular surgery (apart from uncomplicated refractive surgery  $>6$  months prior) were among the exclusion criteria.

Informed consent was taken and the study was started in accordance with the tenets of the Declaration of Helsinki.

Evaluation of refractive errors after administering 1% cyclopentolate hydrochloride, cycloplegic autorefractometry was conducted using a calibrated autorefractor (e.g., Topcon KR-8900, and Tokyo, Japan). The spherical equivalent (SE = sphere + 0.5 \* cylinder) was calculated by averaging three consecutive measurements. Spectral Domain Optical Coherence Tomography (OCT), (Optopol Technology REVO  $n \times 130$ ) was used with an axial resolution of roughly 3.40  $\mu\text{m}$  and can scan 130,000 A-scans per second. For macular scans, a 32-line, high-density radial scan pattern with the fovea at its center was used. To reduce motion artifacts, the eye-tracking function (TruTrack) was turned on and for RNFL scans the optic disc was the center of a peripapillary circular scan with a diameter of 5 mm.<sup>13</sup>

The subjects underwent dilated fundus

examination, intraocular pressure measurement (Goldmann applanation tonometry), slit-lamp biomicroscopy, and BCVA (Log MAR chart). Cycloplegic autorefraction was conducted and participants were categorized into three myopia severity groups. After pupil dilatation with 1% tropicamide and 2.5% phenylephrine, a skilled technician conducted OCT imaging. The radial scan was obtained after the volumetric scan followed by peripapillary RNFL scan. Scans with signal strengths of less than 25 dB (based on device quality metrics) or notable artifacts (such as blink or decentration) were excluded.

IBM SPSS software (version 28.0) was used for data analysis. Normality was evaluated using Shapiro-Wilk test. For clinical and demographic data, descriptive statistics were computed and expressed as mean  $\pm$  standard deviation. A one-way Analysis of Variance (ANOVA) was used to determine whether there were any statistically significant differences in the macular volume and RNFL thickness of the three myopia severity groups. The significance level ( $\alpha$ ) was set at  $p < 0.05$ . Tukey's Honestly Significant Difference (HSD) test was employed to identify specific group differences while accounting for Type I error inflation, if the ANOVA generated a statistically significant result ( $p < 0.05$ ). Furthermore, the significance level for the post-hoc test was established at  $p < 0.05$ .

## RESULTS

There were 69 males and 55 females with an age range of 18 to 45 years. Participants' average age was 30.96 years. Macular volume varied significantly between patients, although RNFL thickness varied little (Table 1).

**Table 1:** Descriptive Statistics of RNFL Thickness, macular volume, refractive error and Degree of Myopia.

	N	Minimum	Maximum	Mean
RNFL Thickness	124	71	110	86.73 $\pm$ 10.95
Macular Volume	124	7	9	8.01 $\pm$ 0.47
Refractive Error	124	-7	-1	-3.94 $\pm$ 91
Degree of Myopia	124	1.000	3.000	1.99 $\pm$ 0.81
Valid N	124			

Macular volume and RNFL thickness steadily decline with increasing myopia severity. It is evident that there is a significant inverse link between the degree of myopia and the structural retinal parameter as given below in Table 2.

According to the ANOVA results, the degree of myopia had a substantial impact on both macular volume and RNFL thickness. This showed that structural alterations in retina were linked to rise in myopia as shown in Table 3.

Table 4 shows that macular volume considerably decreased as myopia severity increased and RNFL thinning was most noticeable in advanced myopia.

**Table 2:** One Way: Descriptive for RNFL Thickness and Macular Volume.

Descriptive	N	Mean $\pm$ SD	Std. Error	95% Confidence Interval for Mean		
				Lower Bound	Upper Bound	
RNFL THICKNESS	MILD MYOPIA	41	99.70 $\pm$ 6.28	0.98	97.72	101.69
	MODERATE MYOPIA	43	85.48 $\pm$ 2.64	0.40	84.67	86.30
	HIGH MYOPIA	40	74.77 $\pm$ 2.15	0.34	74.08	75.45
	Total	124	86.73 $\pm$ 10.95	0.98	84.78	88.67
MACULAR VOLUME	MILD MYOPIA	41	8.20 $\pm$ 0.44	.069	8.06	8.34
	MODERATE MYOPIA	43	8.11 $\pm$ 0.39	0.06	7.99	8.23
	HIGH MYOPIA	40	7.72 $\pm$ 0.70	0.07	7.58	7.86
	Total	124	8.01 $\pm$ 0.47	0.04	7.93	8.10

**Table 3:** One way ANOVA for and RNFL Thickness and Macular Volume Comparison between Groups and Within Groups.

		Sum of Squares	df	Mean Square	F	Sig.
RNFL THICKNESS	Between Groups	12694.23	2	6347.11		
	Within Groups	2052.77	121	16.965	374.129	0.00
	Total	14747.00	123			
MACULAR VOLUME	Between Groups	5.23	2	2.61		
	Within Groups	22.10	121	.183	14.323	0.00
	Total	27.34	123			

**Table 4:** Post Hoc Test and Tukey HSD for Multiple Comparisons of Dependent Variable Macular Volume, RNFL Thickness.

Dependent Variable	(I) DEGREE OF MYOPIA	(J) DEGREE OF MYOPIA	Mean Difference(I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
RNFL THICKNESS	MILD MYOPIA	MODERATE MYOPIA	14.22*	.89	0.00	12.09	16.35
		HIGH MYOPIA	24.93*	.91	0.00	22.77	27.11
		MODERATE MYOPIA	-14.22*	.89	0.00	-16.35	-12.09
	HIGH MYOPIA	HIGH MYOPIA	10.71*	.90	0.00	8.57	12.87
		MILD MYOPIA	-24.93*	.91	0.00	-27.11	-22.77
		MODERATE MYOPIA	-10.71*	.90	0.00	-12.87	-8.57
MACULAR VOLUME	MILD MYOPIA	MODERATE MYOPIA	0.08	.09	.611	-.13	.31
		HIGH MYOPIA	0.47*	.09	0.00	.25	.70
		MODERATE MYOPIA	-.08	.09	.611	-.31	.13
	HIGH MYOPIA	HIGH MYOPIA	0.38*	.09	0.00	.17	.61
		MILD MYOPIA	-.478*	.09	0.00	-.70	-.25
		MODERATE MYOPIA	-.389*	.09	0.00	-.61	-.17

\*.The mean difference is significant at the 0.05 level.

## DISCUSSION

This study found a consistent decrease in retinal volume observed at all groups of myopia severity. Axial elongation in myopia causes retinal tissues to mechanically stretch and thin out.<sup>14</sup> Conversely, RNFL thickness displayed a markedly different pattern. Although the original ANOVA revealed significant differences between the groups ( $F = 374.129$ ,  $p < 0.001$ ), the post-hoc analysis showed a more complicated relationship between them. The comparison of mild and extreme myopia was the main cause of the substantial difference ( $p < 0.001$ ). Additionally, the groups with mild and severe myopia did not differ statistically significantly ( $p < 0.00$ ). This suggests that until high myopia is established, which frequently happens later, RNFL thinning may not become noticeable. However, RNFL thickness showed a quite distinct pattern. The post-hoc analysis revealed a more nuanced relationship between the groups, even though the primary ANOVA revealed substantial differences between them ( $F = 374.129$ ,  $p < 0.001$ ). The primary reason for the significant variance ( $p < 0.001$ ) was the comparison of mild and extreme myopia. RNFL is affected by axial elongation, however its thinning may have a different trajectory or threshold than the overall macular volume.<sup>15</sup>

Early macular modifications in young myopic people are consistent with the observation that macular volume exhibits considerable changes even between mild and moderate myopia.<sup>16</sup> Monitoring macular volume could be a useful biomarker for detecting

those who may develop more severe pathological myopia.<sup>17</sup>

In another study, moderate myopia was associated with an RNFL that was 10.71 units thicker than in high myopia ( $p < 0.001$ ; 95% CI [8.57, 12.87]).<sup>4</sup> Even in advanced stages of myopia, RNFL thickness continued to decrease as severity increased. A linear relationship exists between myopia severity and RNFL thinning, with each increase in myopia grade (mild, moderate, and high) corresponding to a statistically significant reduction in RNFL thickness.

The degree of myopia reduces considerably the quantity of retinal tissue and is the most striking absolute alteration. The different patterns observed in the macular volume and the RNFL thickness in different levels of severity of myopia point out to the possibility that there could be other pathological mechanisms involved. There is a linear relationship between the severity of myopia and the macular volume, but RNFL thinning appears to increase at a faster rate in severe myopia. These results justify the adoption of various methods of monitoring depending on the level of myopia.<sup>18</sup>

A cross-sectional study indicated a slight reduction in mean RNFL thickness in both the right and left eyes, reinforcing the link between high myopia and retinal thinning.<sup>19</sup>

The macular volume significantly differed by group of myopia ( $F = 14.323$ ,  $p < 0.001$ ) and the magnitude of the effect was less than the effect of RNFL thickness. This gives more support to the theory

that the severity of myopia contributes to the loss of volume. The anatomical and vascular responses in the retina are also more evident as the myopia progresses. The deep vascular density has a strong correlation with retinal thickness and the severity of myopia, which points to the validity of both deep vascular density and retinal thickness as the reliable biomarkers of monitoring the progression of myopia by OCTA imaging.<sup>20</sup>

In a cross-sectional study of 123 myopic eyes using OCTA, there was a slight difference in thickness of the ganglion cell complex, RNFL, and superficial vascular plexus between the groups.<sup>21</sup> Axial length had a negative relationship with perifoveal deep vascular plexus (DVP) and retinal thickness, whereas refractive error had a positive relationship with these two parameters. A decrease in the density of perifoveal DVP can be an indicator of microvascular loss in myopia, and OCTA is a useful technique in myopia monitoring.

OCTA and spectral-domain OCT also revealed that the axial length was negatively correlated with the thinner outer nuclear and photoreceptor outer segment outer layer but positively correlated with the deeper capillary plexus vessel density and the foveal, inner and outer plexiform layers which were thicker. Retinal stretching in myopia determines vascular and structural factors, which, consequently, affects vision.<sup>22</sup> As the myopia and the axial length increased, the density of the superficial and deep layers of the macular vascular system was reduced. The density of the superficial macula was also associated with the ganglion cell complex thickness. No apparent vascular density changes in the optic disc with myopia were detected.<sup>23</sup>

The limitations of this study include the cross-sectional approach, which offers a glimpse of correlations but is unable to prove causation or monitor individual changes over time. To verify the temporal order of these structural changes, longitudinal research is required. Second, axial elongation is the fundamental cause of the alterations in myopia, which we classified as mild, moderate, and high. Axial length measurements should be directly included in future research to support the mechanistic interpretation. Third, although our sample was young (18–45 years old), it was sufficient to identify meaningful differences.

In older populations or in those with extreme myopia who have had the condition for a longer

period, the patterns shown may be different because more severe degenerative processes may be present. Lastly, other variables of interest that influence the macular and RNFL parameters including intraocular pressure, ethnicity and genetic background were not considered comprehensively in our analysis.

Longitudinal studies should be conducted for future research to observe the change in macular volume and RNFL thickness in myopia progression. These investigations will help determine essential thresholds or change rates that indicate possible pathological consequences.

## CONCLUSION

This study showed that macular volume decreased significantly and gradually at all myopia levels, including the transition from mild to moderate severity. However, there was no considerable difference between the mild and moderate groups, and only severe myopia showed significant RNFL thinning in comparison to mild myopia. It is essential to understand the specifics of retinal changes to establish specific monitoring strategies and early interventions to maintain retinal health and prevent vision loss in cases with progressive myopia.

**Funding:** This study was not funded by any organization.

**Patient's Consent:** Researchers followed the guidelines set forth in the Declaration of Helsinki.

**Conflict of Interest:** Authors declared no conflict of interest.

**Ethical Approval:** The study was approved by the Institutional review board/Ethical review board (UOL-SMC/001-46/2025)

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### Authors Designation and Contribution

Athar Habib; Optometrist: *Concepts, Design, Data Acquisition.*

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Anila Farid; Lecturer: *Data Analysis, Statistical Analysis, Manuscript Preparation, Manuscript Editing.*

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