



Retinal Nerve Fiber Layer Thickness Around the Optic Nerve in Normal Saudi Population Measured by OCT RNFL-Thickness in Saudi Population

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Submission: June 20, 2025; **Published:** June 26, 2025

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Abstract

Introduction: The retinal nerve fiber layer (RNFL) is used in the evaluation of many retinal and optic nerve diseases. Optical coherence tomography (OCT) is one of the assessment methods that is used in assessing the retinal nerve fiber layer; however, there is a lack of normative data in the Saudi population, therefore, we aim to present normative retinal nerve fiber layer thickness data using optical coherence tomography (OCT) and classify them according to their age and gender.

Methodology: A cross-sectional study at Dhahran Eye Specialist Hospital and King Fahd Hospital University assessed RNFL thickness in 173 participants with normal intraocular pressure. Participants were categorized by age and gender, analyzing RNFL thickness and refractive error relationships.

Results: The mean RNFL thickness was 100.28 μm for the right eye and 100.31 μm for the left eye. With age, we observed that RNFL got thinner, especially in the upper and lower quadrants, except for the right temporal side ($p=0.263$). A thinner left inferior RNFL was found in males ($126 \pm 18.3 \mu\text{m}$) compared to females ($133 \pm 18.4 \mu\text{m}$, $p=0.020$). Refractive error was found to be increased with age ($p=0.003$, right eye), but there was no significant correlation with RNFL thickness.

Conclusion: Age is associated with decreased retinal nerve fiber layer thickness, and it increases the degree of refractive error. Gender was mainly not associated with retinal nerve fiber layer thickness.

Keywords: RNFL (Retinal Nerve Fiber Layer); OD (Right Eye); OS (Left Eye); OCT (Optical Coherence Tomography).

Abbreviations: RNFL: Retinal Nerve Fiber Layer; OCT: Optical Coherence Tomography; SD-OCT: Spectral-Domain Optical Coherence Tomography; SS-OCT: Swept-Source Optical Coherence Tomography; IOP: Intraocular Pressure; DESH: Dhahran Eye Specialist Hospital; KFHU: King Fahd Hospital University; OD: Oculus Dexter (Right Eye); OS: Oculus Sinister (Left Eye); D: Diopter; μm : Micrometer; SD: Standard Deviation; IQR: Interquartile Range

Introduction

The retinal nerve fiber layer (RNFL) is found within the retina and contains the axons of ganglion cells and the basal lamina of Müller cells, all surrounded by the inner limiting membrane [1]. By measuring the RNFL, health professionals can determine the health of the optic nerve and retina because its thickness reflects differences in both healthy and abnormal situations in the visual system [1-6]. Various eye disorders are linked to the changes in RNFL thickness, including glaucoma, age-related macular degeneration, diabetic retinopathy, and optic neuropathy [7-9]. Assessing the thickness of the retinal nerve fiber layer (RNFL) is

important for the early diagnosis, management, and monitoring of eye diseases, timely intervention, and appropriate medical treatment [2,5].

Visualizing RNFL thickness requires tools like scanning laser polarimetry, confocal scanning laser tomography, and wide-angle fundus photography [3,4]. Out of these approaches, OCT is considered the most effective as it is non-invasive and shows detailed images [5,6]. Because of low-coherence interferometry, OCT is able to make very precise images of the optic nerve head, macula, and RNFL [7]. With this technology, health professionals

can easily measure retinal and macular diseases and better manage their treatment [8,9]. Spectral-domain OCT (SD-OCT) and swept-source OCT (SS-OCT) have allowed more accurate measurement of the RNFL thickness than time-domain OCT systems [2,5,6].

OCT is most effective in diagnosis since there are more reference data for RNFL thickness to distinguish healthy eyes from those with disease [10]. Most normative databases are built using data from healthy individuals and are used to set references for measuring RNFL thickness. However, the thickness of RNFL differs among populations since ethnic and demographic factors play a role in its measurements [11,12]. For instance, one Indian study has shown that RNFL in Indian eyes is thicker than that found in Caucasians [13]. As a result of these ethnic differences, it is important to have population-specific databases to correctly interpret OCT images in clinical practice [10,11]. In addition to ethnicity, age, and gender, could affect the thickness of the RNFL. Many studies claim that ordinary ageing causes a decrease in RNFL thickness due to the loss of neurons [14,15]. At the same time, RNFL thickness and gender may not directly influence each other, since some studies have reported no connection between macular thickness and gender in healthy subjects [16].

OCT is a popular worldwide tool for ophthalmic purposes; few studies have examined the typical RNFL thickness in people from the Middle East. Limited studies have been conducted in Saudi Arabia to assess the RNFL in healthy individuals, so the resulting data are not adequate for setting reliable normative values for many age and gender categories [17,18]. For instance, Almarzouki et al. [17] shared some details about the RNFL thickness in the western region of Saudi Arabia, but their findings were limited by a small sample, and they did not separate the results by both age and gender [17]. Just like Raffa and AlSwealh [18] documented normative OCT images for Saudi children, focusing only on children and neglecting results for adults or differences by gender [18]. Since there is a lack of proper normative data, it becomes challenging to accurately detect and treat eye diseases in Saudi Arabia. Additionally, the unique characteristics of the demographic and environmental factors in Saudi Arabia could impact RNFL thickness. Genetic variations in the shape of the retina may result from frequent consanguinity in Saudi Arabia [19]. In addition, factors in the climate, like high ultraviolet light, might impact retinal health, however, it is not known if they affect RNFL thickness [20]. This highlights the importance of using normative information for the population in Saudi Arabia when using optical coherence tomography. There is also a need for further studies to track RNFL thickness over the years in healthy Saudi individuals. Most studies on this topic are cross-sectional. This means they do not show how RNFL thickness might change over time [14,17]. The effect of gender on RNFL thickness among Saudis has not been much explored. Although a number of investigations show that gender does not significantly determine macular thickness [16], other analysis results support that there might be differences between males and females in RNFL thickness due to differences in optic

disc size or hormones [21]. Therefore, these differences should be investigated further in groups of people who have unique genetic and cultural backgrounds, such as those in Saudi Arabia. The study novelty lies in the broad range of methods used to overcome the lack of RNFL reference values specific to people from Saudi Arabia. Because the study involves participants from different age groups and genders, it will give us a more representative series of results than previous studies [17,18].

This study uses SD-OCT to set healthy RNFL thickness levels for Saudi individuals and compares the values based on age and gender. The study aims to provide clinicians in Saudi Arabia with a detailed database to help them correctly diagnose and care for patients with diseases of the retina and optic nerve. Moreover, looking at age and gender in the sample aims to discover how these factors may affect RNFL thickness in the eye. The study is meant to enhance the accuracy of OCT scans in Saudi Arabia and assist in choosing the right treatment for patients.

Materials and Methods

Study Design and Study Settings

A cross-sectional study was performed to assess the relationships between retinal nerve fiber layer (RNFL) thickness and refractive error in several age groups of healthy Saudis from May 1 to June 25, 2024. Specifically, OCT was performed with the H Nidek RS-3000 instrument to take the imaging samples. The study was completed at DESH and KFHU in the Eastern Province, which are both based in Saudi Arabia.

Study Population

Participants included in the study were aged more than 15 years and had intraocular pressure (IOP) lower than 21 mmHg. Participants with glaucoma, diabetic retinopathy, a history of pan-retinal photocoagulation or pars plana vitrectomy, myopia over -2.00 D, hyperopia over +1.50 D, or optic neuropathy were not included in the study.

Sample Size

The required sample size was calculated using G* Power software [22] to detect medium effects in one-way ANOVA for three groups with an alpha level of 0.05 and a power of 0.80. This approach used the same original methods that other normal OCT studies adopted [16]. According to the analysis, 159 participants were required to maximise the precision of normative data and accommodate potential exclusions, 173 participants were included in the study.

Ethical Approval

All participants provided their consent to be included in the study. Ethical Approval was obtained from the board of Dhahran Eye Specialist Hospital (with Approval No. 1164 / 6-3-2025). All activities in the study were conducted following the strict guidelines of the Declaration of Helsinki.

Data Collection

Data were gathered from patients at the emergency room and outpatient clinics who came with problems such as red eye or dryness, as well as from the people who accompanied them. Basic details such as age and gender were noted down. The H Nidek RS-3000 OCT system was used to find out the thickness of the refractive errors and the retinal nerve fiber layer.

Statistical Analysis

The statistical analysis was conducted using the Jamovi Software [23]. The Shapiro-Wilk test was used to assess normality and the data were not normally distributed. For this reason, non-parametric tests were applied. Categorical data were provided as numbers and percentages, and continuous data were given as the median and IQR, or SD mean.

In subgroup analysis, people were divided into three age groups: 15-39 years, 40-59 years, and ≥ 60 years. To check the differences in RNFL thickness, the Kruskal-Wallis H test was first performed, and then Dwass-Steel-Critchlow-Flinger comparisons

were used in the paired groups. A Mann-Whitney U test was performed to compare the age groups.

Spearman's correlation test was chosen to find correlations between RNFL thickness and other factors. A multivariate linear regression was also performed to find out which factors are independently linked to RNFL thickness. All findings were considered significant if the p-value was lower than 0.05.

Results

Our study included 173 participants, with a mean age of 40.53 ± 13.72 years. Among the participants, 90 (52%) were aged 15 to 39, 63 (36.4%) were aged 40 to 59, and 20 (11.6%) were 60 and older. Of all participants, 53.8% were women and 46.2% were men. The overall spherical equivalent refractive error was -0.35 ± 0.88 D in the OD and -0.32 ± 0.95 D in the OS. The average RNFL thickness in each eye was 100.28 ± 9.78 μm in the OD and 100.31 ± 10.26 μm in the OS. In both eyes, the superior and nasal quadrants showed less RNFL thickness compared to the inferior quadrant (Table 1).

Table 1: Baseline Characteristics of the Study Participants (n = 173).

Demographic Characteristics		Mean $\pm$ SD / n (%)
Age (years)		40.53 $\pm$ 13.72
Age Groups	15 to 39 years	90 (52.0%)
	40 to 59 years	63 (36.4%)
	≥ 60 years	20 (11.6%)
Gender	Female	93 (53.8%)
	Male	80 (46.2%)
Refractive Error		
Refractive Error OD ¹ (D ⁴)		-0.35 $\pm$ 0.88
Refractive Error OS ² (D ⁴)		-0.32 $\pm$ 0.95
Retinal Nerve Fiber Layer (RNFL) Thickness		
Right Eye (OD)		
Total RNFL ³ Thickness OD ¹ (μm^5)		100.28 $\pm$ 9.78
Inferior RNFL ³ Thickness OD ¹ (μm^5)		128.80 $\pm$ 16.96
Superior RNFL ³ Thickness OD ¹ (μm^5)		126.25 $\pm$ 16.95
Nasal RNFL ³ Thickness OD ¹ (μm^5)		81.10 $\pm$ 12.11
Temporal RNFL ³ Thickness OD ¹ (μm^5)		72.59 $\pm$ 11.29
Retinal Nerve Fiber Layer (RNFL) Thickness		
Left Eye (OS)		
Total RNFL ³ Thickness OS ² (μm^5)		100.31 $\pm$ 10.26
Inferior RNFL ³ Thickness OS ² (μm^5)		129.82 $\pm$ 18.64
Superior RNFL ³ Thickness OS ² (μm^5)		124.50 $\pm$ 16.51
Nasal RNFL ³ Thickness OS ² (μm^5)		80.36 $\pm$ 12.30
Temporal RNFL ³ Thickness OS ² (μm^5)		70.82 $\pm$ 10.44

¹OD = Right eye; ²OS = Left eye; ³RNFL = Retinal Nerve Fiber Layer; ⁴D = Diopter; ⁵ μm = Micrometer

Table 2 presents significant age-related differences in refractive error and retinal nerve fibre layer thickness. For individuals aged 60 or older, the refractive error in their right eye

was more likely to be hyperopic (0.06 D) compared to other age groups, particularly the 15 to 39 age group ($p = 0.028$). As people age, the combined thickness of the entire RNFL decreases in each

eye. Participants aged 60 years and older generally exhibited the thinnest right eye RNFL ($90.8 \pm 6.2 \mu\text{m}$), which was considerably lower than that observed in participants aged up to 25 years ($p < 0.001$). In both eyes, the inferior, superior, and nasal areas also showed reductions ($p < 0.01$), indicating that the superior and

nasal segments are most adversely affected by ageing in the RNFL. However, the thickness of the temporal quadrant remained nearly constant across all age groups in the right eye ($p = 0.263$), whereas a slight decrease was observed in the left eye ($p = 0.031$) (Table 2).

Table 2: Subgroup Analysis of Retinal Parameters and Refractive Error by Age Group (Mean $\pm$ SD).

Variable	15-39 years	40-59 years	≥ 60 years	P value
Refractive Error				
Refractive Error OD ¹ (D ³)	-0.51 ± 0.80	-0.25 ± 0.91	$0.06 \pm 1.00^*$	0.028
Refractive Error OS ² (D ³)	-0.46 ± 0.93	-0.17 ± 0.86	-0.20 ± 1.25	0.229
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Right Eye (OD)				
Total RNFL Thickness OD ¹ (μm^4)	$101 \pm 10^*$	$103 \pm 8.7\$$	$90.8 \pm 6.2^*\$$	<0.001
Inferior RNFL Thickness OD ¹ (μm^4)	$130 \pm 18^*$	$130 \pm 14.9\$$	$118 \pm 15.1^*\$$	0.01
Superior RNFL Thickness OD ¹ (μm^4)	$129 \pm 16.4^*$	$127 \pm 16.4\$$	$113 \pm 15.8^*\$$	0.003
Nasal RNFL Thickness OD ¹ (μm^4)	$80.7 \pm 11.5^*$	$84.8 \pm 11.8\$$	$71.3 \pm 10.5^*\$$	<0.001
Temporal RNFL Thickness OD ¹ (μm^4)	73 ± 11.8	73.3 ± 9.9	68.8 ± 12.9	0.263
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Left Eye (OS)				
Total RNFL Thickness OS ² (μm^4)	$102 \pm 10.4^*$	$101 \pm 10\$$	$91.8 \pm 5.9^*\$$	<0.001
Inferior RNFL Thickness OS ² (μm^4)	$132 \pm 19.2^*$	$130 \pm 17.6\$$	$118 \pm 15.5^*\$$	0.006
Superior RNFL Thickness OS ² (μm^4)	$129 \pm 15.1^*\&$	$121 \pm 16.7\&$	$114 \pm 15.4^*$	<0.001
Nasal RNFL Thickness OS ² (μm^4)	$81 \pm 11.4^*$	$82.1 \pm 13.2\$$	$72 \pm 10.3^*\$$	0.003
Temporal RNFL Thickness OS ² (μm^4)	$72.3 \pm 9.8^*$	70.2 ± 11.1	$65.8 \pm 9.7^*$	0.031

*Significant difference between ages 15-39 and ≥ 60 .

$\$$ Significant difference between ages 40-59 and ≥ 60 .

$\&$ Significant difference between ages 15-39 and 40-59.

¹OD: Right eye; ²OS: Left eye; ³D: Diopter; ⁴ μm : Micrometer

Table 3 shows that there were no significant differences in refractive error or most RNFL parameters between males and females. It was noticed that the left eye's (OS) inferior RNFL was significantly thinner in males ($126 \pm 18.3 \mu\text{m}$) compared to

females ($133 \pm 18.4 \mu\text{m}$) ($p = 0.020$). In other quadrants and eyes, no statistically significant differences in refractive errors or RNFL thicknesses between genders were noticed ($p > 0.05$) (Table 3).

Table 3: Subgroup Analysis of Retinal Parameters and Refractive Error by Age Group (Mean $\pm$ SD).

Variables	Female (Mean $\pm$ SD)	Male (Mean $\pm$ SD)	P value
Refractive Error			
Refractive error OD ¹ (D ⁴)	-0.301 ± 0.852	-0.403 ± 0.919	0.533
Refractive error OS ² (D ⁴)	-0.368 ± 1.02	-0.272 ± 0.876	0.627
Retinal Nerve Fiber Layer (RNFL3) Thickness			
Right Eye (OD)			
Total RNFL Thickness OD ¹ (μm^5)	100 ± 9.63	100 ± 10	0.831

Inferior RNFL Thickness OD ¹ (μm ⁵)	129 ± 17.6	128 ± 16.2	0.968
Superior RNFL Thickness OD ¹ (μm ⁵)	126 ± 15.4	127 ± 18.7	0.954
Nasal RNFL Thickness OD ¹ (μm ⁵)	80.5 ± 12.9	81.8 ± 11.2	0.33
Temporal RNFL Thickness OD ¹ (μm ⁵)	72.9 ± 10.7	72.2 ± 12	0.857
Retinal Nerve Fiber Layer (RNFL3) Thickness			
Left Eye (OS)			
Total RNFL Thickness OS ² (μm ⁵)	100 ± 10.6	100 ± 9.97	0.905
Inferior RNFL Thickness OS ² (μm ⁵)	133 ± 18.4*	126 ± 18.3*	0.020*
Superior RNFL Thickness OS ² (μm ⁵)	123 ± 15.9	126 ± 17.1	0.252
Nasal RNFL Thickness OS ² (μm ⁵)	80.5 ± 12.6	80.2 ± 12.1	0.968
Temporal RNFL Thickness OS ² (μm ⁵)	70.5 ± 10.2	71.2 ± 10.7	0.966

¹OD: right eye; ²OS: left eye; ³RNFL: retinal nerve fiber layer; ⁴D: diopter; ⁵μm: micrometer

Table 4 shows that Spearman's correlation analyses indicate that age is related to several visual characteristics. There was a positive relationship between each eye's refractive error and age (OD: $\rho = 0.224$, $p = 0.003$; OS: $\rho = 0.153$, $p = 0.045$), showing that people tended to become mildly hyperopic with growing age. On the other hand, age and total RNFL thickness had a negative correlation in both eyes (OD: $\rho = -0.197$, $p = 0.009$) and the significant negative correlation was particularly visible in the inferior ($\rho = -0.246$, $p = 0.001$) and superior ($\rho = -0.212$,

$p = 0.005$) quadrants of the right eye. The findings indicate that RNFL becomes thinner with age, with the most notable decrease occurring in some specific locations. It is observed that superior RNFL thickness in the right eye was connected to the left eye's refractive error ($\rho = 0.159$, $p = 0.037$). A relationship between RNFL thickness and refractive error was not observed in most sectors, and the temporal RNFL did not correspond to age or refractive error ($p > 0.2$ in all comparisons) (Table 4).

Table 4: Spearman's correlation analyses between retinal thickness parameters and baseline factors.

	Variable	AGE	Refractive error OD ¹	Refractive error OS ²
Refractive Error				
Refractive error OD ¹	Spearman's rho	0.224	—	—
	p-value	0.003*	—	—
Refractive error OS ²	Spearman's rho	0.153	0.704	—
	p-value	0.045	< 0.001*	—
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Right Eye (OD)				
Total RNFL ³ Thickness OD ¹	Spearman's rho	-0.197	0.029	0.08
	p-value	0.009*	0.706	0.297
Inferior RNFL ³ Thickness OD ¹	Spearman's rho	-0.246	-0.012	0.018
	p-value	0.001*	0.879	0.812
Superior RNFL ³ Thickness OD ¹	Spearman's rho	-0.212	0.073	0.159
	p-value	0.005*	0.342	0.037*
Nasal RNFL ³ Thickness OD ¹	Spearman's rho	-0.093	0.023	0.021
	p-value	0.225	0.763	0.781
Temporal RNFL ³ Thickness OD ¹	Spearman's rho	-0.013	-0.002	-0.093
	p-value	0.866	0.979	0.226
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Left Eye (OS)				
Total RNFL ³ Thickness OS ²	Spearman's rho	-0.249	0.046	0.103
	p-value	< 0.001*	0.55	0.179

Inferior RNFL ³ Thickness OS ²	Spearman's rho	-0.233	0.044	-0.023
	p-value	0.002*	0.568	0.765
Superior RNFL ³ Thickness OS ²	Spearman's rho	-0.302	-0.082	-0.004
	p-value	< 0.001*	0.284	0.959
Nasal RNFL ³ Thickness OS ²	Spearman's rho	-0.171	0.085	0.076
	p-value	0.025*	0.263	0.323
Temporal RNFL ³ Thickness OS ²	Spearman's rho	-0.172	0.006	0.069
	p-value	0.024*	0.934	0.364

¹OD: right eye; ²OS: left eye; ³RNFL: retinal nerve fiber layer; ⁴D: diopter; ⁵µm: micrometer

Multivariate regression was used to assess which factors were associated with the RNFL thickness and refractive errors. Results of the study reveal that males frequently had a thinner inferior RNFL in their left eye than females (P = 0.004). Age was linked to a greater degree of one-sided and other refractive errors, and the right eye was more affected (P = 0.002) than the left eye (P

= 0.041). Alternatively, aging was associated with a decrease in several RNFL parameters. Results also showed that the total, inferior, superior, nasal, and temporal RNFL thickness in the right and left eyes was negatively connected with aging (P values: 0.001, <0.001, <0.001, 0.006, and 0.014, respectively). The findings are provided in Table 5.

Table 5: Multivariate Regression Analyses of RNFL Thickness and Refractive Error with Sex (Male) and Age.

Dependent Variable	Male Estimate (95% CI)	P Value	Age Estimate (95% CI)	P Value
Refractive Error				
Refractive Error OD ¹	-0.070 (-0.332, 0.187)	0.583	0.014 (0.0054, 0.0244)	0.002*
Refractive Error OS ²	0.012 (-0.168, 0.403)	0.416	0.0109 (0.000465, 0.0213)	0.041*
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Right Eye (OD)				
Total RNFL ³ Thickness OD ¹	0.013 (-2.868, 2.893)	0.993	-0.174 (-0.297, -0.069)	0.001*
Inferior RNFL Thickness OD ¹	-1.864 (-6.820, 3.090)	0.459	-0.333 (-0.514, -0.153)	<0.001*
Superior RNFL Thickness OD ¹	0.108 (-4.840, 5.060)	0.966	-0.334 (-0.515, -0.154)	<0.001*
Nasal RNFL Thickness OD ¹	1.115 (-2.522, 4.750)	0.546	-0.120 (-0.252, 0.013)	0.077
Temporal RNFL Thickness OD ¹	-0.768 (-4.190, 2.656)	0.659	-0.022 (-0.147, 0.103)	0.732
Retinal Nerve Fiber Layer (RNFL3) Thickness				
Left Eye (OS)				
Total RNFL Thickness OS ²	-0.786 (-3.790, 2.217)	0.602	-0.198 (-0.308, -0.088)	<0.001*
Inferior RNFL Thickness OS ²	-7.873 (-13.210, -2.536)	0.004*	-0.369 (-0.563, -0.174)	<0.001*
Superior RNFL Thickness OS ²	2.440 (-2.330, 7.210)	0.314	-0.350 (-0.525, -0.170)	<0.001*
Nasal RNFL Thickness OS ²	-0.664 (-4.310, 2.980)	0.72	-0.187 (-0.320, -0.053)	0.006*
Temporal RNFL Thickness OS ²	0.492 (-2.618, 3.601)	0.755	-0.143 (-0.257, -0.030)	0.014*

*Statistically significant (p < 0.05)

¹OD: right eye, ²OS: left eye, ³RNFL: retinal nerve fiber layer

Discussion

The present study investigated the retinal nerve fiber layer (RNFL) thickness in 173 healthy individuals, with a mean age of 40.52 years. The most common age group was between 15 and 39 years, about 52% of the sample were from this group, and females represented the majority at 53.8%. The average RNFL thickness

was measured at 100.283 µm in the right eye and 100.312 µm in the left eye. We found that refractive errors in the right eye increased with age, whereas this trend was not observed in the left eye. RNFL thickness was significantly higher in the youngest age group and lower in the oldest age group, with the exception of the temporal quadrant of the right eye, where no significant differences were recorded. Interestingly, nasal RNFL thickness

in both eyes was significantly higher in the middle-aged group. Correlation analysis showed a positive relationship between age and refractive errors in both eyes. In contrast, age showed negative correlations with all RNFL thickness parameters, except for the nasal and temporal parts of the right eye. Regression analysis indicated that males were associated with decreased inferior RNFL thickness in the right eye. Additionally, age was linked to increased refractive errors and a reduction in all RNFL thickness parameters, excluding the right eye's nasal and temporal regions.

This study revealed that RNFL thickness in both eyes was lower in older participants and continued to decrease with age. Also in the left eye, there was a reduction from $102.0 \pm 10.4 \mu\text{m}$ to $91.8 \pm 5.9 \mu\text{m}$ ($p < 0.001$). This aligns with a previous study suggesting that with age, people experience thinning in the retinal nerve fiber layer due to about 5000 retinal ganglion cell axons dying each year [1,24-27]. For example, Girkin et al. [25] found that using spectral-domain optical coherence tomography (SD-OCT), RNFL thickness reduced with age in their group of different ethnicities. Also, according to Cheung et al. [26], people without glaucoma tend to have thinner RNFL as they grow older. The rates of RNFL thinning vary between different quadrants in our study. Both superior, inferior, and nasal quadrants experienced significant decreases in thickness with age in both eyes, except for the temporal quadrant in the right eye, which was not affected to the same extent ($p = 0.263$). According to Almarzouki et al. [17] in the Saudi group, the RNFL in both the superior and inferior quadrants was mostly susceptible to ageing changes, but their findings did not indicate a stable pattern. Feuer et al. [28] also indicated that the RNFL in the superior part of the eye is most affected by age, which aligns with our results for both of our eyes. However, the finding of stability in the right temporal quadrant means that this area may change with age differently in the right and left eyes. The results from the left temporal quadrant demonstrated a very mild but significant shrinkage ($p = 0.031$). More research is needed, as most studies do not report this type of asymmetry [17]. During middle age, the nasal quadrant had the maximum RNFL thickness among all quadrants, with readings of $84.8 \pm 11.8 \mu\text{m}$ and $82.1 \pm 13.2 \mu\text{m}$ in the right and left eyes, respectively. Interestingly, the thickness of the RNFL changes non-linearly, which may suggest different ways the brain adapts to changes or variations in retinal ganglion cell density.

These quadrant-specific findings contribute to the novelty of our study, as the stability of the right temporal quadrant and the non-linear pattern of nasal RNFL thickness in the middle-aged group are not widely reported. Even though other groups have reported age-related RNFL thinning, they did not observe the particular asymmetry and curves that we see here [14,15]. Further studies may consider differences in measurement, blood supply, or disc size that occur related to the unequal stability of the right and left temporal quadrants. The nasal RNFL thickness in the middle-aged group may show compensatory mechanisms or regional variations in retinal ganglion cell density, anticipating

the need for further investigation to understand its physiological basis.

The present study found that older individuals (≥ 60 years) developed hyperopia (0.06 ± 1.00 D in the right eye) compared to younger people. This aligns with the findings in the scientific literature that there is a sequence from hyperopia during childhood, to myopia at an early age and then back to hyperopia as the eyes get older [29-31]. Our study observed that myopia in children is corrected between 30 and 40 years, with emmetropia being the midpoint and that after 40, vision tends to become slightly hyperopic. Given that the relationship between hyperopia and IOP was greater on the right side, this difference suggests that a slight asymmetry may exist, although this has not been well studied before.

Surprisingly, we found no significant association between refractive error and the thickness of the RNFL fibres in the retina ($p > 0.2$), consistent with the findings of Pakravan et al. [31] reported for adults with only minor differences in refractive error. All of our cases experienced mildly blurry vision and very little myopia, which may explain why a significant relationship was not observed between myopia and the loss of retinal nerve fibre layer thickness. Budenz et al. [27] found that myopic patients tend to have thinner RNFL, suggesting that having only mild refractive errors may not have altered the RNFL thickness in our subjects. Since the results were not identical for all patients and may vary with the degree of refractive error, this highlights a lack of studies on this relationship.

The stronger correlation between refractive error changes and hearing loss in the right ear ($p = 0.002$) rather than the left ($p = 0.041$) is a discovery not often reported in previous studies. Such differences may be because of features in the Saudi eye or due to special environmental factors in Saudi Arabia, for example, ultraviolet light, which may have an effect on the retina [19]. The lack of association between refractive error and RNFL thickness in our near-emmetropic cohort (OD: -0.35 ± 0.88 D; OS: -0.32 ± 0.95 D) aligns with Pakravan et al. [31] but contrasts with Budenz et al. [27], highlighting the need for studies with broader refractive error ranges to clarify this relationship in the Saudi context.

The study results did not identify any significant differences for the RNFL between men and women, except that the left inferior quadrant was thinner in men ($126 \pm 18.3 \mu\text{m}$) than in women ($133 \pm 18.4 \mu\text{m}$, $p = 0.02$). Some earlier studies also show little difference in RNFL thickness between men and women [32-34]. Additionally, Schuman et al. [32] and Bowd et al. [33] studied healthy people and noticed there were no significant differences between genders in RNFL thickness, as we found. However, what sets our study apart is that we observed thinner left inferior RNFL in male eyes and this has not been described in many previous studies.

Alternatively, Budenz et al. [27] reported that males tended to have thicker RNFLs due to having a higher body mass index.

On the other hand, Almarzouki et al. [17] discovered that for Saudis, only females in the right eye had thicker RNF. The different studies results may be explained by the effect of BMI, hormones or varying ethnic groups on individuals [11,12]. According to Cubuk et al. [11] and Poinosawmy et al. [12], differences in RNFL thickness exist across ethnicities and can influence gender-related results in a wide range of situations. While the thinning in the left RNFL inferior area of men in our research could be caused by anatomical differences or measurement error. Future research should identify and consider factors such as the size of the optic disc, hormone levels or lifestyle differences to understand sex differences in the Saudi population.

The thinner left inferior RNFL in males is a novel finding, as most studies, including those by Schuman [32] and Varma et al. [34], report minimal gender differences. Budenz et al. [27] and Almarzouki et al. [17] report different results from this work because genetic factors or high consanguinity may be involved in Saudi populations and could influence retinal anatomy. Additional scientific studies are necessary to understand these factors and see if unevenness between men and women exists.

The results of this study affect the practice of ophthalmology in Saudi Arabia. Setting normal RNFL thickness values (100.28 μm for OD and 100.31 μm for OS) is crucial for health professionals using SD-OCT for diagnosing and monitoring disorders in the retina and optic nerve. According to Shin et al. [35] and Trinh et al. [36], the thinning of the RNFL in the superior and inferior quadrants in older patients is consistent with OCT detecting age-related damage in the retina. This can help to tell the difference between physiological ageing and glaucoma, as the hallmark of glaucoma includes the thinning of the superior and inferior RNFL [24,28]. Male and female RNFL measurements were not found to be far from each other; normative RNFL collections for Saudi Arabia may be applied to men and women, except for the left inferior quadrant. Since refractive error and RNFL thickness were not linked for emmetropic participants, health professionals can use refractive error ranges to interpret OCT data carefully in populations with a larger number of people with myopia. The presence of these normative values improves the ability of SD-OCT to spot cellular thinning caused by ageing or by diseases such as glaucoma or age-related macular degeneration in Saudi Arabia. The finding in the left inferior quadrant for male's points to a need for clinicians to update the usual norms for this region.

The study addresses RNFL measurements for Saudi adults, contributing to very limited prior work [17,18]. This study provides novel findings that temporal RNFL thickness only stabilises on the same side more often in one eye compared to the other, which needs to be confirmed in more extensive follow-up studies. Also, the unusual pattern of RNFL thickness in the middle-aged group should be investigated to find out its true meaning. It is possible that a wider range of refractive errors would have suggested a different outcome because the lack of relationship between refractive error and RNFL thickness was seen in our

participants. Furthermore, the influence of environmental and population-specific factors had not been fully explored in this study, due to which future studies must investigate both genes and the environmental factors. The novel findings of right temporal quadrant stability and peak nasal RNFL thickness in the middle-aged group highlight research gaps in quadrant-specific RNFL dynamics and inter-eye asymmetries. Few earlier studies carried out in Saudi Arabia, for example, Raffa and AlSwealh [18], have focused on children, so it is important to gather information on adult populations. It is also possible that factors unique to some populations such as related marriage or high ultraviolet light, can affect RNFL thickness.

There are a few limitations associated with this study. As the measurements were at one time only, we cannot assess how the RNFL changes over time and having only 20 people in the oldest age group might lower the statistical significance of age-related comparisons. Furthermore, since the refractive errors in our group were nearly normal, this study may not apply to those with more challenging refractive problems. It is also possible that BMI or the size of the optic disc played a role, which could influence RNFL thickness.

Conclusion

This study examines retinal nerve fiber layer thickness in Saudi participants. The findings showed that RNFL thickness decreases as age increases, mainly in the superior and inferior quadrants, and there is an exception of no decrease in RNFL thickness in the right temporal part and a thicker RNFL was found in the middle nasal region for older people. While there were few gender differences, males were more likely to have a thinner left RNFL in the inferior quadrant, which indicated the need for clinical consideration. This study reported that hyperopia appears to be more common in people with ageing, but a relationship was observed between refractive error and the thickness of the RNFL in Saudi population.

Acknowledgements

The author is thankful to all the associated personnel who contributed to this study by any means.

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DOI: [10.19080/JOJ0.2025.13.555853](https://doi.org/10.19080/JOJ0.2025.13.555853)

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