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Effect of body mass index on retinal nerve fiber layer thickness in adults

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Purpose: *to investigate inter-ocular variation in retinal nerve fiber layer (RNFL) thickness, compare RNFL thickness across body mass index (BMI) categories, and examine the relationship between BMI and RNFL thickness.* ***Material and methods.*** *A cross-sectional study was conducted in September 2024 at Al Shifa Trust Eye Hospital with 107 participants (46 females, 61 males) aged 27.17 ± 6.98 yrs. Visual acuity was assessed using Snellen charts, and refraction and slit-lamp bio-microscopic examination was performed. BMI was calculated and classified into underweight, normal, overweight, and obese categories. Optical coherence tomography (OCT) measured RNFL thickness in the superior, inferior, nasal, and temporal quadrants.* ***Results.*** *Statistically significant BMI differences were found between males and females. Males had an average RNFL thickness of 99.23 ± 4.9 μm, with the thinnest RNFL in the temporal quadrant. Females had an average RNFL thickness of 99.20 ± 5.33 μm, with the temporal quadrant also being the thinnest. Obese females had thicker RNFL in the superior quadrant, while obese males had thicker RNFL in the inferior quadrant. A significant positive correlation between BMI and RNFL thickness was found, particularly in the superior quadrant for obese females and the inferior quadrant for obese males. Inter-ocular differences showed thicker horizontal RNFL quadrants in the right eye and thicker vertical quadrants in the left eye.* ***Conclusion.*** *Significant differences in RNFL thickness exist across BMI categories. The inferior quadrant is thicker in obese males, while the superior quadrant is thicker in obese females. Inter-ocular differences show variations in quadrant thickness between the eyes.*

Keywords: optical coherence tomography; body mass index; retinal neuron
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Влияние индекса массы тела на толщину слоя нервных волокон сетчатки у взрослых

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Цель *работы — исследовать межокулярные различия в толщине слоя нервных волокон сетчатки (СНВС), сравнить толщину СНВС у пациентов с разными категориями индекса массы тела (ИМТ) и изучить взаимосвязь между ИМТ и толщиной СНВС.* ***Материал и методы.*** *В сентябре 2024 г. в офтальмологической больнице Аль-Шифа проведено поперечное исследование с участием 107 человек (46 женщин, 61 мужчина) в возрасте 27,17 ± 6,98 года. Оценивали остроту зрения с помощью таблиц Снеллена, проводили рефрактометрию и биомикроскопию с помощью щелевой лампы. ИМТ рассчитывался и классифицировался на категории: недостаточный вес, нормальный вес, избыточный вес и ожирение. Толщину СНВС измеряли с помощью оптической когерентной томографии (ОКТ) в верхнем, нижнем, носовом и височном квадрантах.* ***Результаты.*** *ИМТ значимо различался у мужчин и женщин. У мужчин средняя толщина СНВС составляла 99,23 ± 4,9 мкм, у женщин 99,20 ± 5,33 мкм, при этом самый тонкий слой у тех и у других находился в височном квадранте. У женщин с ожирением толщина СНВС была больше в верхнем* *квадранте, а у мужчин с ожирением — в нижнем квадранте. Обнаружена значительная положительная корреляция между ИМТ и толщиной СНВС, особенно в верхнем квадранте у женщин с ожирением и в нижнем квадранте у мужчин с ожирением. Выявлены межокулярные различия: толщина СНВС выше в горизонтальных квадрантах (наружном и внутреннем) в правом глазу и в вертикальных (верхнем и нижнем) в левом глазу.* ***Заключение.*** *Толщина СНВС значимо зависит от категории ИМТ. При ожирении у мужчин СНВС толще в нижнем квадранте, а у женщин — в верхнем квадранте. Межокулярные различия показывают вариации толщины СНВС в различных квадрантах.*

Ключевые слова: оптическая когерентная томография; индекс массы тела; нейрон сетчатки
Конфликт интересов: отсутствует.
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The retinal nerve fiber layer (RNFL) is tightly packed between the inner limiting membrane and the retinal ganglion cell layer. The inner limiting membrane, which covers the surface of the nerve fiber layer, is made up of ganglion cell axons, astrocytes, retinal arteries, and Muller cell processes [1, 2]. The number of cells in the human ganglion cell layer peaks between weeks 18 and 30 of gestation, reaching 2.2 to 2.5 million cells. After this period, the cell counts declines rapidly to around 1.5 to 1.7 million cells. In the adult human optic nerve, there are about 1.1 million axons [3, 4]. The retinal nerve fiber layer (RNFL) contains approximately 2.85 million nerve fibers throughout development, with around 35% of them being lost by the third trimester. The thickness of the RNFL decreases by 2.4 mm per decade as a person ages. Assessing the RNFL is vital for detecting glaucoma, optic nerve abnormalities, and other retinal conditions [5].

In glaucoma patients with a high body mass index (BMI), studies have shown that the neuro-retinal thickness is increased, while the optic nerve and cup-to-disc ratio are reduced. Glaucomatous eyes often present with elevated intraocular pressure (IOP) and a restricted visual field. It is hypothesized that a high BMI leads to an increase in cerebrospinal fluid pressure (CSF), which subsequently causes the neuro-retinal rim to thicken [6]. BMI is calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2). It takes height into account and classifies individuals into different categories based on their weight [7].

The standard weight status categories, which are the same for men and women of all ages, are used to interpret BMI for adults 20 years of age and older. The World Health Organization based on BMI has following categories: Underweight with a BMI under 18.50. BMI range for healthy weight is 18.50–24.99. BMI of 25.00–29.99 indicates overweight. BMI of 30.00 to 34.99 is considered obese class I. BMI 35–39.99, class II obesity. Having a BMI of 40 or more and being obese class III.

Obesity is a major public health concern that is increasingly affecting both developed and developing countries. It leads to various physical, social, and economic challenges. Obesity has been linked to four major eye diseases — cataracts, glaucoma, diabetic retinopathy, and age-related maculopathy — that can result in blindness [8]. Epidemiological studies have identified obesity and overweight as significant risk factors for various systemic diseases, including hypertension, dyslipidemia, type 2 diabetes, osteoarthritis, sleep apnea syndrome, reproductive issues, stroke, metabolic syndrome, gallbladder problems, high low density lipids (LDL) cholesterol (bad cholesterol), low high density lipids (HDL) cholesterol (good cholesterol), high blood glucose (sugar), and a family history of premature heart disease [9] and cancer [10]. Changes in RNFL thickness are an important sign of early retinal damage. Therefore, there is increasing attention on RNFL thickness in obesity [11].

Optical Coherence Tomography (OCT) is a non-invasive imaging technique that utilizes near-infrared light to obtain high-resolution cross-sectional images of the retina and optic nerve. With axial resolution approaching 5–10 microns, especially in Spectral Domain OCT (SD-OCT), it allows for detailed visualization of retinal layers, facilitating early detection and monitoring of various posterior segment pathologies. These include age-related macular degeneration (ARMD), diabetic retinopathy, retinal detachment, glaucoma-related changes in the RNFL, macular holes, epiretinal membranes, and vitreomacular interface disorders. The ability of OCT to produce rapid, high-resolution, and quantitative data makes it a powerful diagnostic and research tool in ophthalmology [12, 13]. This method is also used in the early diagnosis of multiple sclerosis [14] , in the differential diagnosis of choroidal nevi and choroidal melanoma [15], in the early diagnosis of degenerative brain diseases (Alzheimer's disease, Parkinson's disease) [16, 17]. OCT models include the Stratus, 3D-OCT 1000, 3D SD-OCT, Cirrus HD-OCT, Spectralis OCT/SLO, Spectralis HRA+OCT, Heidelberg Spectralis, NIDEK, and RS-3000.

In previous studies, a decrease in RNFL thickness on the optic nerve head in obese children has been observed, which could increase the risk of developing glaucoma, along with elevated intraocular pressure (IOP). Additionally, a reduction in Central Corneal Thickness (CCT), Central Foveal Thickness (CFT), and Sub Foveal Choroidal Thickness (SFCT) may contribute to the development of macular diseases [6]. BICH (Edema of the optic nerve disc in the intracranial hypertension) is most often diagnosed in obese young women, BICH can also lead to blindness [18]. This is significant, as it suggests that obesity in childhood can have lasting effects on ocular health, potentially increasing the risk of serious conditions like glaucoma and macular degeneration. However, while there is growing evidence linking obesity and ocular changes in children, studies exploring the relationship between adult BMI and RNFL thickness remain limited so this research tends to fill the literature gap and to better understand these associations in adults.To our knowledge, this was the first study examine the influence of BMI on RNFL thickness in both genders, as well as the inter-ocular difference between the eyes and the correlation between RNFL and BMI in adults.

MATERIAL AND METHODS

A cross-sectional study was conducted to assess the effect of BMI on RNFL at the General Outpatient Department of Al-Shifa Trust Eye Hospital, Rawalpindi. Data collection took place over a three-month period, from August 2023 to October 2023. A Consecutive Non-Random Sampling technique was used to recruit participants. The sample size was calculated using the WHO calculator with a 95% confidence level and 80% power, resulting in a required sample of 107 participants (214 eyes).

The study population included all individuals presenting at the General OPD and Diagnostic Department who met the inclusion criteria. The inclusion criteria included participants aged 18 to 40 years, those with best spherical refraction between ±6.00 D, and those with best-corrected visual acuity of 20/20. The exclusion criteria included participants with ocular diseases (such as ARMD, diabetic retinopathy, macular edema, or media opacity), those using local or systemic medication, individuals with evident systemic or ocular diseases, those undergoing steroid therapy, individuals with a history of bariatric surgery, and diabetic patients.

Data collection was performed using a structured proforma, which included demographic details, ocular examination findings, and BMI measurements. Visual acuity was assessed using a Snellen Chart, refraction was conducted by an expert, and Slit Lamp Bi microscopy was performed to rule out ocular diseases. BMI was calculated using height and weight measurements, and participants were categorized into underweight, normal, overweight, and obese groups. Spectral Domain Optical Coherence Tomography (OCT) was used to measure RNFL thickness. The dependent variable was RNFL thickness (measured in all four quadrants: superior, inferior, nasal, and temporal, along with the average thickness). The independent variables included age, gender, BMI, history of spectacles, refractive status, and type of refractive error.

Data was entered and coded into SPSS Version 26 for analysis. Descriptive statistics were used to summarize categorical and continuous variables, while inferential statistics included Pearson correlation (to assess BMI-RNFL correlation), One-way ANOVA (to evaluate BMI effects on RNFL thickness by gender), and Paired t-tests (to assess inter-ocular differences). Ethical approval was obtained from the Institutional Review Board of the Pakistan Institute of Ophthalmology. Permission was secured from the department heads, and informed consent was obtained from all participants. Confidentiality was maintained, and the data was used exclusively for academic purposes.

RESULTS

A total of 107 subjects were examined in the general outpatient department. The mean age of the subjects was 27.17 years with a standard deviation of 6.98 years, ranging from 18 to 40 years. Among them, 61 participants (57%) were male and 46 (43%) were female. The study included 105 emmetropic eyes (49%) and 109 ametropic eyes, which achieved 6/6 vision after correction. The BMI classification revealed that among 62 male participants, 4 were underweight, 17 were normal, 29 were overweight, and 11 were obese. Among 45 female participants, 9 were underweight, 17 were normal, 17 were overweight, and 3 were obese.

To analyze the relationship between BMI and RNFL thickness, three statistical tests were applied. Pearson Correlation was used to assess the correlation between BMI and RNFL thickness, a paired sample t-test was applied to evaluate interocular differences, and one-way ANOVA was used to compare RNFL thickness across BMI categories.

Table 1. Retinal nerve fiber layer (RNFL) thickness in different grades of BMI in females (mean ± standard deviation)
Таблица 1. Толщина слоя нервных волокон сетчатки при различных уровнях индекса массы тела у женщин (среднее ± стандартное отклонение)

Retinal quadrant Квадрант сетчатки	Underweight Пониженный уровень	Normal Норма	Overweight Повышенный уровень	Obese Ожирение	p-value
Superior, μm Верхний, мкм	113.9 ± 7.7	124.3 ± 15.7	142.8 ± 15.3	134.3 ± 13.1	< 0.001
Inferior, μm Нижний, мкм	123.0 ± 14.1	131.6 ± 13.0	127.1 ± 11.8	126.7 ± 6.8	0.404
Nasal, μm Назальный, мкм	75.2 ± 8.7	73.7 ± 16.8	78.8 ± 13.4	75.3 ± 9.1	0.762
Temporal, μm Темпоральный, мкм	69.4 ± 8.8	67.6 ± 9.1	71.0 ± 8.4	79.3 ± 11.7	0.204
Mean, μm В среднем, мкм	95.9 ± 7.7	100.0 ± 9.0	99.3 ± 24.1	104.0 ± 7.6	0.204

Table 2. Retinal nerve fiber layer thickness in different grades of BMI in males (mean ± standard deviation)
Таблица 2. Толщина слоя нервных волокон сетчатки при различных уровнях индекса массы тела у мужчин (среднее ± стандартное отклонение)

Retinal quadrant Квадрант сетчатки	Underweight Низкий уровень	Normal Норма	Overweight Повышенный уровень	Obese Ожирение	p-value
Superior, μm Верхний, мкм	124.0 ± 24.2	126.4 ± 12.9	118.4 ± 11.1	122.8 ± 15.7	0.275
Inferior, μm Нижний, мкм	125.8 ± 16.6	121.4 ± 12.8	133.3 ± 11.3	137.1 ± .7	0.007
Nasal, μm Назальный, мкм	77.3 ± 23.9	70.3 ± 11.9	76.2 ± 13.5	85.3 ± 12.7	0.056
Temporal, μm Темпоральный, мкм	64.5 ± 6.4	71.6 ± 8.0	69.0 ± 8.8	67.4 ± 8.2	0.378
Mean, μm В среднем, мкм	98.3 ± 12.3	96.6 ± 8.3	99.4 ± 7.7	103.3 ± 9.0	0.239

ANOVA results for female subjects revealed a statistically significant increase in RNFL thickness in the superior quadrant among obese females ($p < 0.001$), while no significant associations were found in the inferior, nasal, or temporal quadrants as indicated in Table 1.

For male subjects, ANOVA results showed a statistically significant increase in the inferior quadrant ($p = 0.007$), while no significant associations were observed in the superior, nasal, or temporal quadrants as shown in table 2.

The Pearson correlation test results showed a moderate positive correlation between the inferior quadrant and BMI in males ($r = 0.339$, $p = 0.007$) and a strong positive correlation between the superior quadrant and BMI in females ($r = 0.563$, $p < 0.001$) as shown in Table 3. Other quadrants showed weak or non-significant correlations.

The paired sample t-test was conducted to compare RNFL thickness between both eyes. The results indicated a specific pattern, where vertical quadrants were thicker in the left eye, whereas horizontal quadrants were thicker in the right eye as shown in table 4.

DISCUSSION

The main objectives of this study were to evaluate the effect of BMI on RNFL thickness in both genders, to evaluate the inter-ocular difference between the eyes and assess the relationship between RNFL and BMI. This study included 107 subjects (214 eyes) in which 46 were females and 61 were males. Out of these 61 males 4 were underweight, 17 were normal, 29 were overweight and 11 were obese. While out of 46 females 9 were underweight, 17 were normal, 17 were overweight and 3 were obese. Most of the subjects included in this study were male. Mostly obese male presented in this hospital setting. BMI increases in adults due to the sedentary life style and due to COVID — 19 most of the subjects gain weight. Due to technology evolvement the time spent outside is replaced by screen time. Obesity have become a huge problem in children in past few years. The effect of obesity on ocular and systemic health is a topic of prime importance. This study included patients with refraction of ± 6.0 D sphere. However, there is evidence that a high degree of myopia can have a different effect on the RNFL thickness [19].

Table 3. Correlation analysis of retinal nerve fiber layer thickness with different grades of BMI
Таблица 3. Коэффициенты корреляции толщины слоя нервных волокон с различными уровнями индекса массы тела

Retinal quadrant Квадрант сетчатки	Males Мужчины		Females Женщины	
	r	p	r	p
Superior Верхний	-.167	0.199	.563	< 0.001
Inferior Нижний	.339	0.007	.194	0.196
Nasal Назальный	.285	0.026	.134	0.375
Temporal Темпоральный	-.106	0.417	.192	0.202
Mean В среднем	.184	0.155	.139	0.356

Note. r — pearson correlation coefficient.
Примечание. r — коэффициент корреляции Пирсона.

In the present study the mean for uncorrected visual acuity for 107 subjects (right eyes and left eyes are 0.2730 ± 0.37280 and 0.2622 ± 0.38611) respectively. While the mean for the corrected visual acuity for right and left eyes are (0.00 ± 0.000). While the mean and the standard deviation for right and left eyes are (-1.2061 ± 1.06289 and -1.2788 ± 1.06832). In the present study different patterns were seen in obese males and females. RNFL thickness were measured using Heidelberg's SD-OCT. The average RNFL thickness in males was found to be 99.23 ± 4.9 µm. RNFL thickness was least for the temporal quadrant (69.16 ± 8.35 µm), followed by the nasal (76.28 ± 14.26 µm), superior (121.77 ± 13.59 µm) and inferior (130.20 ± 13.99 µm). The average RNFL thickness in female was found to be 99.20 ± 5.33 µm. RNFL thickness was least for the temporal quadrant (70.00 ± 9.10 µm), followed by nasal (75.98 ± 13.64 µm), inferior (127.93 ± 12.55 µm) and superior (129.76 ± 17.77 µm). Thus, the study shows that in obese males RNFL is thicker in the inferior quadrant while in obese females' superior quadrant is thicker.

In the present study there is correlation between BMI and RNFL. It also shows different patterns in both genders. In obese females there is a statistically significant strong positive correlation between the superior quadrant and BMI. While there is a weak positive correlation of BMI with inferior quadrant, nasal quadrant, temporal quadrant and mean value. While in obese males there is statistically strong positive correlation was found between the inferior quadrant and BMI and weak positive correlation of BMI with nasal quadrant and mean value, and negative correlation of BMI with superior quadrant and temporal quadrant.

For inter-ocular difference the means of all 4 quadrants of RNFL between two eyes were compared. The mean RNFL of right and left eyes in superior quadrant are (125.21 ± 15.951 µm and 126.82 ± 16.55 µm), for inferior quadrants are (129.22 ± 13.38 µm and 129.76 ± 13.62 µm), for nasal quadrants are (76.15 ± 13.93 µm and 71.94 ± 13.98 µm) and for temporal quadrants are (69.52 ± 8.65 µm and 67.94 ± 8.84 µm) respectively. Thus, the study concluded that there is a specific pattern as the vertical quadrants of RNFL is thicker in left eye whereas horizontal quadrants are thicker in right eye.

A study was conducted by Y. Tariq et al. in which 1521 young adults were enrolled with mean age 17.3 ± 0.6 years. RNFL thickness were measured using Cirrus HD – OCT 4000.

Table 4. Comparing the retinal nerve fiber layer thickness (µm) of both eyes
Таблица 4. Различие в толщине слоя нервных волокон сетчатки (мкм) парных глаз

Retinal quadrant Квадрант сетчатки	Mean ± S.D	p
Superior Верхний	-1.617 ± 9.5	.081
Inferior Нижний	-.533 ± 8.0	.491
Nasal Назальный	4.206 ± 8.5	.000
Temporal Темпоральный	1.579 ± 6.7	.016
Mean В среднем	.093 ± 10.4	.926

The average RNFL was found to be 99.4 ± 9.6 µm. RNFL thickness was least for the temporal quadrant (69.9 ± 11.2 µm), followed by the nasal (74.3 ± 12.8 µm), superior (124.7 ± 15.7 µm) and inferior (128.8 ± 17.1 µm) quadrants [20]. While in the present study the average RNFL thickness in male and female are 99.23 ± 4.9 µm and 99.20 ± 5.33 µm respectively.

L. Hazar et al. [21] conducted a study in children and adolescent to assess the relationship of obesity and other related disorders with ocular parameters. Out of 57 eyes there were 12 (21%) eyes in obese group, 20 eyes (35.1%) in obesity — related hypertension (HT) group and 25 eyes (43.9%) in healthy controls. There was no difference between the groups in terms of central corneal thickness and intraocular pressure. The superior quadrant RNFL was significantly thicker in the obese and obesity — related HT groups for both children and adolescents (p = 0.023). The inferior quadrant RNFL thickness and central foveal thickness were significantly thinner in the obesity — related HT group than the other two groups (p = 0.001 and p = 0.040). However, no statistically significant relationships were found between BMI, waist circumference, systolic blood pressure (BP), diastolic BP, fasting blood sugar, insulin, homeostatic model assessment for insulin resistance (HOMAIR), LDL, HDL, total cholesterol, HbA1c, AST and ALT values and the corneal thickness values (p > 0.05). While in the present study the RNFL is thicker in superior quadrant in obese females while in case of obese males RNFL is thicker in the inferior quadrant [21].

A conducted a study to assess the association of childhood obesity with retinal microvasculature and corneal endothelial cell morphology. 43 subjects were included in this study in which 25 children were obese and 18 were control group. Mean CCT values were significantly lower in obese group (545.0 ± 21.2) then the control group (557.1 ± 26.0) (p = 0.017), however, RNFL thickness for average and all quadrants were similar between both the groups [22]. The results of this study were opposite than the present study.

B. Ozen et al. [23] conducted a study on the assessment of RNFL thickness in non — diabetic children and adolescents. 38 obese and 40 healthy children and adolescents aged 10–18 years were included in this study. No statistically significant difference was found between RNFL thickness in both the sexes or between the two eyes using OCT imaging (p > 0.05). RNFL thickness was lowest in both the control and obese groups in the nasal quadrant, followed by the temporal, superior and inferior quadrants in respective order. A general decrease in RNFL thickness was observed in obese subjects compared to controls, ranging from 2% and 7% in mean values, the greatest change occurring in the inferior quadrant, although these differences were not statistically significant [23].

Another study was conducted in Singapore to evaluate the RNFL thickness in a multiethnic normal Asian population. They included 4475 participants (8178 eyes) consisting of 1371 Chinese, 1303 Malay and 1801 Indian adults. Average RNFL thickness measured was 95.7 ± 9.6 µm in Chinese participants, 94.9 ± 10.6 µm in Malay participants, and 87.3 ± 10.6 µm in Indian participants (p <0.001). While in the present study the average RNFL thickness in males was found to be 99.23 ± 4.9 µm and the average RNFL thickness in female was found to be 99.20 ± 5.33 µm [20].

K. Teberik et al. [24] conducted a study on ocular abnormalities in morbid obese. They concluded that the mean RNFL thickness at the temporal quadrant was reduced in the morbidly obese group (72.7 ± 13.6 vs. 85.05 ± 52.6 mm, p=0.024). Similarly, the mean retinal thicknesses at nasal and temporal were lower in the morbidly obese group (346.6 ± 18.2 vs. 353.7 ± 18.8 mm, p=0.008; 323.1 ± 20.3 vs. 330.0 ± 18.9 mm, p=0.001) [24].

Since BMI has effect on RNFL thickness so the subjects should have a strict check on their BMI. The patients should be guided accordingly to control their bad eating habits and to improve their sedentary lifestyle. To the best of our knowledge, this is the only study that has been done highlighting this important topic in Pakistan. Our study was limited by the fact that both males and females in the obese category had relatively small sample sizes. As this study was hospital-based and only included participants who visited the hospital's regular OPD, it may have certain limitations.

CONCLUSIONS

This study concludes that BMI affects RNFL thickness differently in males and females. In obese females, the superior quadrant is thicker compared to underweight and normal females, whereas in obese males, the inferior quadrant is thicker. A specific inter-ocular difference is observed, where the nasal and temporal quadrants are thicker in the left eye, while the superior and inferior quadrants are thicker in the right eye. There is also a correlation between BMI and RNFL. In obese females, BMI has a strong positive correlation with the superior quadrant and a weak positive correlation with other quadrants. In obese males, BMI has a strong positive correlation with the inferior quadrant, weak positive correlations with the nasal quadrant and mean value, and a negative correlation with the superior and temporal quadrants.

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