Ocular Blood Flow Abnormalities and Their Correlation with Body Mass Index in Obese Patients

Melek Tufek (melektfk@hotmail.com)
Sabuncuoglu Serefeddin Training and Researsch Hospital https://orcid.org/0000-0001-5516-7412
Mustafa Capraz
Sabuncuoglu Serafeddin Training and Research Hospital
Ahmet Turan Kaya
Sabuncuoglu Serafeddin Training and Research Hospital
Kenan Varol
Private Rumeli Hospital
Nihat Aydın
Sabuncuoglu Serafeddin Training and Research Hospital
Pınar Nalcacıoglu
Yıldırım Beyazıt University Medical School

Research Article

Keywords: Body mass index, choroidal thickness, intraocular pressure, obesity, retrobulbar blood flow

Posted Date: June 17th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-574750/v1

Abstract

Purpose

To evaluate the effects of obesity on ocular blood flow including choroidal thickness and retrobulbar blood flow values in comparison with healthy subjects

Methods

The 102 eyes of 102 female patients were included in this prospective study.Color Doppler ultrasonography (CDU) was used to evaluate the retrobulber vessels.Choroidal thickness was measured by using the optical coherence tomography (OCT).

Results

There was a significant difference in IOP values within the groups with the highest values in group 3 and the lowest in group 1.There was also a positive correlation between BMI and IOP. The CT was found to be statistically significantly lower in group 2 and group 3 than in the control group at all measurement points. The choroidal thickness was also statistically significantly lower in group 3 than in group 2 at the subfoveal, nasal 500 μm, and the temporal 500 and 1000 μm measurement points.The mean CRA PSV and EDV values were lower in group 2 and group 3 than in group 1, while group 3 had the lowest mean CRA PSV value among the groups. When compared to group 1, the OA EDV value was lower only in group 3 while the OA PSV value was statistically significantly lower in group 3 than in both group 2 and group 1. There was no significant difference between the groups in terms of RI and PI.

Conclusions

Obesity can create a predisposition to ocular pathologies both by increasing the IOP and decreasing the retrobulbar and choroidal blood flow.

Introduction

Obesity is a common life-threatening condition that results in reduced life expectancy in the modern world. The prevalence of being overweight and obese is increasing in all age groups both in the developing and developed countries. Obesity has been associated with ocular disease including cataracts, glaucoma, diabetic retinopathy, and age-related macular degeneration [1]. Although the underlying mechanism is not fully understood, it has been associated with vascular endothelial dysfunction and ocular vascular damage due to the microvascular changes in the retinal vessels and impaired ocular blood flow [2].

The choroid of the eye is one of the most highly vascular structures of the body and supplies the outer one-third of the retina. Evaluation of the choroidal thickness provides important information for the diagnosis and treatment of various ocular and systemic diseases [3, 4]. The choroidal thickness can be

measured by using Enhanced Depth Imaging (EDI) mode of spectral-domain optical coherence tomography (SD-OCT).

Color Doppler ultrasound (CDU) is now a widely used non-invasive technique for the evaluation of retrobulbar hemodynamics in ocular diseases thanks to Doppler technology that provides quantitative data. It provides measurements that are reproducible and reliable between observers [5]. The ophthalmic artery (OA), central retinal artery (CRA) and vein, and the short posterior ciliary arteries can be measured by CDU.

Previous studies have focused on retrobulbar ocular blood flow or choroidal thickness changes, but not both. Only two previous studies have evaluated the effect of obesity on retrobulbar ocular blood flow, and these have only included morbid obese patients [6, 7]. The above parameters are clinically important as they are part of the ocular circulation, and are also essential in guiding the clinical approach to whether subjects suffering from obesity of various degrees have an increased risk of ocular pathology development.

The aim of this study was to evaluate the changes in both the retrobulbar ocular and choroidal perfusion in patients with obesity of various degrees when compared with subjects with a normal BMI. We also evaluated the relationship between BMI and ocular hemodynamics.

Materials And Methods

The 70 eyes of 70 obese subjects who were referred consecutively to the Ophthalmology Clinic from the Endocrinology Department of Sabuncuoglu Serefeddin Training and Research Hospital between March 2020 and May 2021 were included in this prospective case control study. The control group consisted of the 32 eyes of 32 age- and sex-matched healthy subjects who had presented consecutively to the Ophthalmology Clinic for a routine eye examination and who had no systemic and ocular disease. The study was approved by the Ethics Committee of the Tokat Gaziosmanpasa University Medical School. All procedures were conducted in accordance with the Declaration of Helsinki. An informed consent form was completed by all the subjects.

The body weight and height of the subjects were recorded. The BMI was calculated in both the obese patients and control subjects by dividing the body mass (kg) into the square of the height (m^2). The subjects were divided into three groups according to the WHO classification [8] as group 1 with a BMI of 18.5-24.99, group 2 with a BMI of 30-34.99, and group 3 with a BMI of 35-39.99. There were 32 patients in group 1 (31.4%), and 35 each in group 2 and group 3 (34.3% for each). The systolic and diastolic blood pressure was measured twice a day for one week with an automatic blood pressure device before starting the study protocol. A systolic pressure over 140 mmHg and diastolic pressure over 90 mmHg resulted in exclusion from the study.

All participants underwent a detailed ocular examination including best corrected visual acuity (BCVA) measurement with a Snellen chart, dilated pupil fundus examination with a 90-diopter (D) lens,

intraocular pressure measurement with the Goldmann applanation tonometer, central corneal thickness (CCT) measurement with ultrasonic pachymetry (Nidek UP-1000; Nidek Co., Ltd., Aichi, Japan), and axial eye length measurement with the Echoscan US 800 system (Nidek Co. Ltd, Aichi, Japan).

Inclusion criteria were no history of ocular disease or surgery. Exclusion criteria were age < 18 years, current systemic disease such as diabetes or hypertension; a history of retinal disease, glaucoma, intraocular surgery, laser treatment, ocular trauma, or any ocular inflammation; refractive values above ± 1.50 D, a corneal opacity, cataract, and unstable fixation. Subjects with a history of using medication that could affect ocular blood flow (analgesics, decongestants, or antihistamines) in the last 3 months, and underweight (BMI ≤ 18.5) or morbidly obese (BMI ≥ 40) cases were also not included in the present study. Similarly, subjects with a glycated hemoglobin (Hba1c) level above 6% were excluded.

The choroidal thickness measurement was performed with the EDI mode of the SD-OCT (3D OCT-2000, Topcon, Japan) device following pupil dilatation. The subfoveal macular thickness (CMT) was measured following EDI-OCT imaging in all subjects. The value in the central area from those defined in the Early Treatment Diabetic Retinopathy Study (ETDRS) map containing 9 areas covering an area of 6X6 mm^2 as obtained with the automatic software of the device was accepted as the CMT. The choroidal thickness was measured at the subfoveal area and at 500 µm intervals nasal and temporal to the fovea up to a distance of 1500 µm. All measurements were performed by the same clinician and at the same time (09.00–12.00) to decrease the effect of diurnal fluctuation. Sections with a signal power index below 6/10 were not included in the evaluation. The choroidal thickness measurement was performed manually at different times by two independent physicians (MT, NA) and on masked groups at the outer border of the retinal pigment epithelium hyperreflectivity and the internal border of the choroid-sclera junction using the measurement tool of the software. The measurements were repeated when there was a difference of more than 10 µm between two measurements.

Retrobulbar blood flow was measured with the 10 MHz linear probe of the color Doppler ultrasonography device (Toshiba Aplio 500, Tokyo, Japan) by the same radiologist in all cases. The measurements were performed with the patient in the supine position and the eyes closed. Excessive pressure on the eye was avoided during the measurements to prevent artifact formation. An evaluation was performed with the B-mode after applying methylcellulose gel on the eyelids. The eye was screened in the transaxial, sagittal and oblique planes in the grayscale mode. The color Doppler mode was then used. Color coding of the arterial and venous structure localization was performed with the color Doppler mode. The CRA and OA of the eye to be evaluated was sampled with a Doppler angle of 30–60 degrees. The peak systolic velocity (PSV), end diastolic velocity (EDV), time-averaged velocity (TAV), resistive index (RI) [RI=(PSV-EDV)/PSV], and pulsatility index (PI) [PI=(PSV-EDV)/TAV] values were recorded from the CRA and OA. All the measurements of the same patient were taken on the same day.

Statistical Analysis

Statistical analysis was performed using the SPSS software for Windows, version 22 (SPSS Inc., Chicago, IL, USA). The continuous variables were reported as mean ± standard deviation (SD) while the categorical variables were summarized with the use of frequencies. The normality of all data samples was checked with the Kolmogorov–Smirnov test. Only the right eye values were used for statistical purposes. Comparisons of the parametric values among the groups were performed with One-Way ANOVA. Comparisons of the nonparametric values among the groups were performed with the Kruskal-Wallis test. Tukey HSD and the Bonferroni-adjusted Mann-Whitney U-test were used as a post-hoc test for multiple comparisons between the groups. The Pearson test and Spearman rank test were used to investigate any relationship between the ocular hemodynamic parameters and the BMI or IOP. A two-tailed p value < 0.05 was considered significant.

Results

The 102 eyes of 102 female patients were included in the study. The mean age was 33.6 ± 8.1 years for group 1 (n = 32), 32.7 ± 7.6 for group 2 (n = 35), and 35.7 ± 9.2 for group 3 (n = 35). There was no significant difference between the groups for age, CCT values, refractive errors, and axial length (p = 0.316, p = 0.751, p = 0.976, p = 0.877, respectively). The mean IOP value was 12.4 ± 1.7 mmHg in group 1, 16.5 ± 1.5 mmHg in group 2, and 17.6 ± 2.1 mmHg in group 3. There was a significant difference between the groups in terms of the mean IOP values (Bonferroni-adjusted Mann-Whitney U-test, p < 0.001 between group 1 and 2, p < 0.001 between group 1 and 3, p = 0.007 between group 2 and 3). While the mean IOP values were significantly different between the groups, they were highest in group 3 and lowest in group 1. The demographic clinical characteristics of the groups are shown in table 1.

There was no statistically significant difference in subfoveal macular thickness between the three groups (p = 0.383). However, the choroidal thickness was significantly lower in groups 2 and 3 than in group 1 (p < 0.001) at all measurement points. Furthermore, the mean choroidal thickness was significantly lower in group 3 than in group 2 at FCT, N500, T500 and T1000 (p = 0.001, p = 0.006, p = 0.006, p = 0.005, respectively) (Table 2).

Regarding the CRA parameters, the mean PSV and EDV values were significantly lower in group 2 and 3 than in group 1 (p < 0.001). The mean CRA PSV value was lowest in group 3 and highest in group 1. There was no significant difference between the mean CRA EDV values of group 2 and 3 (p = 0.063). There was no significant difference between the groups in terms of the CRA RI and PI values (p = 0.320, p = 0.292, respectively). Evaluation of the OA parameters revealed that the mean PSV and EDV values were significantly lower in group 3 than in group 1 (p < 0.001). The mean OA PSV value was also significantly lower in group 3 than in group 2 (p < 0.001). However, these parameters were not significantly different between group 1 and 2. In addition, no significant difference was found between the groups in terms of the OA RI and PI values (p = 0.471, p = 0.469, respectively) (Table 3).

A positive significant correlation was found between BMI and IOP (Pearson correlation test, r = 0.263, p = 0.028) (Fig. 1). Conversely, a negative significant correlation was found between choroidal thickness and

BMI at all measurement points except N1000. We also found a significant negative correlation between the CRA and OA PSV values and the BMI (Spearman correlation test, r=-0.515, p < 0.001; r=-0.566, p < 0.001) (Figs. 2 and 3, respectively). Table 4 summarizes the results of the correlation analysis between BMI and the other parameters.

Discussion

Several diseases such as systemic lupus erythematosus, rheumatoid arthritis, and obstructive apnea syndrome result in lower choroidal thickness that leads to microvascular changes in the background of chronic systemic inflammation [9–12]. Obesity is known to be a cause of low-grade systemic or chronic inflammation resulting in cytokine, adipokine, and chemokine release [13]. The inflammatory mediators secreted to the blood in obese patients are believed to increase oxidative stress and hypoxia, and the accompanying chronic low-grade inflammation creates a predisposition for vascular endothelial damage and microvascular changes, as in other systemic disorders [14–16]. We similarly aimed to evaluate the ocular perfusion by investigating both the retrobulbar blood flow and choroidal circulation in order to determine microvascular changes in the current study. We found decreased ocular perfusion in obese patients, as indicated by both the decreased retrobulbar ocular blood flow and lower choroidal thickness.

The hemodynamic abnormalities in the retrobulbar circulation were evaluated with CDU. Impaired ocular perfusion is reflected by low PSV and EDV values while the RI and PI parameters indicate vascular resistance. However, there is an acceptance of the fact that RI is more reliable to determine resistance in small diameter vessels such as the retrobulbar vessels while PI shows the resistance for large diameter vessels [17]. The more obese (group 3) individuals had lower CRA and OA PSV values than both the obese (group 2) and normal weight subjects. The CRA EDV values were significantly lower in each obese patient groups than in the healthy group while this was not statistically significantly different between each obese groups. In addition, the OA EDV values were lower in the more obese group but showed no statistically significant difference between the obese groups while showing a statistically significant difference between the more obese group and the healthy group. No statistically significant difference was found between the groups for the vascular index parameters of the OA or CRA. High vascular resistance can result in decreased PSV and EDV values. However, we found reduced PSV and EDV values in obese patients without a change in vascular resistance, including the RI and PI values.

Ocular blood flow changes are correlated with the amount of retrobulbar adipose tissue. Another study has reported significantly decreased IOP levels and increased OA PSV and EDV values in the postoperative period after bariatric surgery related to the decreased BMI values in morbidly obese patients [6]. Lopez et al. have evaluated the effects of decompression surgery on retrobulbar blood flow in patients with Graves' ophthalmopathy and found a significant decrease in the RI values of the CRA and OA and increased PSV and EDV values of the OA after decompression surgery [18]. We could therefore speculate that increased severity of obesity leads to a change in the vascular resistance and OA flow parameters in parallel to the increase in the retrobulbar adipose tissue and that it can also lead to decreased ocular perfusion including the OA parameters. When we compare the morbid obese studies'

results with this current study, we observed that the CRA-PSV tends to be the more affected subparameter in relation to the severity of the obesity among the retrobulbar blood flow parameters and without a vascular resistance change in less obese cases. Similarly, another study has found a decrease only in the OA PSV and EDV values together with decreased CRA PI in morbidly obese patients [7]. On the other hand, the elevated blood cell count, hemoglobin and hematocrit values in obese patients result in an increase in the blood viscosity [19]. There could therefore be another explanation for the potentially decreased retrobulbar ocular perfusion with the increased viscosity caused by the increased hematocrit values resulting in a decreased flow rate in the vessels. The retina and optic nerve head vessels also have an autoregulation system that enables the maintenance of blood flow velocity even when the perfusion pressure is changed. We monitored changes in both the OA and CRA parameters in this study while other studies on morbidly obese patients have focused only on the OA parameter changes [6, 7]. It is possible that autoregulatory mechanisms become effective in protecting the retinal arteriole perfusion when the OA velocity decreases in association with the increasing retrobulbar fat tissue in the morbidly obese.

The choroidal thickness measurements were evaluated in the current study after making sure the groups were similar as regards any factors that could influence the measurement results such as age, gender, and axial length. The measurements were performed at the same time of the day to avoid any effect of the diurnal variation. The choroidal thickness values were found to be significantly lower in the two obese groups compared to the group with normal BMI for all the measurement points. In addition, the choroidal thickness was statistically significantly lower at the FCT, N500, T500, and T1000 measurement points in the BMI > 35 group compared to the BMI 30 to 35 group. A statistically significant negative correlation was found between the choroidal thickness and the BMI, FCT, N500, N1000, T500, T1000, and T1500 values. Our results are consistent with other studies in the literature [20, 21].

We found a decreased blood flow rate as indicated by our results related to both the retrobulbar and choroidal circulation in this study. The ciliary artery, a branch of the ophthalmic artery, plays a role in the choroidal circulation, and any ophthalmic artery velocity decrease could therefore indicate choroidal circulation changes. We similarly found significantly decreased OA PSV and EDV values in the obese group compared to the healthy group and supported this finding with a decreased choroidal volume in the two obese groups.

Several studies have reviewed the underlying mechanisms of the microvascular changes as related to obesity. The choroidal blood flow decreases with the activation of the choroidal circulation-related sympathetic efferent nerves and the secretion of noradrenaline, while increasing with NO secretion by the parasympathetic efferent nerves, both under the regulation of the autonomic nervous system [22]. The level of nitrous oxide (NO), a vasodilator molecule of endothelial origin that regulates the ocular blood flow and has a positive effect on IOP regulation, is low in obese patients [23, 24], while the level of vasoconstrictor molecules such as endothelin-1 (ET-1) and Angiotensin-II (Ang-II) have been found to increase in the serum in correlation with the BMI [25, 26]. We therefore believe the decreased thickness of the choroid that is rich in vascular supply in our cases is due to the balance between the vasodilator and vasoconstrictor agents shifting towards vasoconstriction.

The IOP was found to be statistically significantly high in the obese patients compared to the control group in this study (although still within the normal range) and there was also a statistically significant positive correlation between the BMI and the IOP. These results are consistent with the literature [27–29]. The IOP elevation in obese patients is explained with vascular and mechanical mechanisms. Accordingly, the increased IOP in these patients has been associated with increased oxidative stress due to the hyperleptinemia [30] that damages the trabecular meshwork [31], and the increased episcleral venous pressure related to the increased orbital fat mass [28] and resultant decreased aqueous outflow [32]. The Beaver Dam Eye study group has reported an increased IOP value in correlation with an increased BMI value [33]. Obesity has been found to be an independent risk factor in IOP elevation [33, 34]. Similarly, we encountered IOP elevation that was parallel to the increased BMI in obese patients in this study.

Evaluation of our results in the light of this information showed that both the retrobulbar ocular perfusion and the choroidal vascular perfusion could decrease in correlation with the severity of the obesity as a result of the increased inflammatory mediators related to the increased adipose tissue, the vascular endothelial dysfunction developing in the presence of increased oxidative stress and hypoxia; the elevated blood cell count, hemoglobin and hematocrit values; and the shift in the balance between the vasodilator and vasoconstrictor agents towards vasoconstriction.

Our study had various limitations. The first one was the small size of our groups. Another limitation was the lack of information on the obesity duration of the subjects and the blood levels of the inflammatory cytokines named adipokines.

In conclusion, we found that obese patients had higher IOP values while the choroidal thickness and the CRA and OA PSV and EDV values were lower compared to the control group. This indicates decreased retrobulbar and ocular blood flow with an effect on the vascular perfusion. We also found decreased choroidal thickness together with decreased CRA and OA PSV values as the severity of the obesity increased. The results indicate that obesity can create a suitable background for ocular pathologies by causing microvascular changes as a result of both the increase in IOP and the decrease in the retrobulbar and choroidal blood flow.

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Tables

Table 1. The demographic and clinical characteristics of the subjects

Parameters	Group 1 (n=32)	Group 2 (n=35)	Group 3 (n=35)	P
Age, years	33.6±8.1	32.7±7.6	35.7±9.2	0.316*
IOP (mmHg) <0.001**	12.4±1.7	16.5±1.5	17.6±2.1	
CCT (µm)	545.6±17.3	543.8±19.2	546.2±20	0.877*
Refractive error, D	-0.05±0.5	0.02±0.04	0.02±0.6	0.976**
Axial length, (mm)	22.2±0.9	22±1.05	22.1±0.7	0.751**
BMI (kg/m^2) <0.001**	21.6±1.7	32.7±1.5	37.6±1.3	

D: Diopter, *: One-WAY ANOVA test , **: Kruskal-Wallis test, IOP: Intraocular pressure, CCT: Central corneal thickness, BMI: Body mass index

Table 2. Comparison central macular thickness and choroidal thickness measurements between groups

Parameters (min-max)	Group 1 (n=32)	Group 2 (n=35)	Group 3 (n=35)	p value	Adjusted p value
CMT (µm)	218.8±10.2 (204 to 242)	215.6±10.1 (200 to 237)	218.6±11.1 (203 to 249)	0.383*	---
FCT (µm)	361.5±13.5 (335 to 399)	319.8±13.5 (295 to 346)	308.7±14.5 (290 to 346)	**<0.001****	**<0.001[1], <0.001[2], 0.001[3, a]**
N 500 µm	351.8±14.4 (325 to 380)	308.7±12.4 (275 to 333)	301±14.6 (280 to 334)	**<0.001****	**<0.001[1], <0.001[2], 0.006[3, a]**
N 1000 µm	343.5±12.6 (318 to 364)	301.9±12.1 (269 to 328)	297.9±15.9 (275 to 328)	**<0.001****	**<0.001[1], <0.001[2],** 0.077[3, a]
N 1500 µm	335.68±13.78 (310-370)	294.94±17.60 (233-328)	292.14±19.63 (246-340)	**<0.001****	**<0.001[1], <0.001[2],** 0.178[3, a]
T 500 µm	356.1±15 (329-399)	314.8±13.4 (285-339)	305±15.7 (275-340)	**<0.001***	**<0.001[1], <0.001[2], 0.006[3, b]**
T 1000 µm	351.4±16.7 (311-387)	309.4±11.1 (283-328)	302±15.88 (269-340)	**<0.001****	**<0.001[1], <0.001[2], 0.005[3, a]**
T 1500 µm	346.5±16.4 (318-399)	305.5±11.6 (275-322)	298.5±16.5 (272-341)	**<0.001****	**<0.001[1], <0.001[2],** 0.017[3, a]

CMT: Central macular thickness, FCT: Foveal choroidal thickness, N: Nasal T: Temporal, *: One-WAY ANOVA test, **: Kruskal-Wallis test ($p<0.05$), ($p<0.016$), [a] : Bonferroni-adjusted Kruskal-Wallis test , [b]:

posthoc Tukey HSD (p<0.016), [1]: P value between Group 1 and Group 2, [2]: P value between Group 1 and Group 3, [3]: P value between Group 2 and Group 3. Boldfaced values are statistically significant.

Table 3. Comparison of color Doppler ultrasonography parameters between the groups

Parameters	Group 1 (n=32)	Group 2 (n=35)	Group 3 (n=35)	p* value	Bonferroni-adjusted p value**
CRA PSV (cm/s)	19.9±3.1 (11.5 to 24.6)	15.9±4.1 (8.7 to 23.5)	12.3±2.5 (7.3 to 16.36)	**<0.001**	**<0.001[1], <0.001[2], <0.001[3]**
CRA EDV (cm/s)	6.6±1.5 (3.7 to 9.1)	4.8±1.6 (2 to 9.4)	4.3±1.6 (2.3 to 7.63)	**<0.001**	**<0.001[1], <0.001[2]**, 0.063[3]
CRA RI	0.6±0.1 (0.57 to 0.79)	0.6±0.1 (0.52 to 0.82)	0.6±0.1 (0.42 to 0.80)	0.320	---
CRA PI	1.1±0.2 (0.78 to 1.45)	1.2±0.3 (0.79 to 1.72)	1.1±0.3 (0.61 to 1.72)	0.292	---
OA PSV (cm/s)	44.6±5.2 (37 to 56.4)	43.8±4.4 (31.60 to 50.60)	36.5±5.9 (20.92 to 45)	<0.001	0.920[1],**<0.001[2],<0.001[3]**
OA EDV (cm/s)	12.5±3.1 (5.7 to 18.3)	11.1±2.6 (6.7 to 14.9)	9.7±2.9 (5.30 to 13.20)	<0.001	0.075[1],**<0.001[2]**,0.019[3]
OA RI	0.7±0.9 (0.54 to 0.89)	0.7±0.8 (0.56 to 0.87)	0.7±0.1 (0.44 to 0.87)	0.471	---
OA PI	1.43±0.4 (0.89 to 2.35)	1.5±0.3 (0.94 to 2.04)	1.5±0.3 (0.68 to 2.08)	0.469	---

CRA: central retinal artery , OA: ophthalmic artery, PSV: peak systolic velocity, EDV: end-diastolic velocity, RI: resistive index, PI: pulsatility index, *: Kruskal-Wallis test (p<0.05), **: Bonferroni-adjusted Kruskal-Wallis test (p<0.016), [1]: P value between Group 1 and Group 2, [2]: P value between Group 1 and Group 3, [3]: P value between Group 2 and Group 3. Boldfaced values are statistically significant (p<0.0166).

Table 4. The correlation analysis between body mass index and intraocular pressure, central macular thickness, choroidal thickness, and color Doppler ultrasonography parameters

Parameters	Correlation coefficient, r; p value
IOP	0.263; **0.028***
CMT	-0.010; 0.936**
FCT	-0.380; **0.001****
Nazal 500 µm	-0.319; **0.007****
Nazal 1000 µm	-0.255; **0.033****
Nazal 1500 µm	-0.208;0.084**
Temporal 500 µm	-0.361; **0.002****
Temporal 1000 µm	-0.344; **0.003****
Temporal 1500 µm	-0.318; **0.007****
CRA PSV	-0.515; **<0.001****
CRA EDV	-0.167; 0.167**
CRA RI	-0.301; **0.011***
CRA PI	-0.087; 0.473**
OA PSV	-0.566; **<0.001****
OA EDV	-0.165; 0.172**
OA RI	-0.218; 0.070**
OA PI	-0.74; 0.541**

IOP: Intraocular pressure, CMT: Central macular thickness, FCT: Foveal choroidal thickness, CRA: Central retinal artery, OA: Ophthalmic artery, PSV: Peak systolic velocity, EDV: End-diastolic velocity, RI: Resistive index, PI: Pulsatility index, *:Pearson correlation test, **: Spearman correlation test. Boldfaced values are statistically significant ($p<0.05$).

Figures

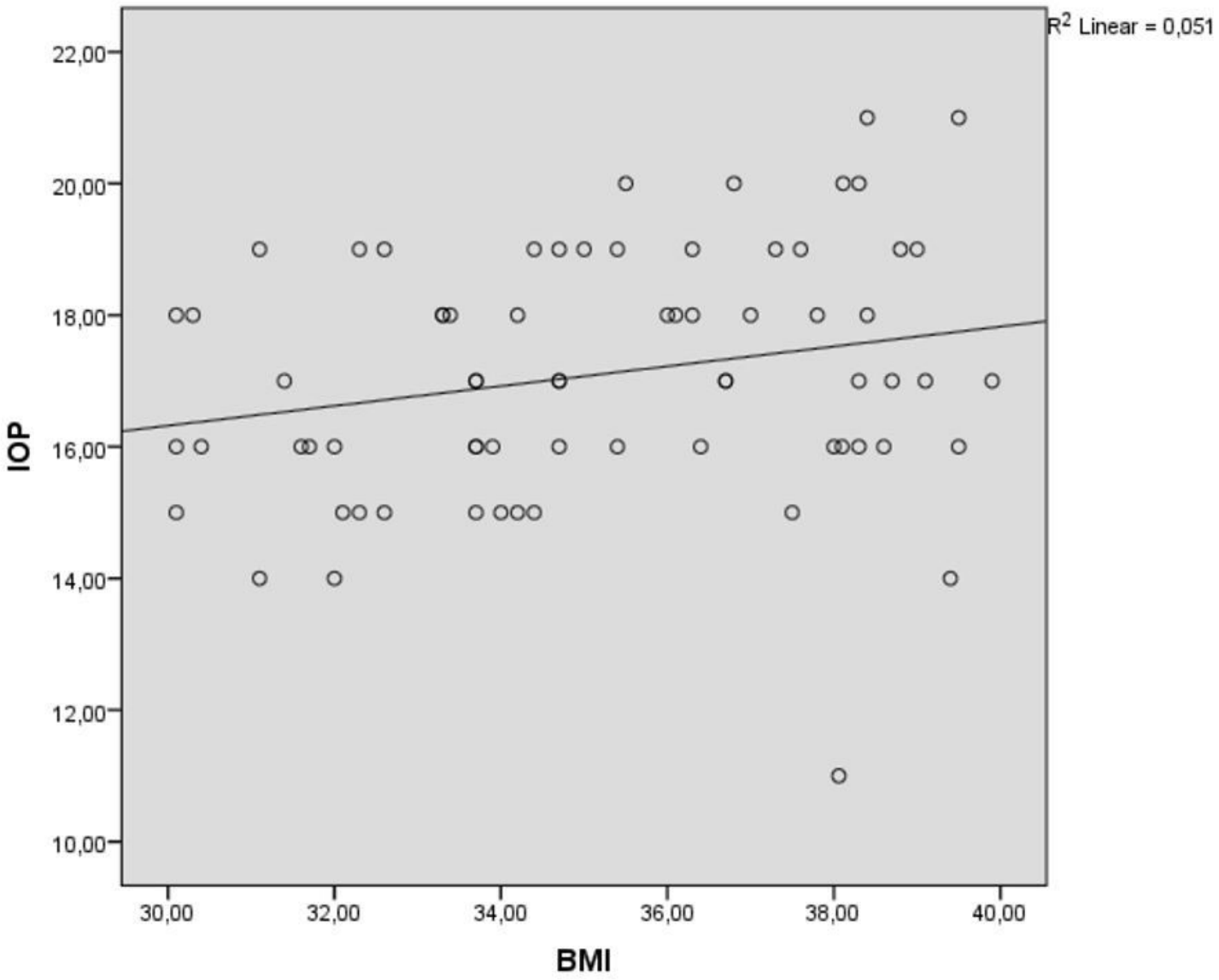

Figure 1

Positive correlation between body mass index and intraocular pressure (Pearson correlation test; p=0.028, r=0.263)

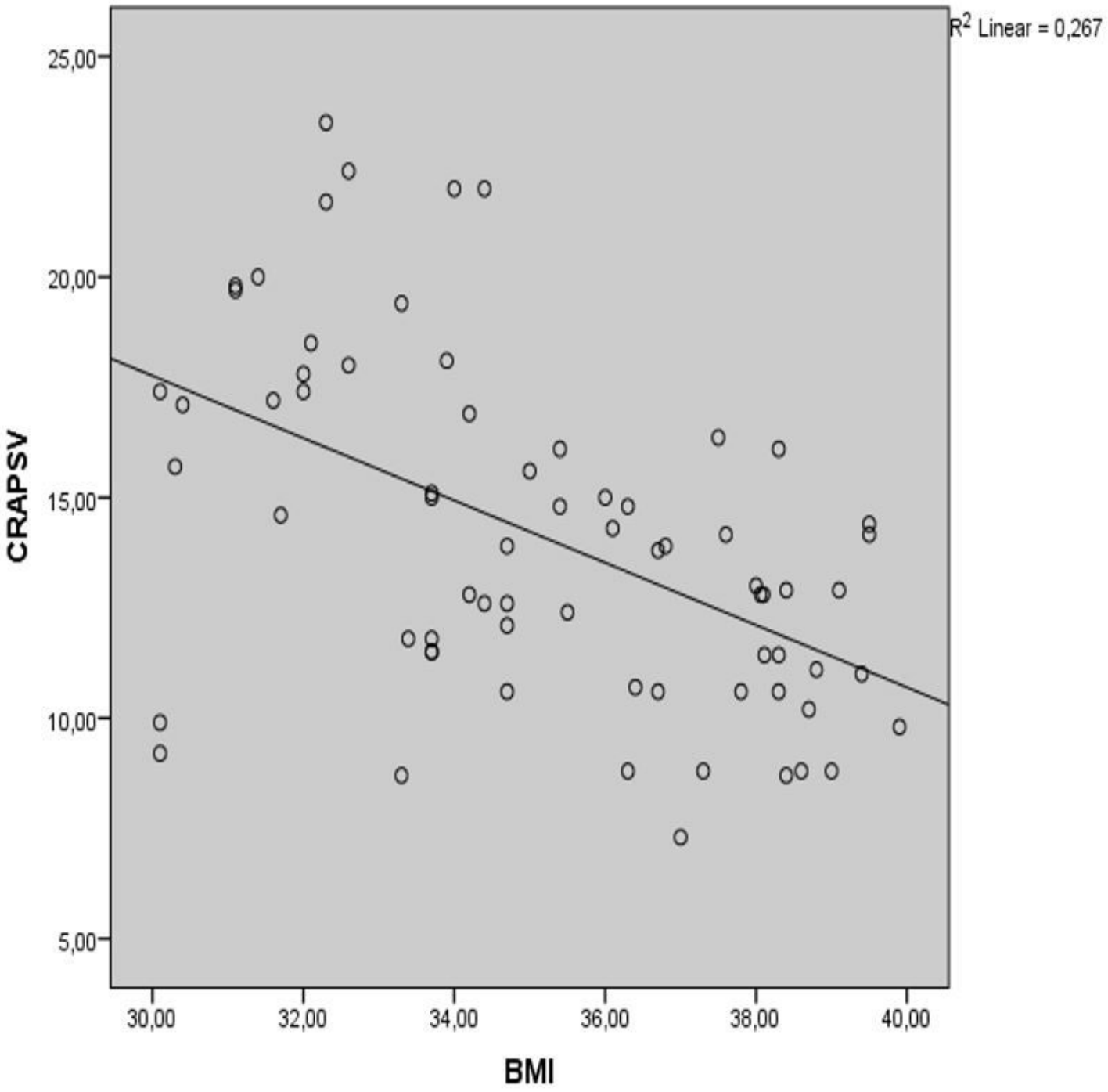

Figure 2

Negative correlation between body mass index and central retinal artery peak systolic velocity (Spearman correlation test; p= <0.001, r= -0.515)

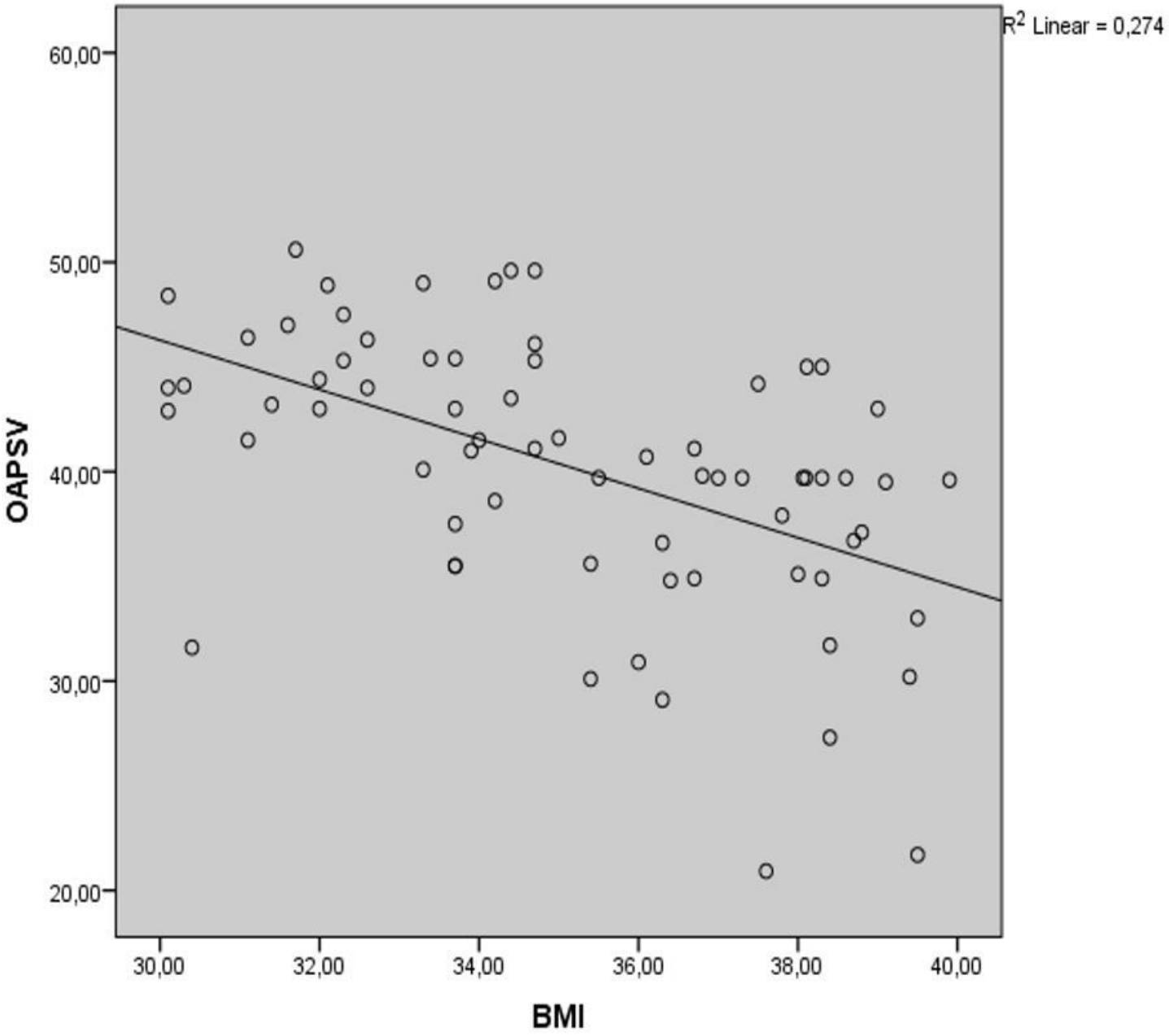

Figure 3

Negative correlation between body mass index and ophthalmic artery peak systolic velocity (Spearman correlation test; p= <0.001, r= -0.566)