Arabi *et al. BMC Ophthalmology* (2025) 25:118
https://doi.org/10.1186/s12886-025-03942-y

BMC Ophthalmology

RESEARCH Open Access

Association of childhood obesity on retinal microvasculature and the role of biochemical markers for its early detection

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Abstract

Background Childhood obesity is a growing public health concern, associated with several systemic disorders including changes in retinal microvasculature. This study aims to assess the relationship between body composition, biochemical markers, and retinal microvascular changes in obese children.

Methods In this cross-sectional study, 45 overweight and obese children and 46 age- and sex-matched healthy individuals were evaluated. In addition to physical examination, anthropometric measurements were obtained using a body composition analyzer. A comprehensive ophthalmic assessment was conducted for all participants, which included advanced optical biometry, autorefractometry, visual acuity testing, and slit-lamp examination. Retinal microvasculature was assessed using optical coherence tomography angiography (OCT-A). Biochemical markers, including lipid profile, liver function tests, and CRP (as marker of inflammation), were also analyzed.

Results The mean ages were 10.18 and 9.40 years in the obese/overweight and normal weight groups, respectively. Increased foveal thickness ($p=0.04$) and foveal vessel density ($p=0.01$) in the superficial capillary plexus, and decreased vessel density in the inferior parafoveal region of the deep capillary plexus ($p=0.03$) were observed in obese/overweight children. Adjusted and crude regression analysis showed significant associations between body mass index, percent body fat, fasting blood glucose, and serum alanine transaminase levels with foveal vessel density, as well as between body mass index and serum triglycerides levels with foveal thickness.

Conclusions Our findings suggest that childhood obesity is associated with significant alterations in retinal microvasculature. We propose that retinal health assessments and biochemical evaluations be considered in the clinical management of obese children.

Keywords Childhood obesity, Optical coherence tomography angiography, Retinal vasculature, Retinopathy

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Introduction

Childhood obesity has become a major public health challenge in both developing and developed countries [1]. Currently, one-third of children and adolescents in the United States are classified as either overweight or obese [2]. The prevalence of obesity has risen over the past few decades, especially following the COVID-19 pandemic, which has been associated with increased rates of childhood obesity globally [3]. As obesity becomes more common, the prevalence of obesity-related diseases has also risen. Therefore, it is crucial for healthcare providers to identify obese children at early stages to provide necessary counseling and treatment. Furthermore, early detection of obesity-related diseases is essential. It has been demonstrated that childhood obesity is associated with a range of comorbidities, including cardiovascular, endocrine, gastrointestinal, neurologic, and psychosocial disorders [1].

Despite growing concerns over the increasing prevalence of childhood obesity, obesity-related ocular diseases in this population have not been sufficiently studied. Recent studies using optical coherence tomography angiography (OCT-A) have highlighted potential associations between childhood obesity and changes in the retinochoroidal microvasculature [4, 5]. This non-invasive imaging technique has emerged as a valuable tool for visualizing the microvasculature of the retina and choroid, enabling the identification of early alterations in the superficial capillary plexus (SCP), deep capillary plexus (DCP), choroid, and optic nerve head [6]. Notably, studies have reported increased macular vessel density in the foveal and parafoveal regions within the SCP and DCP in obese children [4, 5, 7]. In addition to vessel density, significant changes have also been observed in choroidal thickness at various measurement points and in the retinal nerve fiber layer (RNFL) thickness among children with obesity [8, 9]. Moreover, the central retinal venular equivalent (CRVE) and central retinal arteriolar equivalent (CRAE), which are standardized measures used to assess the average diameters of retinal venules and arterioles, were significantly altered in children with overweight and obesity [10, 11].

In addition to ocular comorbidities, studies have shown that the prevalence of metabolic syndrome increases with the severity of obesity in children. Elevated plasma levels of triglycerides, low-density lipoprotein (LDL), cholesterol, fasting blood glucose (FBG), and C-reactive protein (CRP) have been observed among obese children [12].

While valuable findings have been reported on the alterations in retinal microvasculature in children with obesity, our knowledge on this subject remains insufficient. Previous studies have been limited by small sample sizes or inadequate measurement of key variables. In this study, we addressed these gaps by using a body composition analyzer to accurately measure body mass index (BMI), percent body fat (PBF), and skeletal muscle index (SMI). Furthermore, we evaluated the SCP, DCP, RNFL, and ganglion cell complex (GCC) using OCT-A, as well as advanced optical biometry and refractometry techniques. To explore potential association between ocular findings and metabolic syndrome-related laboratory tests, we measured blood glucose level, lipid profiles, and other relevant biomarkers.

Methods

Study population

This cross-sectional study was conducted from July 2023 to August 2024 at Feiz eye hospital, affiliated with Isfahan University of Medical Sciences, Isfahan, Iran. Participants were selected from pediatric clinics during routine growth check-ups and subsequently referred to the hospital for further assessment. A total of 45 overweight and obese children aged 5 to 15 years were enrolled, along with 46 age- and sex-matched healthy children. Obesity status was determined based on the WHO 2007 growth reference for children aged 5–19 years, defining overweight as a BMI > 1 standard deviation (SD), and obesity as a BMI > 2 SD above the median for age and sex [13]. Participants were excluded from the study if they had any of the following conditions: amblyopia, history of ocular surgery or trauma, nystagmus, glaucoma, uveitis, strabismus or refractive error exceeding 2 diopters (D). In addition, children with known endocrine disorders, such as diabetes or hyperthyroidism/hypothyroidism and those with neurological, renal or immune diseases were also excluded. Participants with head or neck injuries that prevented proper positioning during examinations were further excluded from the study.

This study was approved by the Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran (ethical code: IR.ARI.MUI.REC.1402.148). Oral assent was obtained from children, and written informed consent was obtained from their parents or legal guardians. All procedures carried out in the study were conducted in line with the Declaration of Helsinki [14].

Anthropometric measurements

Anthropometric indices including weight, BMI, Body Fat Mass (BFM), Percent Body Fat (PBF) and Skeletal Muscle Index (SMI) were measured using InBody 270 body composition analyzer (InBodyUSA, Cerritos, CA). Weight was measured with the child standing upright, barefoot and in light clothing, with the scale placed on a flat, hard surface for accuracy. Measurements were recorded to the nearest 0.1 kg. Moreover, circumferences of the hip and waist were measured using a Seca 201 measuring tape (Seca GmbH & Co, Hamburg, Germany).

Ocular imaging and examination

All participants were subjected to a comprehensive ophthalmic assessment including advanced optical biometry, OCT-A, autorefractometry, visual acuity (VA) testing and slit-lamp examination.

Initially, all children were given a thorough examination of the anterior segment using a binocular slit-lamp (Haag-Streit AG, Köniz, Switzerland), and participants who showed signs of abnormalities, such as keratitis or conjunctivitis, were excluded from the study. Subsequently, visual acuity was assessed using the Tumbling E eye chart, with results converted to the logarithm of the minimum angle of resolution (logMAR) for standardized analysis. Refractive errors (sphere, cylinder and axis) were then measured by a Topcon KR-8900 autorefractometer (Topcon, Tokyo, Japan). Besides, given the potential influence of anterior segment ocular diseases such as keratoconus on OCT-A images [15], optical biometry parameters, including keratometry and axial length, were evaluated using the IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany), and participants with abnormal biometry values suggestive of keratoconus were excluded to minimize potential confounding effects on the OCT-A measurements.

OCT-A was performed on all participants by a single experienced technician using the Optovue AngioVue system (Optovue Inc., Fremont, CA) under standardized conditions. This device, with a scan rate of 70,000 A-Scan/Second, provides high-resolution (5 μm) imaging of the retinal microvasculature. A 6 × 6 mm scan centered on the fovea and a 4.5 × 4.5 mm scan centered on the optic nerve head (ONH) were performed on both eyes. The AngioVue software automatically segmented the retinal layers into the SCP and DCP. Quantitative assessments involved measuring vessel density and macular thickness through the foveal, parafoveal and perifoveal regions. Furthermore, peripapillary RNFL thickness was measured in the superior, inferior, nasal and temporal quadrants, as well as GCC and foveal avascular zone (FAZ) area. Figure 1 depicts OCT-A images.

Biochemical measurements

For biochemical analysis, 6 mL venous blood was drawn from children. All serum samples were analyzed for FBG, total cholesterol, triglycerides, LDL, alanine aminotransferase (ALT), complete blood count (CBC), Vitamin D (25-hydroxycholecalciferol), CRP, and total antioxidant capacity (TAC).

Covariate assessment

To account for potential confounding factors, such as physical activity and screen time [16], information on these variables was obtained from parents. Screen time was defined as the total time spent on electronic devices, including watching television, playing video games and using computers, tablets or smartphones. Parents were asked to report their children's average daily screen time over the past week. Physical activity was defined as any structured or unstructured exercise, sports or recreational activities involving moderate to vigorous physical exertion, such as running, swimming, cycling and also participation in sports clubs. Considering the potential influence of axial length on OCT-A parameters [17], we assessed optical biometry measurements and incorporated axial length as a covariate in our analysis regarding its potential confounding effects.

Statistical analysis

Analysis was performed using IBM SPSS statistics software (Version 25.0. IBM Corp, USA). Categorical (qualitative) variables are presented as percentages and continuous (quantitative) variables are shown as mean ± standard deviation (SD). The normality of the continuous data was assessed using the Kolmogorov–Smirnov (K–S) test; depending on the results, either Student's t-test or Mann-Whitney U test was applied. OCT-A was performed on both eyes of all participants, and the mean value for each parameter from both eyes was used in the analysis. Furthermore, adjusted and crude linear regression analysis was conducted to assess the significance of association between foveal parameters and biochemical parameters. A p-value of less than 0.05 was considered statistically significant.

Results

Patient characteristics

A total of 91 subjects were included in the final analysis, comprising 45 overweight/obese and 46 normal weight children. There were 50 (54.9%) males and 41 (45.1%) females in the study, with a mean age (years) of 9.78 (median: 10.00). There were no statistically significant differences in gender or age between two groups. Conversely, significant differences were observed regarding BMI ($p < 0.01$), PBF ($p < 0.01$) and waist-to-hip ratio (WHR; $p = 0.01$) between groups. While no significant difference was observed in screen time ($p = 0.09$), the normal weight group had significantly higher physical activity time ($p < 0.01$). The demographic and anthropometric characteristics of the participants are presented in Table 1.

Biochemical profile

In the biochemical analysis, no significant differences were observed in the serum levels of FBG ($p = 0.26$), total cholesterol ($p = 0.14$), vitamin D ($p = 0.24$), or CBC parameters. However, the overweight/obese group had significantly higher levels of triglycerides ($p < 0.01$), LDL ($p = 0.01$), ALT ($p < 0.01$), CRP ($p < 0.01$), and TAC

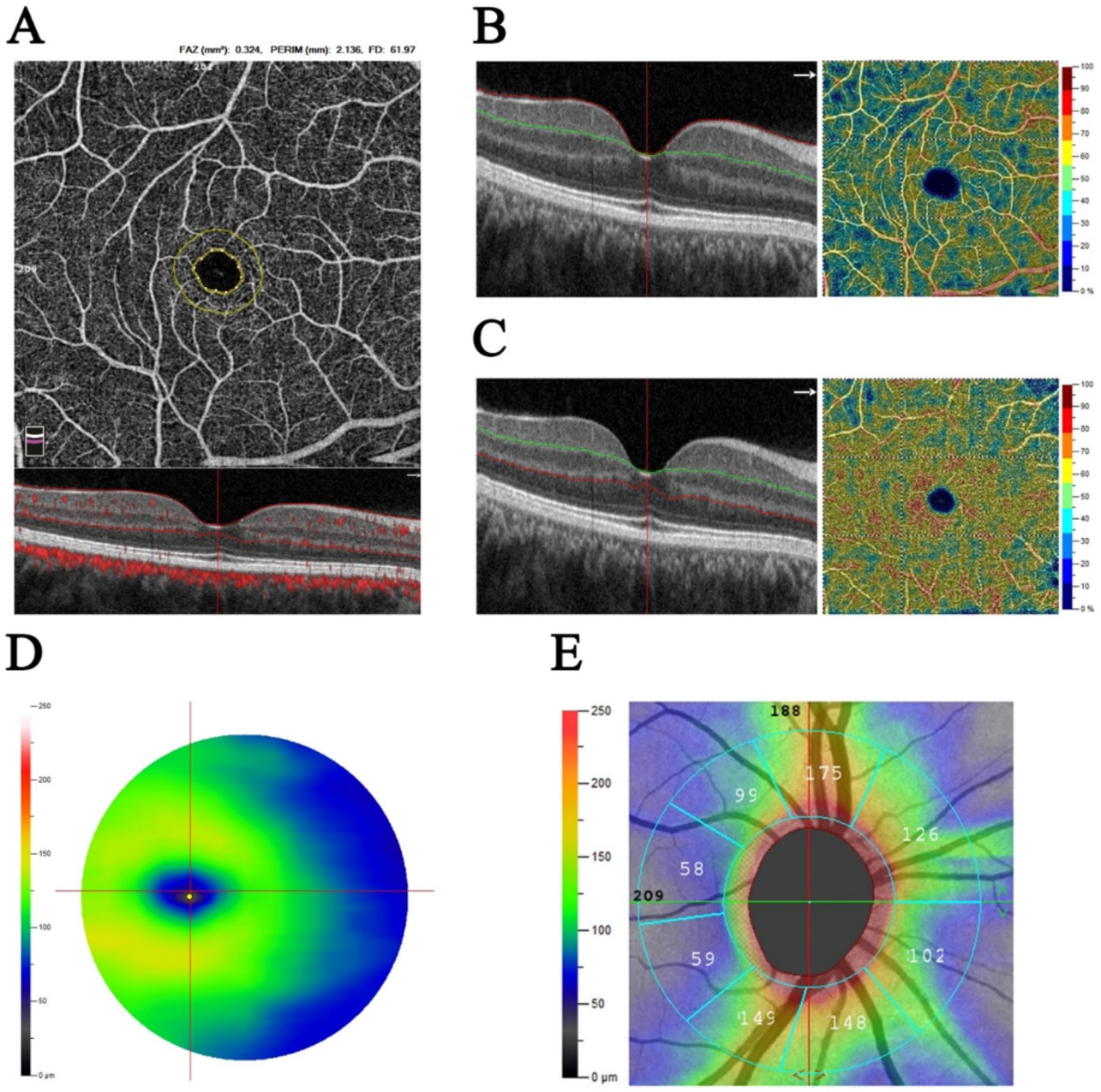

Fig. 1 Illustration of OCT-A images: (**A**) Foveal avascular zone (FAZ), (**B**) Superficial capillary plexus (SCP) vessel density, (**C**) Deep capillary plexus (DCP) vessel density, (**D**) Ganglion cell complex (GCC) thickness map, and (**E**) Peripapillary retinal nerve fiber layer (RNFL) thickness

($p = 0.04$) compared to normal weight group. The biochemical profile results are summarized in Table 1.

Ocular imaging outcomes

All participants were subjected to a comprehensive ophthalmic assessment. No statistically significant differences were observed in uncorrected visual acuity (UCVA) between the groups (OD: $p = 0.19$, OS: $p = 0.63$). Similarly, no significant differences were found in autorefractometry parameters (sphere, cylinder, and spherical equivalent) as well as biometric parameters. The biometric and refractive parameters of the groups are presented in additional file 1.

The whole image SCP vessel density was 50.97 ± 3.09 and 50.27 ± 2.25 in the obese/overweight and normal weight groups, respectively ($p = 0.24$). However, obese children were found to have a significantly higher SCP vessel density in the foveal Sect. (24.29 ± 5.44 vs. 21.51 ± 4.62, $p = 0.01$), as well as the superior perifoveal region (51.67 ± 3.86 vs. 50.46 ± 3.09, $p = 0.04$). No

Table 1 Demographic, anthropometric and biochemical characteristics of participants

Variable	Obese/overweight group *n* = 45	Normal weight group *n* = 46	*p*-value
a. Demographic and anthropometric characteristics			
Gender, *n* (%)			0.83
Male	24 (53.3)	26 (56.5)	
Female	21 (46.7)	20 (43.5)	
Age (years), Mean ± SD (Median)	10.18 ± 3.07 (10.00)	9.40 ± 2.87 (9.50)	0.28
BMI, Mean ± SD	23.87 ± 4.15	16.29 ± 2.13	**< 0.01**
Z-scores, *n* (%)			**< 0.01**
-2SD to + 1SD	-	46 (100)	
>+1SD	17 (37.8)	-	
>+2SD	28 (62.2)	-	
WHR, Mean ± SD	0.88 ± 0.09	0.83 ± 0.06	**0.01**
PBF, Mean ± SD	37.40 ± 6.77	21.25 ± 5.69	**< 0.01**
SMI, Mean ± SD	5.18 ± 1.34	3.75 ± 1.33	**< 0.01**
Screen Time (min/day), Mean ± SD	260 ± 113	218 ± 115	0.09
Activity Time (min/day), Mean ± SD (Median)	37 ± 21 (30)	78 ± 36 (60)	**< 0.01**
b. Biochemical profile			
FBG, md/dL, Mean ± SD	94.87 ± 7.66	93.07 ± 7.36	0.26
Total cholesterol, mg/dL	161.16 ± 27.08	152.68 ± 20.49	0.14
Triglyceride, mg/dL	129.00 ± 73.26	76.39 ± 32.22	**< 0.01**
LDL, mg/dL	83.93 ± 18.49	74.66 ± 14.41	**0.01**
ALT, U/L	23.91 ± 15.24	14.57 ± 4.19	**< 0.01**
WBC, 10^3/μL	7.86 ± 1.82	7.21 ± 1.30	0.06
RBC, 10^6/μL	5.34 ± 0.43	5.19 ± 0.41	0.11
Hb, g/dL	14.01 ± 1.06	13.87 ± 1.23	0.55
Vitamin D, ng/mL	30.46 ± 7.76	33.16 ± 9.61	0.24
CRP, mg/L	2.50 ± 2.79	0.84 ± 1.62	**< 0.01**
TAC, nmol/mL	235.67 ± 43.32	215.30 ± 48.95	**0.04**

SD, Standard deviation; BMI, Body mass index; WHR, waist-to-hip ratio; PBF, Percent body fat; SMI, Skeletal muscle index; FBG, Fasting blood glucose; LDL, Low-density lipoprotein; ALT, Alanine transaminase; WBC, White blood cells; RBC, Red blood cells; Hb, Hemoglobin; CRP, C-reactive protein; TAC, Total antioxidant capacity

significant differences in vessel density were observed in other SCP sections.

In the DCP, no significant differences were observed in vessel density across the whole image ($p = 0.28$), as well as in the foveal and perifoveal regions. However, obese children showed a significantly lower vessel density in the inferior parafoveal region ($p = 0.03$). Furthermore, macular thickness was measured using OCT-A, and it revealed that obese/overweight children had significantly higher foveal thickness compared to normal weight participants (243.65 ± 18.46 vs. 235.94 ± 14.04, $p = 0.04$). Detailed results for SCP and DCP vessel density, along with macular thickness, are provided in Table 2.

Additional OCT-A parameters were also assessed, and no statistically significant differences were found between the groups for GCC thickness, peripapillary RNFL thickness, or FAZ area. Detailed information on these variables is presented in additional file 2.

Table 2 Findings of retinal parameters by OCT-A: SCP and DCP vessel density, macular thickness

Section	Obese/overweight group *n* = 45	Normal weight group *n* = 46	*p*-value
a. SCP vessel density			
Whole, %, Mean ± SD	50.97 ± 3.09	50.27 ± 2.25	0.24
Fovea	24.29 ± 5.44	21.51 ± 4.62	**0.01**
Parafovea	53.18 ± 3.82	53.06 ± 3.07	0.35
- Temporal	52.38 ± 4.52	52.91 ± 3.65	0.81
- Superior	53.97 ± 4.46	53.06 ± 3.87	0.17
- Nasal	52.11 ± 4.53	52.15 ± 3.71	0.96
- Inferior	54.14 ± 3.70	54.03 ± 3.19	0.43
Perifovea	51.96 ± 3.15	51.28 ± 2.40	0.15
- Temporal	49.20 ± 4.20	49.28 ± 3.42	0.52
- Superior	51.67 ± 3.86	50.46 ± 3.09	**0.04**
- Nasal	54.69 ± 3.01	53.95 ± 2.89	0.25
- Inferior	52.15 ± 3.66	51.40 ± 2.78	0.29
b. DCP vessel density			
Whole, %, Mean ± SD	47.54 ± 4.89	48.63 ± 4.50	0.28
Fovea	40.78 ± 6.64	40.10 ± 7.42	0.65
Parafovea	52.31 ± 3.89	53.79 ± 4.79	0.12
- Temporal	54.20 ± 3.87	54.63 ± 5.63	0.68
- Superior	51.13 ± 4.91	52.78 ± 5.37	0.14
- Nasal	53.39 ± 4.24	54.97 ± 6.10	0.16
- Inferior	50.53 ± 4.71	52.80 ± 5.06	**0.03**
Perifovea	48.35 ± 5.34	49.65 ± 4.65	0.23
- Temporal	50.87 ± 4.95	52.61 ± 4.85	0.10
- Superior	47.98 ± 6.39	48.54 ± 5.15	0.66
- Nasal	47.15 ± 5.65	48.34 ± 6.13	0.35
- Inferior	47.31 ± 6.22	49.25 ± 5.09	0.12
c. Macular thickness			
Whole, μm, Mean ± SD	284.88 ± 10.53	285.21 ± 11.08	0.89
Fovea	243.65 ± 18.46	235.94 ± 14.04	**0.04**
Parafovea	317.29 ± 13.74	317.34 ± 12.86	0.99
- Temporal	307.78 ± 14.00	309.51 ± 12.70	0.55
- Superior	323.03 ± 13.70	322.67 ± 13.03	0.90
- Nasal	319.20 ± 14.92	319.07 ± 13.21	0.96
- Inferior	319.31 ± 14.14	318.11 ± 14.12	0.69
Perifovea	283.82 ± 10.69	284.73 ± 11.65	0.71
- Temporal	270.35 ± 10.92	271.77 ± 11.29	0.55
- Superior	284.76 ± 10.96	286.82 ± 11.44	0.40
- Nasal	302.54 ± 13.39	302.70 ± 13.35	0.96
- Inferior	277.75 ± 10.65	277.73 ± 12.93	0.99

SD, Standard deviation; SCP, Superficial capillary plexus; DCP, Deep capillary plexus

Predictors of foveal parameters

A linear regression analysis was performed to assess the association between foveal parameters and anthropometric and biochemical variables. The adjusted analysis revealed that obesity, higher PBF, and elevated ALT and FBG levels were associated with higher SCP foveal vessel

density (Obesity: B = 3.19, SE = 1.23, 95% CI = 0.75–5.63, $p = 0.011$; PBF: B = 0.18, SE = 0.06, 95% CI = 0.06–0.31, $p = 0.003$; ALT: B = 0.12, SE = 0.05, 95% CI = 0.02–0.21, $p = 0.015$; FBG: B = 0.19, SE = 0.08, 95% CI = 0.04–0.36, $p = 0.016$). The adjusted and crude regression analysis on SCP foveal vessel density are presented in Table 3. Additional file (Figure) 3 illustrates the scatter plot with the regression line showing the association between PBF and SCP foveal vessel density. Moreover, obesity and higher triglyceride levels were found to be associated with increased foveal thickness (Obesity: B = 9.03, SE = 4.03, 95% CI = 1.01–17.06, $p = 0.028$; TG: B = 0.08, SE = 0.03, 95% CI = 0.02–0.15, $p = 0.008$). The adjusted and crude regression analysis on foveal thickness are presented in Table 4.

Discussion

In the present study, we found that childhood obesity is associated with significant alterations in retinal microvasculature. These alterations include increased or decreased vessel density and thickness in specific retinal regions, particularly in the foveal area. Furthermore, we demonstrated that metabolic syndrome-related biochemical parameters, such as elevated triglycerides and ALT levels, can be predictors of retinal health in obese children. This underscores the importance of monitoring metabolic indicators to identify children at risk of ocular complications associated with obesity.

Although the ocular effects of childhood obesity remain relatively underexplored, recent studies using advanced imaging techniques have provided valuable insights into the alterations in retinal microvasculature associated with pediatric obesity [18]. These findings highlight the potential impact of obesity on retinal health in children, emphasizing the importance of further investigation in this area. For instance, previous studies have demonstrated that childhood obesity is associated with alterations in retinal vessel caliber, characterized by narrower retinal arterioles (lower CRAE), wider retinal venules (higher CRVE), and a reduction in arteriolar-to-venular ratio (AVR) [11, 19, 20]. These vascular changes, which are associated with an increased risk of cardiovascular diseases, have been shown to be mitigated by physical activity [20–22].

OCT-A is an advanced imaging technique that provides a detailed evaluation of retinal microvasculature, including vessel density of the SCP and DCP, as well as retinal thickness. Thus far, a limited number of studies have used OCT-A to investigate retinal microvasculature among obese children [18].

In the current study, we found that obesity is associated with both increased and decreased vessel density in specific retinal regions. One of the key alterations

Table 3 Linear regression analysis predicting SCP foveal vessel density

Predictor Variable	β	SE	Standardized β	95.0% Confidence Interval for β	*R*	*p*-value
a. Crude model						
Obese/Overweight	2.78	1.09	0.27	0.61–4.95	0.268	**0.013**
PBF	0.14	0.05	0.27	0.03–0.25	0.274	**0.011**
TG	0.01	0.01	0.16	-0.01-0.03	0.157	0.153
LDL	0.02	0.03	0.06	-0.05-0.08	0.064	0.563
ALT	0.11	0.05	0.25	0.02–0.19	0.250	**0.022**
CRP	0.17	0.25	0.08	-0.31-0.66	0.078	0.482
TAC	0.01	0.01	0.08	-0.02-0.03	0.079	0.480
FBG	0.17	0.07	0.25	0.02–0.32	0.246	**0.024**
Vitamin D	0.08	0.07	0.03	-0.12-0.15	0.028	0.800
Total cholesterol	0.01	0.02	0.04	-0.04-0.06	0.042	0.702
b. Adjusted model*						
Obese/Overweight	3.19	1.23	0.30	0.75–5.63	0.320	**0.011**
PBF	0.18	0.06	0.36	0.06–0.31	0.357	**0.003**
TG	0.02	0.01	0.19	-0.01-0.04	0.242	0.105
LDL	0.01	0.04	0.05	-0.06-0.09	0.164	0.700
ALT	0.12	0.05	0.28	0.02–0.21	0.314	**0.015**
CRP	0.14	0.26	0.06	-0.38-0.66	0.170	0.587
TAC	0.01	0.01	0.08	-0.02-0.04	0.187	0.527
FBG	0.19	0.08	0.28	0.04–0.36	0.313	**0.016**
Vitamin D	0.02	0.07	0.03	-0.13-0.16	0.160	0.816
Total cholesterol	0.01	0.03	0.02	-0.05-0.06	0.159	0.887

SE, Standard error; PBF, Percent body fat; TG, Triglyceride, LDL, Low-density lipoprotein; ALT, Alanine transaminase; CRP, C-reactive protein; TAC, Total antioxidant capacity; FBG, Fasting blood glucose.

*Adjusted for age, sex, screen time, and axial length

Table 4 Linear regression analysis predicting foveal thickness

Predictor Variable	β	SE	Standardized β	95.0% Confidence Interval for β	*R*	*p*-value
a. Crude model						
Obese/Overweight	7.71	3.63	0.23	0.47–14.94	0.229	**0.037**
PBF	0.25	0.18	0.15	-0.11-0.61	0.153	0.168
TG	0.08	0.03	0.30	0.02–0.14	0.292	**0.008**
LDL	-0.01	0.11	-0.01	-0.23-0.21	0.012	0.916
ALT	0.20	0.15	0.15	-0.09-0.50	0.148	0.187
CRP	-0.13	0.80	-0.02	-1.73-1.45	0.019	0.867
TAC	0.07	0.04	0.19	-0.01-0.16	0.187	0.100
FBG	0.39	0.25	0.18	-0.10-0.89	0.176	0.116
Vitamin D	-0.33	0.22	-0.16	-0.76-0.12	0.163	0.145
Total cholesterol	-0.06	0.08	-0.08	-0.21-0.09	0.083	0.460
b. Adjusted model*						
Obese/Overweight	9.03	4.03	0.26	1.01–17.06	0.323	**0.028**
PBF	0.31	0.21	0.18	-0.10-0.71	0.266	0.140
TG	0.08	0.03	0.31	0.02–0.15	0.360	**0.008**
LDL	-0.02	0.12	-0.02	-0.25-0.22	0.200	0.888
ALT	0.20	0.16	0.15	-0.12-0.52	0.246	0.214
CRP	-0.34	0.84	-0.05	-2.02-1.33	0.205	0.685
TAC	0.06	0.05	0.15	-0.04-0.16	0.239	0.240
FBG	0.35	0.26	0.16	-0.17-0.88	0.251	0.185
Vitamin D	-0.33	0.24	-0.16	-0.81-0.13	0.257	0.158
Total cholesterol	-0.06	0.09	-0.09	-0.23-0.11	0.216	0.471

SE, Standard error; PBF, Percent body fat; TG, Triglyceride, LDL, Low-density lipoprotein; ALT, Alanine transaminase; CRP, C-reactive protein; TAC, Total antioxidant capacity; FBG, Fasting blood glucose.

*Adjusted for age, sex, screen time, and axial length

was observed in the SCP, in which obese children had significantly higher vessel density in the foveal section. This result corroborates the findings of previous studies that have reported increased foveal vessel density in obese children [4, 5]. Moreover, our results demonstrate that foveal changes were not limited to vessel density, as foveal thickness was also significantly increased in the obesity/overweight group. There is still no objective explanation for the changes in foveal vessel density and thickness observed in childhood obesity. However, our regression analysis revealed significant positive associations between levels of BMI, PBF, and ALT with foveal vessel density, as well as between BMI and triglyceride levels with foveal thickness. These findings are consistent with a study showing that children with retinopathy had significantly higher triglyceride levels, with a positive correlation identified between liver fibrosis and the severity of retinopathy. [23]. Apart from triglycerides, elevated levels of CRP in obese children have also been associated with alterations in retinal vessel diameter [18, 24]. In the present study, serum CRP levels were significantly higher in obese children; however, no significant association was found between CRP levels and changes in foveal vessel density or thickness.

In agreement with the previous studies demonstrating lower vessel density in the DCP among children with obesity [4], we observed a reduction in vessel density in the inferior parafoveal region of the DCP. While similar patterns of obesity-induced retinal microvascular changes have been reported, the underlying mechanisms remain poorly understood. However, existing literature suggests that obesity may significantly alter the choroidal layer, which plays a crucial role in supplying oxygen and nutrients to the outer layer of retina. Several studies have shown that children with obesity have reduced choroidal thickness (CT) compared to age-matched healthy controls [19, 25, 26]. It has been suggested that these alterations in CT may result from increased oxidative stress and obesity-related inflammatory factors [9]. In the present study, the serum level of TAC was significantly higher in children with obesity which could be compensatory response to higher levels of oxidative stress [27, 28]. Moreover, childhood obesity has been associated with impaired microvascular endothelial function and changes in ocular pulse amplitude (OPA) [29, 30].

Although the exact underlying mechanism of retinal microvascular alterations in children with obesity has not been sufficiently understood, it is our understanding that obesity profoundly impacts the vascular system, contributing to cardiovascular diseases through multiple pathways. One of the key consequences of obesity is vascular dysfunction, caused by chronic inflammation, oxidative stress, and endothelial impairment, which can lead to elevated blood pressure and atherosclerosis [31].

A meta-analysis has demonstrated that higher BMI in children is associated with narrower retinal arterioles and wider venules, with these changes intensified in the presence of elevated systolic and diastolic blood pressure [21]. These findings suggest that obesity and consequent hypertension contribute to early subclinical vascular impairments, which may increase the risk of cardiovascular diseases and retinal dysfunction later in life.

Furthermore, obesity has been shown to influence ocular hemodynamics, with studies reporting an association between childhood obesity and increased intraocular pressure, which may further contribute to retinal and optic nerve changes [18, 32, 33]. Despite these known associations, the precise pathophysiological mechanisms linking obesity to retinal alterations remain unclear and require further investigation in future research.

The detrimental consequences of obesity on retinal health have been previously reported in adults [34, 35]. However, based on both previous studies and the findings of the current study, it has become evident that obesity, even in its early stages, is detrimental to retinal health in children. Moreover, we found that systemic disorders, such as abnormal lipid profiles and liver function tests, are significantly associated with alterations in retinal parameters. A key strength of this study is the use of OCT-A which is an advanced imaging technique that provides high-resolution images. Furthermore, we evaluated the biochemical profiles of our patients, allowing us to explore potential associations between retinal alterations and systemic disorders. Using a body composition analyzer also enabled precise measurement of anthropometric variables, such as PBF, which was identified as an important predictor of foveal alterations.

While we provide evidence of obesity-induced retinal changes in children, this study has limitations. Firstly, cross-sectional study design limits our ability to detect longitudinal changes, underscoring the need for future longitudinal cohort studies. Secondly, including functional tests, such as electroretinography (ERG) or visual evoked potential (VEP), along with structural assessments would be beneficial in identifying early retinal dysfunction that cannot be assessed through imaging alone. Besides, genetic predispositions, including variations in genes associated with lipid metabolism, inflammation, and vascular development, may influence the impact of obesity on vascular health and retinal microvasculature [36, 37]. One limitation of this study is that we did not assess genetic factors, which could provide valuable insights into individual susceptibility. Future research is needed to explore these genetic influences and their potential role in obesity-related vascular changes. In addition to genetic factors, future studies should evaluate the potential impact of dietary intake on retinal health. The Food Frequency Questionnaire (FFQ) could be a useful tool for assessing calorie intake and overall diet quality [38]. Investigating the association between energy, fat, and sugar consumption and alterations in retinal microvasculature would provide valuable insights into the metabolic and nutritional influences on retinal vascular changes.

Conclusion

Our findings suggest that childhood obesity is associated with significant alterations in retinal vessel density and thickness. In addition, we demonstrated that biochemical markers such as lipid profiles and liver function tests can be used as predictor variables for these changes. We propose that retinal health assessments, in combination with biochemical evaluations, should be taken into consideration in the clinical management of obese children. Further longitudinal research is also needed to elucidate the long-term detrimental effects of obesity on ocular health.

Abbreviations

ALT	Alanine Aminotransferase
BFM	Body Fat Mass
BMI	Body Mass Index
CRAE	Central Retinal Arteriolar Equivalent
CRP	C-reactive protein
CRVE	Central Retinal Venular Equivalent
DCP	Deep Capillary Plexus
ERG	Electroretinography
FBG	Fasting Blood Glucose
FFQ	Food Frequency Questionnaire
LDL	Low-Density Lipoprotein
logMAR	Logarithm of the Minimum Angle of Resolution
OCT-A	Optical Coherence Tomography Angiography
PBF	Percent Body Fat
RNFL	Retinal Nerve Fiber Layer
SCP	Superficial Capillary Plexus
SD	Standard Deviation
SMI	Skeletal Muscle Index
TAC	Total Antioxidant Capacity
UCVA	Uncorrected Visual Acuity
VA	Visual Acuity
VEP	Visual Evoked Potential
WHO	World Health Organization

Supplementary information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-03942-y.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Acknowledgements

We would like to express our sincere gratitude to all participants and their families as well as the staff at Feiz eye hospital for their invaluable assistance throughout this study. We especially thank Dr. Ali Shahsavari for his indispensable assistance throughout the project.

Author contributions

S.A. drafted the original manuscript, performed the formal analysis, and prepared the figures. M.P. conceived the study, validated the findings, developed the methodology, and reviewed and edited the manuscript.

M.H.-B. reviewed and edited the manuscript and contributed to the investigation. M.Y. analyzed the data, validated the results, and reviewed and edited the manuscript. R.K. conceived the study, validated the findings, developed the methodology, and reviewed and edited the manuscript. All authors reviewed the manuscript.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This research was funded by Isfahan University of Medical Sciences.

Data availability
The datasets used and analyzed during the current study is not publicly available. The datasets used or analyzed during the current study is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran. (ethics code: IR.ARI.MUI.REC.1402.148). Oral assent was obtained from children, and written informed consent was obtained from all parents. All methods were carried out in line with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no conflict of interests.

Received: 8 December 2024 / Accepted: 24 February 2025
Published online: 10 March 2025

References

1. Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, et al. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. The New England journal of medicine. 2017;377(1):13–27.
2. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of Obesity and Severe Obesity in US Children, 1999–2016. Pediatrics. 2018;141(3).
3. Lange SJ, Kompaniyets L, Freedman DS, Kraus EM, Porter R, Blanck HM, et al. Longitudinal Trends in Body Mass Index Before and During the COVID-19 Pandemic Among Persons Aged 2–19 Years - United States, 2018–2020. MMWR Morbidity and mortality weekly report. 2021;70(37):1278-83.
4. Han S, Leng Z, Li X, Yan W, Shen S, Liu L, et al. Retinochoroidal microvascular changes in newly developed obese children: an optical coherence tomography angiography study. BMC ophthalmology. 2022;22(1):443.
5. Kurtul BE, Çakmak A, Elbeyli A, Karaaslan A, El Ç. Association of childhood obesity with retinal microvasculature and corneal endothelial cell morphology. Journal of pediatric endocrinology & metabolism: JPEM. 2021;34(2):171-6.
6. Spaide RF, Fujimoto JG, Waheed NK, Sadda SR, Staurenghi G. Optical coherence tomography angiography. Progress in retinal and eye research. 2018;64:1–55.
7. Dereli Can G, Kara Ö, Can ME. High body weight-related retinal vasculopathy in children with obesity. European journal of ophthalmology. 2021:11206721211006570.
8. Baran RT, Baran SO, Toraman NF, Filiz S, Demirbilek H. Evaluation of intraocular pressure and retinal nerve fiber layer, retinal ganglion cell, central macular thickness, and choroidal thickness using optical coherence tomography in obese children and healthy controls. Nigerian journal of clinical practice. 2019;22(4):539 – 45.
9. Bulus AD, Can ME, Baytaroglu A, Can GD, Cakmak HB, Andiran N. Choroidal Thickness in Childhood Obesity. Ophthalmic surgery, lasers & imaging retina. 2017;48(1):10 – 7.
10. Rijks J, Vreugdenhil A, Dorenbos E, Karnebeek K, Joris P, Berendschot T, et al. Characteristics of the retinal microvasculature in association with cardiovascular risk markers in children with overweight, obesity and morbid obesity. Scientific Reports. 2018;8(1):16952.
11. Van Aart CJ, Michels N, Sioen I, De Decker A, Nawrot TS, De Henauw S. Body fat evolution as predictor of retinal microvasculature in children. International journal of obesity (2005). 2017;41(4):527 – 32.
12. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the metabolic syndrome in children and adolescents. The New England journal of medicine. 2004;350(23):2362-74.
13. Jebeile H, Kelly AS, O'Malley G, Baur LA. Obesity in children and adolescents: epidemiology, causes, assessment, and management. The lancet Diabetes & endocrinology. 2022;10(5):351 – 65.
14. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. Jama. 2013;310(20):2191-4.
15. Leclaire MD, Storp JJ, Lahme L, Esser EL, Eter N, Alnawaiseh M. Reduced Retinal Blood Vessel Densities Measured by Optical Coherence Tomography Angiography in Keratoconus Patients Are Negatively Correlated with Keratoconus Severity. Diagnostics (Basel, Switzerland). 2024;14(7).
16. Gopinath B, Baur LA, Wang JJ, Hardy LL, Teber E, Kifley A, et al. Influence of physical activity and screen time on the retinal microvasculature in young children. Arteriosclerosis, thrombosis, and vascular biology. 2011;31(5):1233-9.
17. Park KS, Lim HB, Shin YI, Park GS, Lee WH, Kim JY. Effect of axial length on peripapillary microvasculature: An optical coherence tomography angiography study. PloS one. 2021;16(10):e0258479.
18. Dezor-Garus J, Niechciał E, Kędzia A, Gotz-Więckowska A. Obesity-induced ocular changes in children and adolescents: A review. Frontiers in pediatrics. 2023;11:1133965.
19. Erşan I, Battal F, Aylanç H, Kara S, Arikan S, Tekin M, et al. Noninvasive assessment of the retina and the choroid using enhanced-depth imaging optical coherence tomography shows microvascular impairments in childhood obesity. Journal of AAPOS: the official publication of the American Association for Pediatric Ophthalmology and Strabismus. 2016;20(1):58–62.
20. Ho A, Cheung CY, Wong JS, Zhang Y, Tang FY, Kam KW, et al. Independent and Synergistic Effects of High Blood Pressure and Obesity on Retinal Vasculature in Young Children: The Hong Kong Children Eye Study. Journal of the American Heart Association. 2021;10(3):e018485.
21. Köchli S, Endes K, Infanger D, Zahner L, Hanssen H. Obesity, Blood Pressure, and Retinal Vessels: A Meta-analysis. Pediatrics. 2018;141(6).
22. Sousa-Sá E, Zhang Z, Pereira JR, Wright IM, Okely AD, Santos R. Systematic review on retinal microvasculature, physical activity, sedentary behaviour and adiposity in children and adolescents. Acta paediatrica (Oslo, Norway: 1992). 2020;109(10):1956-73.
23. Liccardo D, Mosca A, Petroni S, Valente P, Giordano U, Mico AG, et al. The association between retinal microvascular changes, metabolic risk factors, and liver histology in pediatric patients with non-alcoholic fatty liver disease (NAFLD). Journal of gastroenterology. 2015;50(8):903 – 12.
24. Hanssen H, Siegrist M, Neidig M, Renner A, Birzele P, Siclovan A, et al. Retinal vessel diameter, obesity and metabolic risk factors in school children (Juven-TUM 3). Atherosclerosis. 2012;221(1):242-8.
25. Teberik K, Eski MT, Doğan S, Pehlivan M, Kaya M. Ocular abnormalities in morbid obesity. Arquivos brasileiros de oftalmologia. 2019;82(1):6–11.
26. Topcu-Yilmaz P, Akyurek N, Erdogan E. The effect of obesity and insulin resistance on macular choroidal thickness in a pediatric population as assessed by enhanced depth imaging optical coherence tomography. Journal of pediatric endocrinology & metabolism: JPEM. 2018;31(8):855 – 60.
27. Anaya-Morua W, Villafan-Bernal JR, Ramírez-Moreno E, García-Ortiz H, Martínez-Portilla RJ, Contreras-Cubas C, et al. Total Antioxidant Capacity in Obese and Non-Obese Subjects and Its Association with Anthropo-Metabolic Markers: Systematic Review and Meta-Analysis. Antioxidants (Basel, Switzerland). 2023;12(8).
28. Marrocco I, Altieri F, Peluso I. Measurement and Clinical Significance of Biomarkers of Oxidative Stress in Humans. Oxidative medicine and cellular longevity. 2017;2017:6501046.
29. Aydemir GA, Aydemir E, Asik A, Bolu S. Changes in ocular pulse amplitude and choroidal thickness in childhood obesity patients with and without insulin resistance. European journal of ophthalmology. 2022;32(4):2018-25.
30. Hedvall Kallerman P, Hagman E, Edstedt Bonamy AK, Zemack H, Marcus C, Norman M, et al. Obese children without comorbidities have impaired microvascular endothelial function. Acta paediatrica (Oslo, Norway: 1992). 2014;103(4):411-7.
31. Koenen M, Hill MA, Cohen P, Sowers JR. Obesity, Adipose Tissue and Vascular Dysfunction. Circulation research. 2021;128(7):951 – 68.

32. Aydin Eroglu S, Akyuz Unsal AI, Verdi F, Kurt Omurlu I, Unuvar T, Anik A. The Effect of Childhood Obesity on Intraocular Pressure, Corneal Biomechanics, Retinal Nerve Fiber Layer, and Central Macular Thickness. Journal of glaucoma. 2024;33(6):417 – 21.
33. Tufek M, Nalcacioglu P, Capraz M, Varol K, Kaya AT, Aydın N, et al. The impact of obesity on ocular hemodynamics and choroidal thickness. Therapeutic Advances in Ophthalmology. 2023;15:25158414231180985.
34. Ding Q, Wu H, Wang W, Xiong K, Gong X, Yuan G, et al. Association of Body Mass Index and Waist-to-Hip Ratio With Retinal Microvasculature in Healthy Chinese Adults: An Optical Coherence Tomography Angiography Study. American journal of ophthalmology. 2023;246:96–106.
35. Ozgur G, Gokmen O. Associations between body mass index and choroidal thickness, superficial and deep retinal vascular indices, and foveal avascular zone measured by OCTA. Photodiagnosis and photodynamic therapy. 2023;42:103515.
36. Priščáková P, Minárik G, Repiská V. Candidate gene studies of diabetic retinopathy in human. Molecular Biology Reports. 2016;43(12):1327-45.
37. Winter Y, Sankowski R, Back T. Genetic determinants of obesity and related vascular diseases. Vitamins and hormones. 2013;91:29–48.
38. Kobayashi T, Kamimura M, Imai S, Toji C, Okamoto N, Fukui M, et al. Reproducibility and validity of the food frequency questionnaire for estimating habitual dietary intake in children and adolescents. Nutrition Journal. 2011;10(1):27.

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