# Evaluation of Choroidal Thickness and the Choroidal Vascularity Index in Underweight Children: Case-Control Study

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## ABSTRACT

**Purpose:** To compare choroidal thickness (CT) and the choroidal vascularity index (CVI) between underweight children and age-matched peers with normal body mass index (BMI), and to explore potential associations between BMI and choroidal parameters.

**Methods:** This cross-sectional study included 72 children (35 underweight, 37 normal weight) who underwent enhanced depth imaging optical coherence tomography (EDI-OCT). CT was measured at subfoveal, 1000 µm nasal, and 1000 µm temporal locations. Image binarization in ImageJ software was used to calculate total choroidal area (TCA), luminal area (LA), stromal area (SA), CVI (LA/TCA), and LA/SA ratio. Group comparisons and correlations between BMI and choroidal parameters were performed.

**Results:** There were no significant differences between the groups in terms of age, sex, axial length, or intraocular pressure ($p > 0.05$). TCA, LA, and SA were significantly higher in underweight children than in controls ($p < 0.001$ for all), whereas CT, CVI, and LA/SA ratios did not differ significantly between groups ($p > 0.05$). BMI showed significant negative correlations with subfoveal CT ($r = -0.236$, $p = 0.040$), TCA ($r = -0.457$, $p < 0.001$), LA ($r = -0.414$, $p < 0.001$), and SA ($r = -0.475$, $p < 0.001$).

**Conclusion:** Underweight children demonstrated increased choroidal structural areas (TCA, LA, SA), while CVI remained unchanged, suggesting a proportional increase in both vascular and stromal components. These findings indicate that BMI may influence choroidal structure, although the vascular-stromal balance appears to be preserved.


**Keywords:** body mass index, optical coherence tomography, choroid

## INTRODUCTION

Malnutrition and being underweight in childhood are still major public health concerns. According to global estimates, approximately 23.2% of children under 5 years old were stunted, 7.4% were wasted, and 13.9% were underweight.[1] Malnutrition is closely associated with impaired growth and neurocognitive development, increased susceptibility to infections, immune system dysfunction, and long-term cardiovascular morbidity.[2] Nutritional status has a profound impact on vascular structure and function, and children with undernutrition may exhibit systemic microvascular alterations.[3]

The choroid is a layer of highly vascularised tissue embedded between the sclera and the retina, playing a pivotal role in sustaining retinal function and ocular homeostasis. Due to its extensive vascular network, the choroid is particularly susceptible to various ocular and systemic disorders.[4,5]

Optical coherence tomography (OCT) enables rapid, non-contact, and non-invasive evaluation of the optic

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nerve and retina. Enhanced depth imaging OCT (EDI-OCT) provides improved visualization of deeper structures such as the choroid.[6] The choroidal vascularity index (CVI) has emerged as a robust and reproducible biomarker for assessing choroidal vascular status.[7]

Previous pediatric studies have demonstrated that choroidal thickness (CT) may be influenced by refractive errors, amblyopia, and obesity.[8-12] While several adult studies have evaluated CT and CVI in underweight individuals, investigations in pediatric underweight populations remain scarce.

The present study aimed to compare CT and CVI between underweight children and age-matched children with normal body mass index (BMI). By employing EDI-OCT imaging and image binarization techniques, we sought to determine whether nutritional status influences choroidal structural parameters in the pediatric population.

## MATERIALS AND METHODS

This cross-sectional designed study was conducted with the approval of the local ethics committee (Approval No: 2022-110) and in accordance with the Declaration of Helsinki. Written informed consent was secured from all subjects and their parents.

The study was conducted on a total of 72 children, comprising 35 underweight participants (BMI < 18.5 kg/m²) and 37 age- and sex-matched controls with normal BMI (18.5–24.9 kg/m²), according to reference values for Turkish children.[13] Exclusion criteria included: best-corrected visual acuity (BCVA) worse than 10/10, spherical equivalent (SE) refractive error > ±3.00 diopters, history of ocular surgery, strabismus, amblyopia, glaucoma, retinal or uveal disease, systemic diseases (e.g., diabetes mellitus, hypertension), use of systemic or topical medication, and poor cooperation during OCT imaging.

All participants underwent slit-lamp biomicroscopy, best-corrected visual acuity (BCVA) assessment with a Snellen chart, and fundus examination. The IOP and the spherical equivalent (SE) of the participants were measured with an autorefractometer (Topcon KR-8900; Topcon Corporation, Japan).

Height and weight were measured without shoes and in light clothing using an automated stadiometer and weighing scale (Densi GL-150, DENSI Industrial Weighing Systems). BMI was calculated as weight (kg) / height² (m²).

The measurement of axial length (AL) was conducted utilising an optical biometer (AL-Scan; Nidek Corp., Japan). Macular images were acquired using a spectral-domain OCT (Heidelberg Engineering, GmbH, Heidelberg, Germany) and choroidal images were acquired in enhanced depth imaging (EDI) mode between 10:00 and 13:00 to minimize diurnal variation. Only the right eye of each participant was analyzed.

The measurement of CT was conducted manually, defined as the vertical distance from the outer border of the retinal pigment epithelium to the choroidal–scleral interface. The measurement was taken at three points: the subfoveal region, the 1000 µm nasal region, and the 1000 µm temporal region, referenced to the fovea. The central macular thickness (CMT) was obtained automatically using the OCT device.

The choroidal structures, including the total choroidal area (TCA) and the luminal area (LA) were calculated using the binarisation of EDI-OCT images using the ImageJ software programme (National Institutes of Health, USA).Stromal area (SA) was found from the difference of TCA and LA. The CVI values were calculated using the LA/TCA ratio (Figure 1).

## STATISTICAL ANALYSIS

SPSS V22 (IBM Corp.,NY, USA) was used for data analysis. Normality was assessed using the Kolmogorov–Smirnov / Shapiro-Wilk test. Intergroup comparisons were performed using independent samples t-test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Categorical variables were compared using the chi-square test. Correlations between BMI and choroidal parameters were assessed with Spearman's correlation analysis. The data are expressed as the mean ± standard deviation (SD). P-values < 0.05 were considered statistically significant.

## RESULTS

The study included 72 children: Thirty-five were in the underweight group and 37 were in the normal-weight control group. The mean age was 12.57±3.66 years in the underweight group and 12.03 ± 3.78 years in the control group,

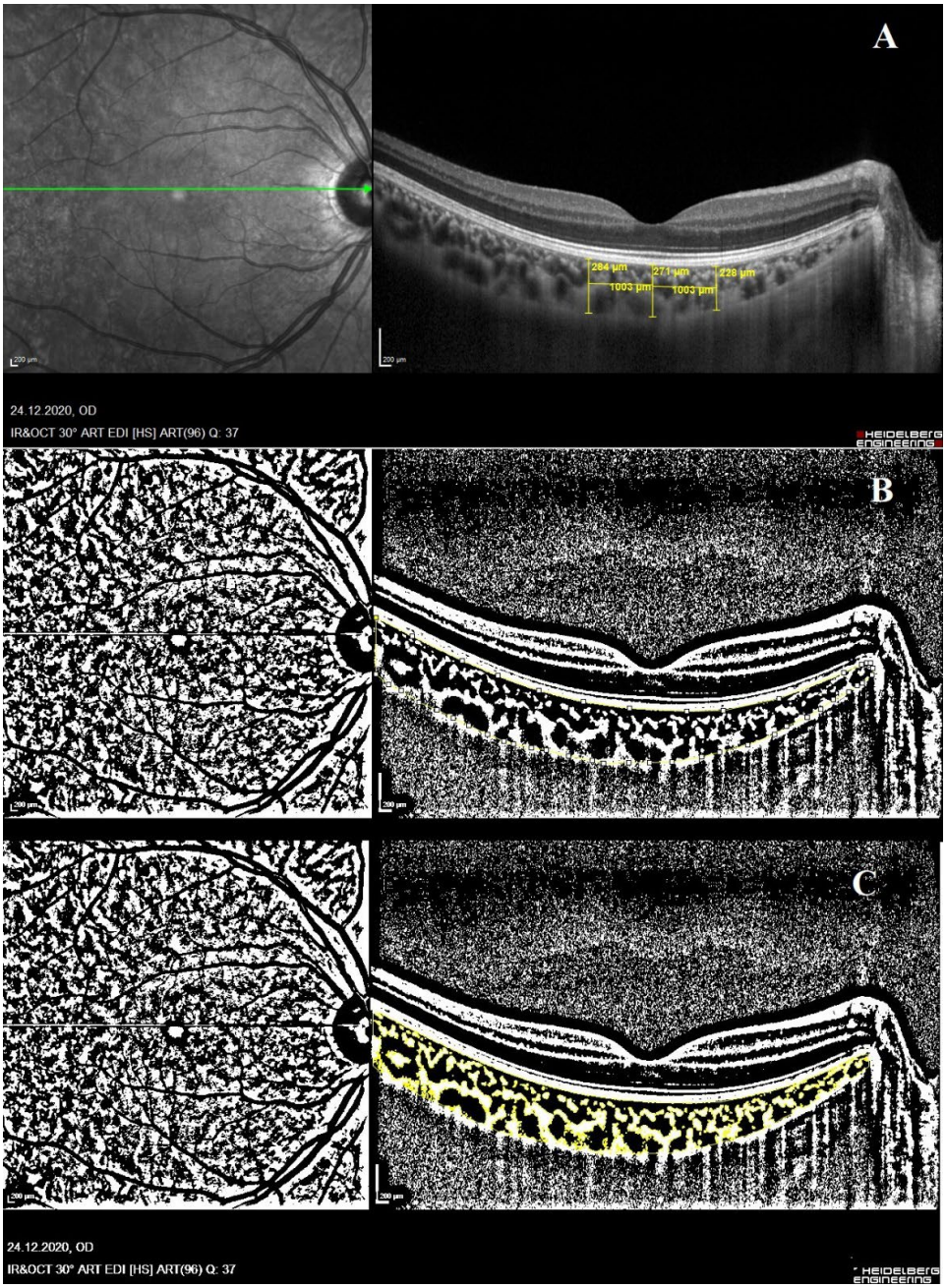


**Figure 1: A)***Subfoveal, 1000 µm temporal and nasal choroidal thickness measurement,* **B)** *The image was binarized using Niblack's auto-local threshold,* **C)** *The color threshold tool was used to select the dark pixels, representing the luminal area.*

with no significant difference between groups (p = 0.601). The sex distribution was comparable (p = 0.799).

There were no significant intergroup differences in height, SE, IOP, AL, or CMT (p > 0.05 for all). As expected, BMI, BMI standard deviation score (BMI SDS), and weight were significantly lower in the underweight group (p < 0.001 for all) (Table 1).

Choroidal measurements are summarized in table 2. Subfoveal, temporal, and nasal CT values were higher in the underweight group; however, these differences were not statistically significant. (p = 0.070, p = 0.175, and p = 0.336, respectively).

In contrast, SA, LA, and TCA were significantly larger in underweight group (p < 0.001 for all). Neither the LA/SA ratio nor the CVI (LA/TCA) differed significantly between groups (p = 0.626 and p = 0.774, respectively).

Correlation analysis revealed a significant negative relationship between BMI and subfoveal CT (r = −0.236, p = 0.040), TCA (r = −0.457, p < 0.001), LA (r = −0.414, p < 0.001), and SA (r = −0.475, p < 0.001). There were no significant correlations between BMI and either CVI or LA/SA ratio (Figure 2).

**Table 1:** *Comparison of demographic characteristics of groups*

| | Underweight (n=35) | Control (n=37) | P |
|---|---|---|---|
| Gender (m/f) (%) | 10/25 28.6/71.4% | 9/28 24.3/75.7% | 0.799* |
| Age (year) | 12.57±3.66 | 12.03±3.78 | 0.601** |
| Height (cm) | 152.93±19.35 | 150.08±18.33 | 0.577*** |
| Weight (kg) | 36.71±12.51 | 49.46±11.14 | <0.001*** |
| BMI (kg/m$^2$) | 15.17±1.49 | 21.77±1.45 | <0.001*** |
| BMI SDS | -1.78±0.62 | 0.87±0.80 | <0.001*** |
| SE (D) | -1.0±1.91 | -0.51±1.27 | 0.107** |
| IOP (mmHg) | 14.00±2.44 | 14.24±2.43 | 0.679** |
| AL (mm) | 23.78±1.03 | 23.50±1.02 | 0.386*** |
| CMT (µm) | 263.79±16.75 | 263.19±15.23 | 0.947** |

m/f: male/female, BMI: Body mass index, BMI SDS: body mass index standart deviation score, SE: sferical equivalent, D: Diopter, IOP: Intraocular pressure, AL: Axial length, CMT: Central macular thickness, *: Chi-square test, **: Mann Whitney U test, ***: Independent samples T test, bold p<0.05.

**Table 2:** *Comparison of temporal CT,subfoveal CT, nasal CT, TCA, LA, SA, LA/SA and CVI between groups*

| | Underweight (n=35) | Control (n=37) | P |
|---|---|---|---|
| Temporal CT (µm) | 353.29±61.17 | 320.84±82.90 | 0.175* |
| Subfoveal CT(µm) | 37.50±68.22 | 322.19±88.21 | 0.070** |
| Nasal CT (µm) | 318.29±65.41 | 296.05±86.48 | 0.336* |
| TCA (mm$^2$) | 0.66±0.14 | 0.50±0.12 | <0.001* |
| LA (mm$^2$) | 0.44±0.11 | 0.33±0.08 | <0.001* |
| SA (mm$^2$) | 0.22±0.04 | 0.17±0.04 | <0.001* |
| LA/SA (%) | 1.96±0.23 | 1.95±0.27 | 0.626** |
| CVI (%) | 0.66±0.03 | 0.66±0.03 | 0.774* |

CT: Choroidal thickness, TCA: Total choroidal area, LA: Luminal area, SA: Stromal area, LA/SA: Luminal area and stromal area ratio, CVI: Choroidal vascularity index, *: Independent samples T test, **: Mann Whitney U-test, bold p<0.05.

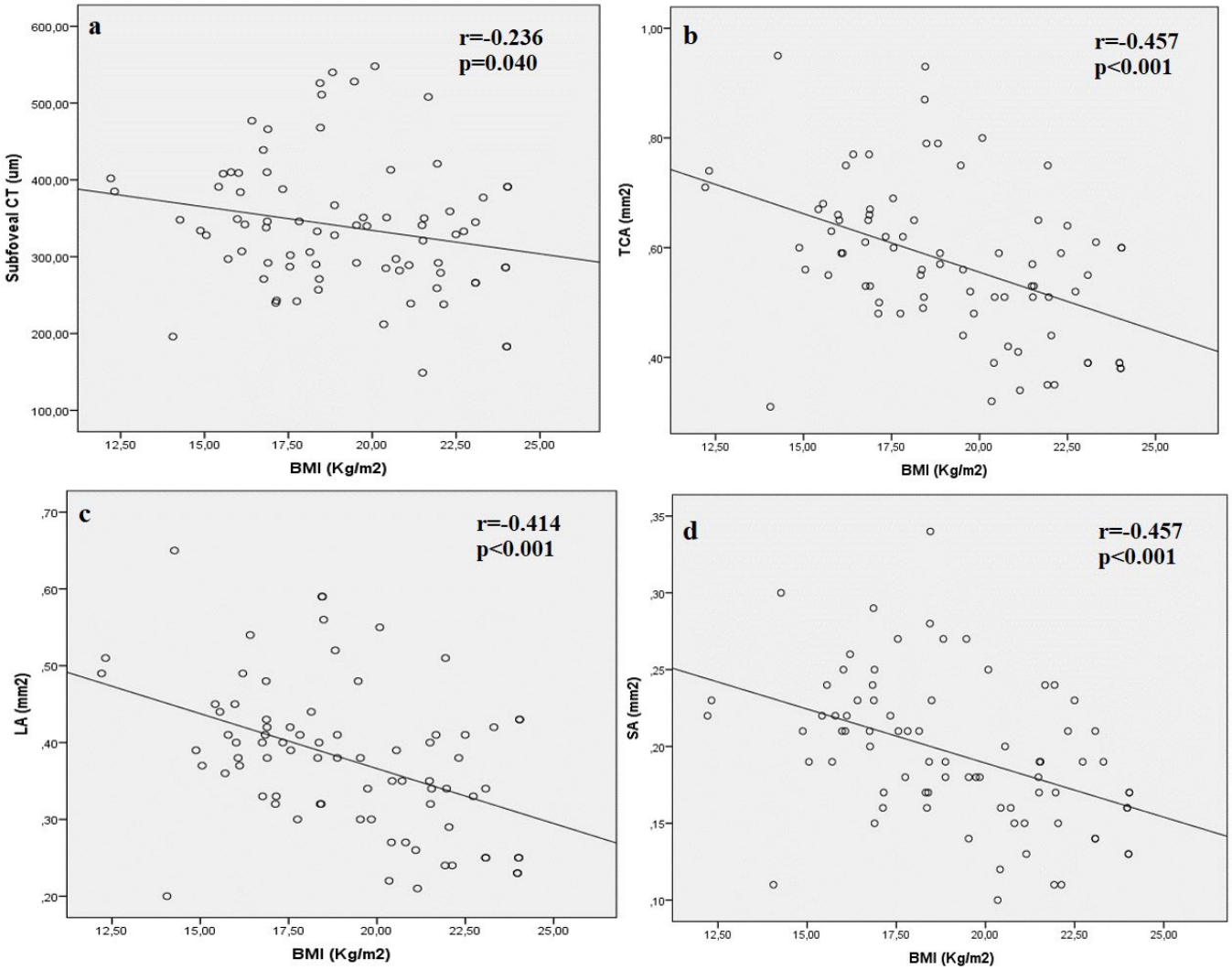


**Figure 2:** *Linear regression line between BMI and a) Subfoveal choroidal thickness (CT) b) Total choroidal area (TCA) c) Luminal area (LA) d) Stromal area (SA).*

## DISCUSSION

There are limited studies evaluating the both CT and CVI in underweight children. Our results demonstrated that the LA,TCA, and SA were larger in underweight children. Although CT values were higher at subfoveal, nasal and temporal locations in the underweight group, these differences were not statistically significant. Importantly, there were no significant differences observed in CVI or LA/SA ratios, suggesting a proportional enlargement of both vascular and stromal components in underweight eyes. Furthermore, BMI was inversely correlated with subfoveal CT, TCA, LA, and SA.

In healthy pediatric populations, reported mean subfoveal CT values have ranged from approximately 330 to 356 µm.[11,14] Our cohort showed similar values, with an overall mean of 339.68 ± 85.97 µm.

Choroidal thickness is influenced by multiple factors including age, AL, and sex, as well as systemic parameters such as BMI.[15,16] Prior studies investigating the relationship between CT and BMI, have primarily focused on obesity, and the results have been inconsistent. Panon et al. reported no significant CT differences between obese and non-obese individuals.[17] A study conducted on obese women showed that CT was higher in the obese group than in the non-obese

group.[18] In contrast, Yılmaz et al. showed that people with low and normal BMI had higher CT than overweight and obese people in their study involving 160 adults aged 18–39.[19] Several studies have also examined CT in pediatric obese populations. For example, Bulus et al. showed that CT was higher in obese children compared to healthy controls in a study involving 44 obese and 42 normal-weight children.[8] In contrast, Özen et al. observed reduced choroidal thickness in 38 obese children relative to 40 age-matched healthy children[20] Similarly, Topcu-Yilmaz et al. found that choroidal thickness was lower across all quadrants in 36 obese children compared to 26 normal-weight peers, with the most significant reduction observed in the temporal quadrant.[21]

In underweight populations, available data are limited and largely restricted to adults. Moschos et al. reported reduced CT in women with anorexia nervosa, whereas Yaprak et al. found greater subfoveal CT and choriocapillaris flow area in underweight women. [22,23] Our findings align more closely with the latter, suggesting that in children, low BMI may be associated with greater choroidal dimensions, possibly reflecting developmental or hormonal influences on choroidal vasculature.

The inverse association between BMI and CT parameters in our study may be explained by differences in systemic vascular regulation. Obesity is associated with reduced nitric oxide (NO) availability and increased vasoconstrictors such as endothelin-1 and angiotensin-II, potentially leading to vascular narrowing.[24-26] Conversely, underweight status may be linked to higher NO levels, promoting vasodilation and increasing choroidal perfusion. Experimental studies in animal models have shown a positive correlation between NO levels and choroidal thickness, supporting this hypothesis.[27-29] While our data are consistent with these mechanisms, biochemical studies in pediatric cohorts are warranted to confirm this relationship.

CT provides a useful structural measure but is influenced by multiple ocular and systemic factors, including refractive status, blood pressure, and axial length. In contrast, CVI—a ratio reflecting the vascular-to-stromal proportion of the choroid—has been shown to be more stable and less susceptible to such confounders.[7,30-32] Recent studies have also investigated the relationship between BMI and the CVI, although findings have been inconsistent. Agrawal et al. reported a decrease in CVI among individuals with higher BMI, suggesting that increased adiposity may impair choroidal vascular health, potentially due to systemic inflammation and endothelial dysfunction associated with obesity.[7] Although many studies emphasize the impact of BMI on choroidal parameters, some evidence suggests that CVI remains relatively unaffected even when CT changes occur with BMI alterations**.** For instance, a prospective study by Dogan et al. evaluated 60 obese patients (30 undergoing bariatric surgery and 30 managed conservatively) using swept-source OCT and OCT-angiography. The results showed that after 3 months, while CT significantly increased in the surgery group, CVI did not change significantly in either group compared to baseline.[33]

Only one study in the literature has analysed CT and CVI in underweight children. Şükün et al. reported that CVI was significantly lower in underweight children compared to controls, while choroidal thickness showed no significant difference.[34] In our study, although underweight children exhibited significantly larger choroidal areas (TCA, LA, SA), the CVI remained comparable between groups. This may suggest a proportional increase in both luminal and stromal components in underweight individuals, thereby preserving the vascular–stromal balance of the choroid.

This research has a number of limitations. The findings' generalisability may be limited by the relatively small sample size. The cross-sectional design precludes conclusions about causality or temporal changes in CT and CVI. Participants included children with a range of refractive errors within ±3.00 diopters, which may influence choroidal metrics. Future longitudinal studies involving larger cohorts and a broader spectrum of refractive statuses are warranted.

Nevertheless, the strengths of our study include well-matched groups in terms of age, AL, and sex, and rigorous OCT methodology including EDI-OCT and ImageJ-based binarization. To the best of our knowledge, this is the second study to investigate both CT and CVI in underweight children.

## CONCLUSION

In conclusion, underweight children exhibited significantly higher TCA, LA, and SA compared to normal-weight peers, and BMI was negatively correlated with subfoveal CT and choroidal structural areas. However, no difference

was observed in CVI, indicating that the vascular-stromal balance within the choroid is preserved. These findings indicate that nutritional status may influence choroidal structure, and emphasise the need for further research to clarify the clinical significance of these changes.

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