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Choroidal Thickness and Visual Acuity in High Myopia Without Myopic Maculopathy: Insights From a Chinese Population Study

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Purpose: To evaluate the association of choroidal thickness (ChT) with best-corrected visual acuity (BCVA) in patients with high myopia (HM) and without myopic maculopathy.

Methods: This study was a retrospective, cross-sectional study of participants aged 7 to 70 years with bilateral HM but without myopic maculopathy. Swept-source optical coherence tomography was used to measure ChT at the fovea. A BCVA of logMAR 0.1 was regarded as the benchmark for normal. The association between ChT and BCVA was evaluated by linear regression models with confounders fully adjusted. Subgroup analyses were performed across sex and age groups.

Results: A total of 412 eligible participants were enrolled in this study. The mean age, spherical equivalence, and subfoveal (SF) ChT of the included participants were 21.17 $\pm$ 9.55 years, -9.77 ± 2.40 diopters, and 171.56 $\pm$ 61.33 µm, respectively. The SF ChT was thinner in participants with abnormal BCVA (normal. 176.74 $\pm$ 60.24 µm; abnormal, 139.30 $\pm$ 58.63 µm). A thinner ChT in all subregions of the posterior pole of the Early Treatment Diabetic Retinopathy Study grid was associated significantly with a worse BCVA after adjusting for age, sex, and axial length (SF ChT: coefficient, $\times 10^{-4}$, -2.64; 95% confidence interval, -4.73 to -0.55; $P < 0.05$ in all subregions). The strongest correlation was observed in the outer inferior region, where a per 21 µm thinning of ChT led to a 0.01 worsening of BCVA. This correlation presented a stronger magnitude in male aged more than 40 years.

Conclusions: In patients with HM without myopic maculopathy, a thinner ChT was associated independently with a worse BCVA.

Translational Relevance: The findings of this study suggest that thinning ChT should be considered a vital risk factor for irreparable visual acuity impairment.

Introduction

High myopia (HM), usually defined by a spherical equivalent (SE) worse than -5 or -6 diopters (D), is a common vision-threatening eye disease that has expanded rapidly worldwide in recent decades.[1] The prevalence of HM in urban Asian regions (e.g., China, Taiwan, Korea, and Japan) has nearly doubled from less than 10% to approximately 20% in the last 10

to 15 years.[1] Furthermore, it is estimated that the number of patients with HM will reach 1 billion in 2050.[2] Various ocular morbidities and pathologies closely related to HM are heavy burdens for patients and public health; they are especially predominant among young individuals and cause severe impairment in visual function, including irreversible blindness.[3–5]

Patients with both pathological and simple HM have documented compromised visual function, including vision impairment and visual field defect.[6–8] In comparison with mild and moderate myopia patients, HM individuals are at a higher risk of developing impaired best-corrected visual acuity (BCVA).[9] Myopic maculopathy is one major cause of irreparable visual acuity in the HM population, with approximately 30.8% of patients presenting with pathological changes with a BCVA of worse than 20/60.[4,5,10] Some demographic and clinical characteristics have also been established as risk factors for impaired visual acuity in patients with myopia (e.g., old age, female sex, long axial length [AL], and a large SE).[11–14] However, these parameters primarily affect populations with myopic maculopathy and are unable to fully explain the compromised vision outcome in all HM cases. Therefore, potential factors that might explain irreparable visual acuity in patients without myopic maculopathy are still under investigation.

The choroid plays a key role in the mechanism of HM development and progression, as thinning choroidal thickness (ChT) and altered choroidal vascular features have been observed in highly myopic eyes.[15–17] ChT has also been associated with visual impairment, although the findings reported for the HM population are controversial.[18] Some researchers have demonstrated a close positive association between ChT and visual acuity in patients with HM,[19] whereas others have found it to be of little significance.[20] Because these previous studies were limited to small populations and unable to exclude myopic maculopathy, the effect of maculopathy on impaired visual acuity may be an important confounder of interest. Therefore, it is critical to document further and extensively the relationship between ChT and BCVA after excluding the potential confounding effect of maculopathy.

In this study, we aimed to elucidate the association between ChT and BCVA in a large population of patients with HM without myopic maculopathy. We retrospectively evaluated and analyzed the clinical data of Chinese participants with HM recruited from the Zhongshan Ophthalmic Centre–Brien Holden Vision Institute (ZOC-BHVI) Cohort after excluding those with myopic maculopathy. A review of the relevant previous literature was also undertaken to gain a full understanding of the conditions involved.

Materials and Methods

Participants and Clinical Data

In this retrospective study, participants were recruited from the ZOC-BHVI cohort. Detailed methodology of the ZOC-BHVI cohort has been previously reported elsewhere.[21] All data of included participants were collected in 2014 and 2015 and were reviewed retrospectively in the Zhongshan Ophthalmic Center. This study was approved by the Institutional Review Board of ZOC (2012KYNL002) and was conducted in compliance with the Declaration of Helsinki. For each participant in the ZOC-BHVI cohort, written informed consent was obtained.

This study enrolled patients with HM aged 7 to 70 years; HM was defined as a myopic spherical power of −6.0 D or less in both eyes. Only those who had been examined by optic coherence tomography (OCT) with sufficient qualified images captured in 2014 and 2015 were eligible for inclusion in this study. Demographic information, including age and sex, and clinical information (e.g., medical history and follow-up status) were also collected for each participant. The exclusion criteria were as follows: (1) any nontessellated myopic maculopathy, (2) secondary myopia, (3) a history of intraocular or refractive surgeries, (4) a history of other severe eye disorders (e.g., diabetic retinopathy, age-related macular degeneration, and uveitis), (5) severe systemic conditions, and (6) a lack of a comprehensive medical record.

Ophthalmic Examination

General Ophthalmic Examinations

All participants underwent a series of comprehensive ophthalmic examinations, including BCVA assessment, slit-lamp biomicroscopy examination, AL measurement, dilated fundus examination, fundus photography, and subjective refraction. BCVA was measured by a licensed optometrist based on the results of subjective refraction using the Early Treatment Diabetic Retinopathy Study (ETDRS) logarithm of the minimum angle of resolution (logMAR) visual acuity chart (Precision Vision, Villa Park, IL). Biometry measurements were carried out by experienced nurses in a dark room. AL was measured using optical low-coherence reflectometry (Lenstar LS900; Haag-Streit AG, Koeniz, Switzerland). Cases of extra-long AL over 32 mm, which exceeds the valid range

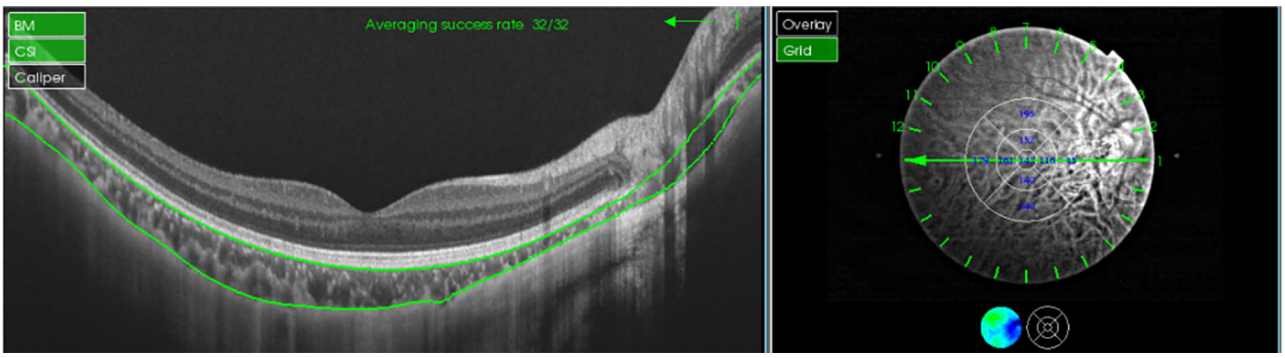

Figure 1. Measurement of ChT by SS-OCT in regions of the ETDRS grid based on an automatic segmentation software. This figure showed an interface of a validated commercial software, which can automatically perform segmentation for choroid layer, and accordingly calculate the thickness of choroid in each ETDRS grid. SS, swept source.

of the Lenstar measurement, was measured using an IOLMaster (Carl Zeiss Meditec, Oberkochen, Germany) instead. Pupil dilation was induced using compound tropicamide eye drops (5 mg tropicamide and 5 mg phenylephrine hydrochloride in 1 mL) administrated three times at intervals of 5 minutes. Once full mydriasis occurred, fundus photography and slit-lamp biomicroscopy examinations were conducted. A trail frame of subjective refraction after pupil dilation was measured by an optometrist as SE.

OCT Measurement

Images of OCT were obtained from each participant after pupil dilation and were centered at the macular fovea and optic disc using a swept source OCT instrument (DRI OCT-1; Topcon, Tokyo, Japan) to achieve deeper tissue penetration and better photography of the choroid.[24] This swept source OCT used a 1050-nm wavelength and can perform 100,000 A-scans per second with a lateral resolution of 20 µm and an axial resolution of 8 µm. An A-scan with 12-line radial was performed for each image to produce a mean of 32 overlapped consecutive scans and an area of 12 × 12 mm^2. Before each scan, the AL was input into the OCT system to allow for automatic compensation for associated magnification. Only images with a quality score of greater than 45 (maximum, 160) were considered good quality and those centered at the macular fovea were used in this study for further measurements. Unusable OCT images (e.g., with severe refractive media opacity, signal loss caused by blinking, motion artifacts) were excluded from the subsequent analyses.

A validated commercial swept source-OCT segmentation software (Topcon, 9.12.003.04) was used to automatically segment the choroid on the OCT images into nine regions according to the ETDRS grid as follows: subfoveal (SF), inner nasal (IN), outer nasal (ON), inner temporal (IT), outer temporal (OT), inner superior (IS), outer superior (OS), inner inferior (II), and outer inferior (OI) (Fig. 1). Then, the choroid in each ETDRS grid was corrected manually by a retina specialist for any segmentation mistakes. After manual correction, the software automatically measure ChT in ETDRS grids based on the segmentation. This automatic procedure of choroid segmentation and measurement has been proved having high repeatability.[22] The measurements were performed three times for each image and a final value was derived from the mean.[23]

Definition of Myopic Maculopathy

To identify myopic maculopathy, two retinal fundus images of each eye (centered on the macular fovea and the other centered on the optic disc) were taken using a digital fundus camera (Canon CX-1; Tokyo, Japan). Eligible images of good quality were applied. Myopic maculopathy was identified and classified according to International Meta-Analysis for Pathologic Myopia (META-PM) by a panel of four ophthalmologists.[24] Standard categories of the classification were provided as follows: category 0 (C0), where the retina has no lesions of myopic maculopathy; category 1 (C1), where the retina displays tessellated fundus; category 2 (C2), where the retina has diffused chorioretinal atrophy; category 3 (C3), where retina has patchy atrophy; and category 4 (C4), where retina shows macular atrophy. Other relative maculopathies, including lacquer crack, Fuch's spot, and choroidal neovascularization, were classified as plus lesions. Because myopic maculopathy is commonly defined as C2 and above grades for clinical significance, the definition for myopic maculopa-

thy in our analysis included nontessellated retinopathy changes.[25]

In addition, further evidence of maculopathy related to HM, including macular schisis and macular hemorrhage, was also considered to comply with the exclusion criteria in this study, which were identified by a licensed ophthalmologist. All OCT images were reviewed for any evidence of maculopathy that might be undetectable on the retinal fundus images.

Statistical Analysis

Of each participant in this study, the right eye was included arbitrarily for statistical analysis based on the high correlation between the two eyes.[26] BCVA was initially recorded as a decimal and recalculated as the logMAR. BCVA with a logMAR of 0.1 equivalent to 0.8 (20/25) on Snellen chart was defined as a reference for normal BCVA.[18] Thus, patients with a BCVA of better than a logMAR of 0.1 were considered as having a normal visual acuity free from interferences to daily life activities; others were considered to have abnormal visual acuity. The SE of refractive error was calculated as the spherical power plus half of the cylindrical power calculated by the results of subjective refraction. Continuous variables were presented as mean and standard deviation for those in normal distribution; otherwise, they were presented as median and interquartile range. Categorical variables were presented as number and percentage. Student's *t* test, one-way analysis of variance test, and Kruskal–Wallis test were used to analyze demographics and clinical characteristics between patient with normal or abnormal BCVA. To assess the correlation of continuous BCVA and ChT, independent Student's *t* test, as well as linear regression models, were adopted. All analyses were performed using Stata, version 16.0 (Stata Corporation, College Station, TX). A two-sided *P* value of less than 0.05 was considered statistically significant.

Results

Demographics and Clinical Characteristics

A total of 412 eyes in 412 participants with HM without myopic maculopathy in the ZOC-BHVI HM cohort study were included in the present study. Table 1 provides a summary of the demographic and clinical characteristics of the participants included in this study. Biological examinations of the participants (mean age, 21.17 ± 9.55 years; female: 218 [52.9%]) showed an AL of 27.26 ± 1.17 mm and an SE of −9.77 ± 2.40 D. The mean BCVA of these participants was 0.09 ± 0.12 in logMAR. The mean SF ChT was 171.56 ± 61.33 mm. According to demographic and clinical characteristics, SF ChT in subgroups were measured separately, as shown in Table 2. SF ChT showed to be significantly thinner in older participants, as well as in those with longer AL and worse SE ($P < 0.05$), yet no difference was found across sex. Participants with abnormal BCVA were found to have approximately 37 mm thinner SF ChT (139.30 ± 58.63 µm) compared with those with normal BCVA (176.74 ± 60.24 µm) ($P < 0.001$).

Table 1. Characteristics of High Myopic Patients Without Myopic Maculopathy

Parameter	Value
No. of participants	412
Age (years)	21.17 ± 9.55
Female sex	218 (52.91%)
AL (mm)	27.26 ± 1.17
SE (diopter)	−9.77 ± 2.40
BCVA (logMAR)	0.09 ± 0.12
SF ChT (µm)	171.56 ± 61.33

Table 2. SF ChT of Participants by Clinical Characteristics

	Participants ($n = 412$)		
Characteristics	*N*	Mean ± SD (µm)	*P* Value
Age (years)			
7–18	239	175.49 ± 55.37	0.009*
19–39	148	170.94 ± 70.02	
40–70	25	137.68 ± 51.31	
Sex			
Male	194	172.02 ± 59.35	0.887
Female	218	171.15 ± 63.17	
AL (mm)			
<27.0	182	191.36 ± 62.31	<0.001*
≥27.0–29.0	203	160.24 ± 55.35	
≥29.0	27	123.19 ± 49.55	
SE (diopters)			
≤−6 to −8	93	192.87 ± 61.59	<0.001*
≤−8 to −10	158	178.49 ± 58.71	
≤−10	161	152.44 ± 58.48	
BCVA			
≤ LogMAR 0.1	355	176.74 ± 60.24	<0.001*
> LogMAR 0.1	57	139.30 ± 58.63	

*For statistical significance.

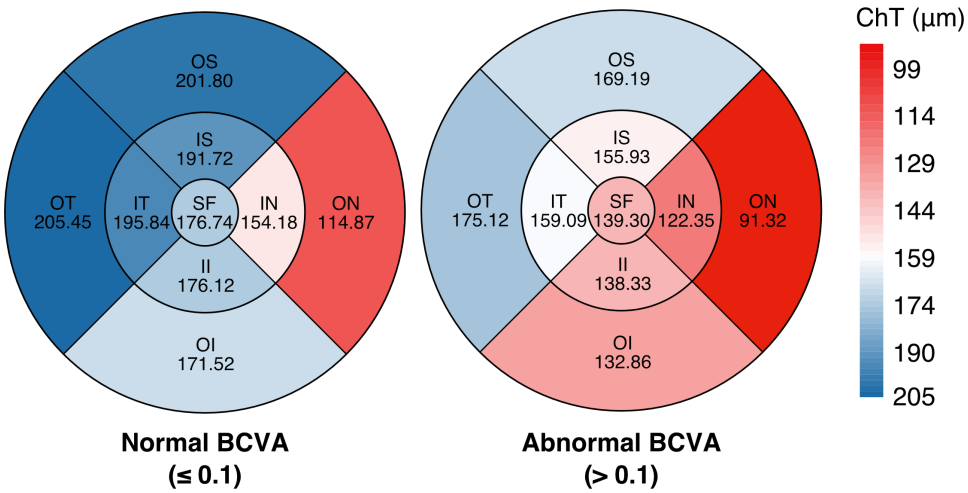

Figure 2. Distribution of ChT in participants with normal or abnormal BCVA. The distribution was presented according to the ETDRS grid. Mean ChT of each grid was presented. Blue represents thick ChT, and red represents thin ChT (μm).

ChT at Different Grids in Participants of Different BCVA

The choroid was further characterized in nine regions of the ETDRS grid centered on the macula, and the distribution pattern and thickness were analyzed. Supplementary Table S1 shows the ChT in each grid according to the differing BCVA. The smallest ChT was found in the ON region (114.87 ± 42.22 μm with normal BCVA, 91.32 ± 35.48 μm with abnormal BCVA), followed by the IN region. The largest ChT was in the OT region (205.45 ± 56.73 μm with normal BCVA, 175.12 ± 56.26 μm with abnormal BCVA). The OI, II, and SF regions presented with approaching ChT. A similar distribution pattern of ChT was observed in both BCVA groups, but with diverging thickness. In each grid, a significantly thinner ChT was found in participants with abnormal BCVA compared with those with normal BCVA ($P < 0.001$). The greatest discrepancy was observed in the OI region at approximately 39 μm for impaired BCVA compared with normal BCVA. At the horizontal and longitudinal measuring levels, ChT showed a gradual decreasing trend from temporal to nasal, as well as from superior to inferior in both groups (Fig. 2).

Correlation Between ChT and BCVA

To determine the correlation of ChT with continuous BCVA in highly myopic eyes without myopic maculopathy, three linear regression models were implemented (Table 3). Model 1 analyzed ChT using a univariable method. The results indicated that thin ChT was correlated with impaired BCVA (Fig. 3). Threshold values of ChT indicating abnormal BCVA for each ETDRS grid were calculated from linear regression equations (Supplementary Table S2). By dividing these threshold values by the average ChTs in the normal BCVA groups, it can be determined that a ChT thinner than approximately 80% of the normal value may indicate visual impairment. Correlations between SF ChT, BCVA and potential confounders (age, sex, AL, and SE) are explored in Supplementary Figure S1. These confounders showed linear correlations with SF ChT, but a nonlinear pattern correlation with BCVA. Specifically, BCVA improved with advancing age among participants aged less than 18 years of age, yet after reaching 18 years, a slight deterioration was noted as age continued to advance. For AL, we found no significant correlation between AL and BCVA when the AL was less than approximately 28 mm. Nonetheless, a positive correlation emerged once AL exceeded approximately 28 mm. The correlation pattern between BCVA and SE resembled that of the AL, where the correlation slope gradually becomes less steep with a smaller SE.

To further eliminate potential confounding effects from risk factors above, we developed two multivariable models. Model 2 adjusted for age and sex, and model 3 incorporated AL in addition to age and sex adjustment in model 2. The SE was not adjusted to avoid overfitting owing to collinearity between AL and SE. Significant associations between ChT and BCVA were identified in each grid in all models (model 3, SF coefficient $\times 10^{-4}$, −2.64; 95% confidence interval, −4.73 to −0.55; all $P < 0.05$). The strongest correlation was found in the OI region (model 3, coefficient, $\times 10^{-4}$, −4.67; 95% confidence interval, −6.97 to −2.38;

Table 3. Linear Regression Models for the Association of BCVA and ChT

	Model 1				Model 2				Model 3			
	Coefficient	95%CI ($\times 10^{-4}$)			Coefficient	95% CI ($\times 10^{-4}$)			Coefficient	95% CI ($\times 10^{-4}$)		
ChT (μm)	($\times 10^{-4}$)	Lower	Upper	*P* Value	($\times 10^{-4}$)	Lower	Upper	*P* Value	($\times 10^{-4}$)	Lower	Upper	*P* Value
SF	−3.66	−5.6	−1.71	<0.001*	−3.42	−5.35	−1.49	0.001*	−2.64	−4.73	−0.55	0.013*
IN	−4.02	−6.23	−1.8	<0.001*	−3.71	−5.89	−1.52	0.001*	−2.81	−5.17	−0.44	0.02
ON	−4.82	−7.66	−1.98	0.001*	−4.51	−7.31	−1.7	0.002*	−3.37	−6.36	−0.38	0.027*
IT	−3.95	−5.89	−2	<0.001*	−3.73	−5.66	−1.79	<0.001*	−3.02	−5.09	−0.95	0.004*
OT	−3.59	−5.67	−1.51	0.001*	−3.43	−5.5	−1.35	0.001*	−2.69	−4.86	−0.52	0.015*
IS	−3.7	−5.64	−1.76	<0.001*	−3.41	−5.34	−1.49	0.001*	−2.7	−4.74	−0.66	0.01*
OS	−4.08	−6.08	−2.08	<0.001*	−3.92	−5.91	−1.93	<0.001*	−3.28	−5.35	−1.2	0.002*
II	−4.36	−6.36	−2.36	<0.001*	−4.06	−6.04	−2.07	<0.001*	−3.36	−5.5	−1.21	0.002*
OI	−5.52	−7.68	−3.36	<0.001*	−5.29	−7.45	−3.14	<0.001*	−4.67	−6.97	−2.38	<0.001*

LCI, lower confidence interval; UCI, upper confidence interval.
Model 1 is a univariate logistic regression model. Model 2 adjusted for age group and sex. Model 3 adjusted for age group, sex, and AL.
*Represents statistical significance.

$P < 0.001$), indicating that a per 21 μm thinning in ChT in the OI region would worsen BCVA by 0.01. In addition, logistic regression was performed for normal and abnormal BCVA under adjustment of age, sex, and AL (data not shown). The receiver operating characteristic curve for SF ChT showed an area under the curve of 0.708, indicating that SF ChT could explain 70% of the abnormal BCVA. The results of the regression models provided further evidence that ChT could be considered an independent risk factor for uncorrectable BCVA after excluding confounding effects of age, sex, and AL.

Subsequently, to further validate the predictive value of ChT for BCVA across age and sex, subgroup analyses were performed. According to the age at which they agreed to accept OCT measurement, the participants were assigned to three groups (aged 7–18 years, 19–39 years, and 40–70 years). In the group of participants aged more than 40 years, the ChT in all subregions, except the OT region, still presented significant correlations with BCVA after adjusting for sex and AL (Supplementary Table S3) ($P < 0.05$). ChT thinning in the OS and OI regions was significantly correlated with worsened BCVA in the 19 to 39 age group, whereas no significant differences were observed in the youngest group aged 7 to 18 years. In addition, similar correlations in male participants showed that ChT in all subregions was significantly correlated with BCVA as shown in Supplementary Table S4 (all $P < 0.05$).

Discussion

This retrospective study was embedded in a large cohort of participants with HM without myopic maculopathy. The findings of the present study demonstrated that, in all ETDRS grids of the macular region, a thinner ChT was correlated independently with impaired BCVA after adjusting for age, sex, and AL. The strongest correlation was found in the OI region, where a per 21 μm thinning in ChT caused uncorrectable vision impairment by 0.01 of logMAR BCVA. This association was particularly significant in male patients and those aged 40 years and older.

The participants in this study were recruited from the ZOC-BHVI HM cohort study, which included a large population of patients with HM over a wide range of ages. Thus, to the best of our knowledge, this study is the largest retrospective study to focus on the association between ChT and BCVA in patients with HM without myopic maculopathy. Previous studies have reported controversial results on the relationship between ChT and BCVA in highly myopic

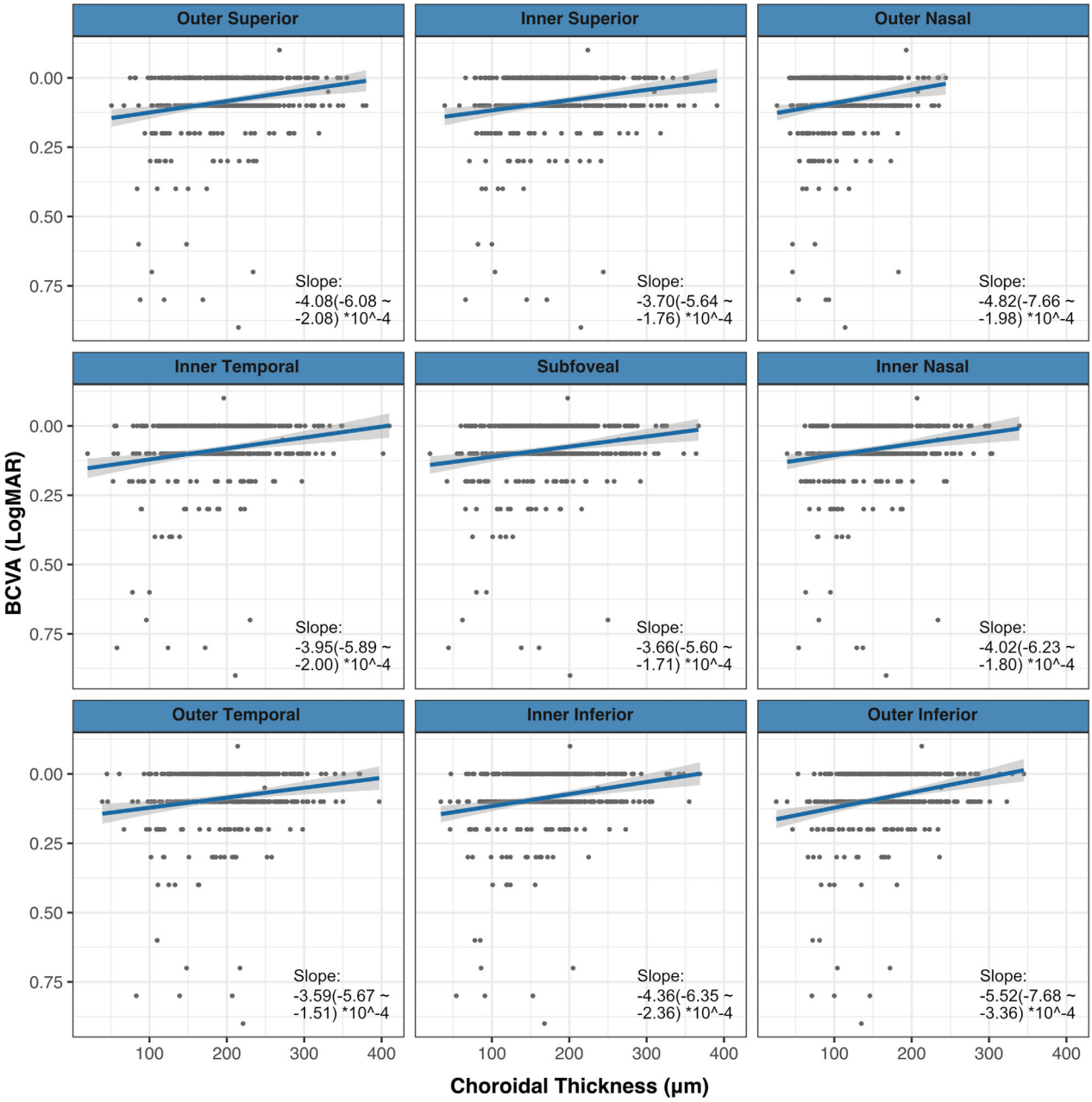

Figure 3. Correlation between ChT in each ETDRS grid and continuous BCVA. The gray region represents the 95% CIs for the regression lines. The slopes of the best fit line and 95% CIs are presented for each ETDRS grid. CI, confidence interval.

eyes (Supplementary Table S5). Our findings strongly support a positive correlation between thinner ChT and the uncorrectable impairment of visual acuity. In addition, our findings revealed an increased risk for individuals aged older than 18 years, those with an AL exceeding 28 mm, and those with a larger SE to experience poorer BCVA, even when the SF ChT remains constant.

The correlation between ChT and BCVA was only found in males. Previous studies have observed higher ChT in male than female participants after adjusting for age and AL.[27] Therefore, it can be hypothesized that, although both males and females may exhibit an association between thinner ChT and poorer BCVA, males might demonstrate a greater ChT variation compared with females. As a result, the association could potentially reach statistical significance in males rather than females.

Two previous studies performed with European and Asian populations found significant associations

between thinning ChT and worsening BCVA, which was in line with our results.[28,29] Notably, a subgroup analysis in our study confirmed this association among participants aged more than 40 years. In contrast, studies with younger populations or smaller sample sizes showed minimal significance.[20,30,31] In addition, a greater average SF ChTs and better BCVA were reported in previous studies. For instance, Lee et al.[32] reported significant associations in individuals aged 30 years or younger. However, our study, focusing on patients with HM, may have missed instances of better vision in young individuals owing to BCVA measurement limitations up to a logMAR of 0. Consequently, the association between ChT and BCVA in young populations with vision better than a logMAR of 0 may be underestimated. Additionally, the lack of standardized exclusion criteria for myopia maculopathy across studies may limit generalizability.

Choroids in highly myopic eyes usually present with normal morphology when myopia maculopathy has not occurred,[33] but a reduced trend in thickness can be detected even at an asymptomatic stage.[34] The thickness of the choroid can indirectly reflect the circulation of choriocapillaris; thus, a thin ChT may be a vital signal of worsening choroidal blood perfusion and an indicator of myopia progression.[35,36] It has been speculated that the thin ChT resulting from reduced choroidal blood perfusion may potentially induce a series of downstream processes that promote pathological changes in myopia.[37] Reduced ChT may serve as an important risk factor for visual function impairment, whereas the associated decline in visual acuity has been shown to be correlated with vision-threatening myopia-related complications. Further research should be conducted to validate the underlying mechanism of potential correlation.

Previous research on ChT has focused on metrics in the SF region, whereas peripheral ChT, especially in vertical regions, has been investigated rarely using standard ETDRS segmentation. To the best of our knowledge, this study is the first to find a strong correlation between OI ChT and BCVA in the HM population. In normal eyes, a thin inferior choroidal layer extending from the peripapillary regions to the macula has been identified as a natural anatomical architecture.[38] This anatomical feature may indicate a greater susceptibility to hypoxia or elevated intraocular pressure in this area.[38] Combined with previous evidence, it can be hypothesized that, during the early progression of HM, peripheral inferior ChT shows a higher sensitivity to early pathological changes.[39] With advances in automated segmentation and measurement, peripheral ChT changes can be further investigated as potential indicator of subclinical visual impairment.

The strength of this study is that it was based on a large population with HM without myopic maculopathy in the age range of 7 to 70 years. Compared with previous research, this study achieved a comprehensive analysis of patients of different ages. Moreover, the accurate measurement of ChT was achieved using validated automatic segmentation software and manual measurement by a retina specialist, which reinforced the reliability of the findings. Nevertheless, the following limitations should be noted. First, the number of HM participants without myopic maculopathy aged more than 40 years was limited to 25, which may restrict the generalization of our findings in this subgroup to a wider population. Second, we did not exclude eyes with a tessellated fundus because myopic maculopathy is commonly defined as META category $\geq$2.[25] As the most frequent preliminary structural change in myopic eyes, a tessellated fundus usually did not interfere with the correlation between ChT and BCVA. Diffuse choroidal atrophy was generally defined as the point whereafter visual acuity would become being compromised.[6] However, the inclusion of patients with simple tessellated fundus would largely increase sample size and the reliability of the findings.[40] Third, only established risk factors (age, sex, and AL) were adjusted as confounders in the multivariable regression models. Environmental risk factors for myopia (e.g., lifestyle, daily time spent on near work) were not considered in this study, owing to the largely intrinsic nature of HM. Finally, participants with optic disc tilt, optic disc rotation, peripapillary atrophy, and peripapillary intrachoroidal cavitation were not excluded from the sample because the criteria for exclusion exclusively pertained to maculopathy, and fundus photographs provided a restricted view of these pathological alterations. In addition, we performed an added analysis by adjusting these optic disc pathologies as confounders and found the significant associations between ChT and BCVA in each grid remaining robust (Supplementary Table S6).

Conclusions

In HM population without myopic maculopathy, a thinning ChT in each ETDRS grid of the posterior fundus was found to be an independent risk factor for the uncorrectable worsening of visual acuity after adjusting for age, sex, and AL. This manifestation of thin ChT warrants particular atten-

tion in male patients and those aged 40 years and older. Our findings shed light on the important role of ChT in an individual's visual function. Further research is warranted to investigate the underlying mechanism and causality between ChT and visual acuity.

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