

Effect of short-wavelength light on subfoveal choroidal thickness with induced hyperopic defocus in young adult emmetropes



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ABSTRACT

Purpose: This study aimed to investigate the effect of short term exposure to shorter wavelengths and induced hyperopic defocus on subfoveal choroidal thickness (SFCT).

Materials and methods: A pre- and post-quasi experimental study was conducted in the diagnostic department of a tertiary eye care hospital using judgmental sampling technique. Visual acuity and refractive status were measured using logMAR and a Retinoscope. Dual exposure included 405 nm laser for 60, 120, and 180 s, and an android phone in blue mode for 2 h with hyperopic defocus. Subfoveal choroidal thickness was measured with OPTOVUE AVANTI spectral domain-optical coherence tomography (SD-OCT). Data entry and analysis were done with JAMOV.

Results: The study included 30 subjects with a mean age of 20.67 (± 0.96) years, ranging from 19 to 23 years. In terms of SFCT measurements before and after defocus at various intervals of blue light exposure, significant changes were observed. The mean pre-defocus subfoveal choroidal thickness (PDSFCT) was 298.23 (± 45.44) μm , increasing to 320.53 (± 51.89) μm after defocus (ADSFC). This change was statistically significant, as indicated by a paired sample t-test ($t = -4.805$, $p < 0.001$) after 2 h of android phone in full blue mode with hyperopic defocus. Similarly, significant differences were noted at 60 sec. ($t = -3.796$, $p < 0.001$), 120 s ($t = -2.013$, $p = 0.027$), and 180 s ($t = -2.028$, $p = 0.026$) of blue light exposure.

Conclusion: Exposure to shorter wavelengths induces an increase in subfoveal choroidal thickness that is independent of defocus.

Key words: hyperopic defocus, subfoveal choroidal thickness, shorter wavelength

HIGHLIGHTS

Short-wavelength light exposure significantly increases subfoveal choroidal thickness (SFCT).

Combined exposure to blue light and hyperopic defocus shows minimal additive effect. Choroidal thickness demonstrates rapid responsiveness to short-term light exposure. Findings may contribute to understanding light-based modulation in myopia development.

INTRODUCTION

The choroid, a component of the eye's middle tunic, develops from surrounding mesenchyme during embryonic growth, distinct from the retina and retinal pigment epithelium. It comprises blood vessels, melanocytes, and supportive tissue, serving functions such as oxygen supply, light absorption, and intraocular pressure modulation. Choroidal thickness adjusts in response to optical defocus, playing a role in refractive adjustments and myopia development in various animal models. Mechanisms underlying choroidal blood flow regulation and its correlation with ocular development remain under investigation [1]. This occurs in situations that impose myopic defocus, either by wearing positive spectacle lenses or by removing the diffuser from an eye that had developed deprivation-induced myopia. The same applies to hyperopic defocus [2].

Blood flow in the choroid during recovery is believed to precede choroidal thickening, suggesting a role in subsequent thickness changes. The regulation of choroidal blood flow and its impact on ocular development remain unclear, with researchers suggesting the involvement of non-vascular smooth muscles along choroidal vessels [3]. Studies on animal models demonstrate that optical defocus can induce refractive errors, with mechanisms similar to those observed in human myopia, shedding light on the study of myopia development [4]. Additionally, the use of plus or minus lenses can alter emmetropization, with induced hyperopic defocus consistently stimulating axial elongation across species, contributing to myopia progression [5].

Concerns about the impact of artificial light on health, particularly blue light emitted by digital devices, have emerged due to its potential to affect ocular components and disrupt circadian rhythms [6]. Animal studies suggest a relationship between the chromaticity of light and eye growth, with blue light exposure implicated in accelerated ocular growth, possibly influencing myopia development [7]. The presence of intrinsic choroidal neurons in humans underscores the importance of subfoveal choroidal thickness (SFCT), with potential involvement of the autonomic nervous system in its regulation [8]. Optical coherence tomography offers a non-invasive assessment of choroidal thickness in humans, aiding in the understanding of ocular health and developmental processes [9].

This study sought to determine the impact of hyperopic defocus on SFCT, as previous research suggested that hyperopic defocus on the peripheral retina may be a risk factor for human myopia [10]. Myopia progresses due to a lack of proper management and is linked to an increased risk of retinal detachment from choroidal thinning and scleral stretching, glaucoma, cataract, and myopic retinopathy. Previous research indicates that myopic patients have more accommodative lag, which causes hyperopic defocus during close work and serves as a warning sign of increased myopia [11].

MATERIALS AND METHODS

A pre- and post-quasi-experimental study was conducted in the diagnostic department of a tertiary eye care hospital. Non-probability judgmental sampling technique was used to collect data. The sample size for this study was calculated to be 30 using the online software OpenEpi Version 3. A 50% prevalence was used, the confidence level was set at 95%, and the confidence limit was set at 5%. Young adults aged 18–25 years with normal ocular health, no manifest eye deviation, and visual acuity of 0 logMAR or better in each eye at 6 m and 40 cm distances were included in the study. Individuals with systemic illnesses that affect choroidal thickness were excluded from the study. All participants were examined between 8:30 am and 11:30 am to reduce the impact of diurnal fluctuation. The study involved measuring the SFCT in the right eye of the subjects using OPTOVUE AVANTI spectral domain-optical coherence tomography (SD-OCT). Following SFCT measurements, the eye was exposed to shorter wavelength blue light for 60 s, 120 s, and 180 s. Using the OPTOVUE AVANTI SD-OCT, a series of SFCT measurements were taken following exposure to blue stimuli at baseline, and at 60, 120, and 180 s after stimulus offset from the right eye. The right eye was undilated for this experiment to maintain a consistent amount of induced defocus throughout the trial.

To investigate the combined impact of blue light exposure and SFCT modifications due to short-term optical blur, measurements were repeated after 2 h of exposure to defocus. To induce hyperopic defocus, participants wore a -3.00 DSph spectacle lens in front of the right eye for 2 h. Subjects watched a movie binocularly at 1 m with maximum brightness and full blue mode while sitting in a dimly lit room during the 2-hour defocus period. Vergence and accommodation cues have been demonstrated to sustain defocus in the intended eye under these binocular conditions with -3 D defocus in one eye. The thickness was measured before and after the subjects were exposed to shorter wavelengths and underwent defocus for 2 h. The pre- and post-defocus SFCT was compared, and the data was analyzed using a dependent paired sample t-test in JAMOVİ.

RESULTS

A detailed analysis of the socio-demographic and clinical characteristics of 30 study subjects is presented, focusing on age distribution, gender ratio, visual acuity in the right eye (VAOD), and spherical equivalent refraction of the right eye (SEROD). The subjects, with an average age of 20.67 years and a narrow age range 19–23 years, consist of 4 males and 26 females. They exhibit consistent visual acuity measurements and slight variability in the spherical equivalent. Additionally, a comparative analysis of pre-defocus and post-defocus subfoveal choroidal thickness measure-

ments under different time intervals of blue light exposure is conducted. It highlights significant differences between pre-defocus and post-defocus measurements across all intervals. This analysis employs paired sample t-test analyses, revealing negative effect sizes. This indicates that pre-defocus measurements tend to be smaller than post-defocus measurements, thus providing valuable insights into the impact of blue light exposure on choroidal thickness.

TABLE 1

Descriptive socio-demographic and clinical characteristics of study subjects.

	N	Mean ($\pm$ SD)	Range
Age (years)	30	20.67 ($\pm$ 0.96)	19–23
Male	4	20.50 ($\pm$ 0.00)	19–21
Female	26	20.54 ($\pm$ 0.00)	19–23
VAOD	30	0.00 ($\pm$ 0.00)	0.00–0.00
SEROD	30	0.09 ($\pm$ 0.10)	0.00–0.25

SEROD – spherical equivalent right eye; SD – standard deviation; VAOD – visual acuity right eye.

Table 1 summarizes the socio-demographic and clinical characteristics of 30 study subjects. On average, the subjects were 20.67 years old, with a narrow age range from 19 to 23 years. Among them, 4 were male and 26 were female, with uniform ages within each gender group. Visual acuity in the right eye was consistently measured at 0.00, indicating no variability among subjects. The spherical equivalent of the right eye averaged 0.09, with a slight variability observed, ranging from 0.00 to 0.25. Overall, the table provides a concise overview of the study population's key characteristics, including age, gender distribution, visual acuity, and spherical equivalent of the right eye.

TABLE 2

Comparative analysis of pre- and post-defocus sub-foveal choroidal thickness measurements at different time intervals of blue light exposure.

N = 30	Mean ($\pm$ SD)	SD of mean	95% Confidence Interval Mean		Range
			Upper	Lower	
PDSFCT	298.23 ($\pm$ 45.44)	8.297	315.20	281.26	152–396
ADSFCT	320.53 ($\pm$ 51.89)	9.473	339.91	301.16	167–408
PD 60 s	308.53 ($\pm$ 44.44)	8.114	325.13	291.94	182–402
AD 60 s	325.67 ($\pm$ 49.43)	9.025	344.13	307.21	213–414
PD 1:20 s	315.10 ($\pm$ 44.70)	8.162	331.80	298.41	186–414
AD 1:20 s	322.83 ($\pm$ 48.93)	8.933	341.10	304.56	182–414
PD 1:80 s	314.93 ($\pm$ 48.33)	8.823	332.98	296.89	167–424
AD 1:80 s	324.10 ($\pm$ 48.98)	8.942	342.39	305.81	176–399

AD – after defocus; ADSFCT – after defocus subfoveal choroidal thickness; N – sample size; PD – pre-defocus; PDSFCT – pre-defocus sub-fovea choroidal thickness; SD – standard deviation.

Table 2 presents a comparative analysis of pre- and post-defocus subfoveal choroidal thickness measurements at different time intervals of blue light exposure. The table includes data from 30 subjects, showing the mean values along with standard deviations, standard errors of the mean, and 95% confidence intervals. The measurements are categorized into pre-defocus subfoveal choroidal thickness (PDSFCT) and after defocus subfoveal choroidal thickness (ADSFCT) at various time intervals of blue light exposure, ranging from 60 s to 80 s. The range of measurements varies, with PDSFCT ranging from 152 to 396, and ADSFCT ranging from 167 to 408.

TABLE 3

Paired sample t-test analysis of pre- and post-defocus subfoveal choroidal thickness measurements at different time intervals of blue light exposure.

N = 30	t	df	p	Cohen's d	SE Cohen's d
PDSFCT–ADSFCT	-4.805	29	<0.001	-0.877	0.109
PD 60 s–AD 60 s	-3.796	29	<0.001	-0.693	0.105
PD 1:20 s–AD 1:20 s	-2.013	29	0.027	-0.368	0.083
PD 1:80 s–AD 1:80 s	-2.028	29	0.026	-0.370	0.096

AD – after defocus; ADSFCT – after defocus subfoveal choroidal thickness; df – degrees of freedom; N – sample size; PD – pre-defocus; PDSFCT – pre-defocus sub-fovea choroidal thickness; SE – standard errors.

Table 3 presents the results of paired sample t-test analyses comparing pre and post defocus subfoveal choroidal thickness measurements at different time intervals. The table includes data from 30 subjects, showing the t-values, degrees of freedom (df), p-values, Cohen's d effect sizes, and standard errors of Cohen's d. Each row represents a specific time interval, such as 60 s or 1:20 s, comparing PDSFCT to ADSFCT. The results indicate significant differences in choroidal thickness between pre and post defocus measurements across all time intervals, with negative Cohen's d values indicating that pre-defocus measurements tend to be smaller than post-defocus measurements.

DISCUSSION

In the current investigation, short-term exposure to hyperopic defocus resulted in a significant change in SFCT in young emmetropic adults. Hyperopic defocus was induced in 30 eyes of 30 patients for 2 h along with screen exposure. The study demonstrated that there is an increased SFCT after defocusing, with a mean difference of -22.3 ($\pm$ 25.42) ($p < 0.001$). The study also showed that choroidal thickness changes within seconds in response to blue light. For 60 s of exposure, SFCT increased with a mean difference of -10.3

(± 12.72) ($p < 0.001$). After 120 s and 180 s of exposure to blue light, SFCT changed significantly compared to baseline, with a mean difference of $-16.87 (\pm 17.34)$ ($p < 0.001$) for the former and $-16.70 (\pm 20.94)$ ($p < 0.001$) for the latter. Results showed that after defocus, there was no significant increase in SFCT with short-term exposure to blue light for 60 s ($p = 0.73$), 120 s ($p = 0.476$), and 180 s ($p = 0.329$). When we studied the combined effect of hyperopic defocus and short-term exposure to blue light after defocus, there was no significant change in choroidal thickness compared to baseline.

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vs. $3.04 (\pm 0.60)\%$ vs. $-1.34 (\pm 0.74)\%$. The magnitude of choroidal thickening in the eyes recovering from hyperopic defocus after 2 h was greater than that at the 1-hour interval ($p < 0.01$, paired t-test) [13].

Despite the same amount of defocus, the choroidal response to myopic and hyperopic defocus differed quantitatively. There were more alterations in hyperopic defocus. This contrasts sharply with the choroidal response in chicks, where the choroid is more responsive to myopic defocus even when the same amount of hyperopic and myopic defocus is projected into the eye at the same time [14]. As a result, whereas both human and chick choroids responded to optical defocus in qualitatively comparable ways (thinning and thickening), the quantitative responses were considerably different. The precise mechanism underlying these choroidal changes is unknown; however, changes in the tone of choroidal non-vascular smooth muscle or changes in choroidal blood flow have been proposed as two probable reasons for alterations in choroidal blood flow in eyes recovering from retinal image-mediated ocular growth [4]. Human research has shown that choroidal blood flow can be influenced by visual input (e.g., light-dark transitions, flickering blue light) [15, 16]. Future research into the effect of defocus on choroidal blood flow may help us understand the underlying cause of defocus-induced choroidal thickness changes in humans.

The above studies demonstrate that hyperopic defocus always leads to choroidal thinning as it is considered a stimulus for myopia and causes myopiagenesis. However, according to the current investigation, hyperopic defocus causes choroidal thickening. The discrepancy could be attributed to shorter wavelengths emitted by screen exposure. According to a study, short-term exposure to narrowband blue and red light induced differential responses in choroidal thickness. A paired t-test comparing the change in choroidal thickness between experiments found that red light and dark exposure thinned the choroid more than blue light exposure ($p = 0.006$ and 0.006). The 1-hour choroidal thickness change was not significantly different between broadband and blue light exposure ($p = 0.06$) [17]. Blue light exposure had no significant change in choroidal thickness. According to Yu et al., short-wavelength light is protective against lens-induced myopia in guinea pigs through a retinoic acid mechanism. Reduced retinal retinoic acid levels seen during short-wavelength exposure may mediate inhibited eye growth under short wavelengths [18]. The authors reported a small but statistically significant increase in choroidal thickness after light therapy for 30 min every morning for 1 week. Light therapy was delivered using glasses that emitted 506 lux of blue-green light with a peak wavelength of 500 nm, which is close to the peak sensitivity of ipRGCs [19]. After being exposed to blue light for a short period, the choroidal thickness significantly increased and axial length decreased. Blue light significantly increased choroidal thick-

ness in the current investigation and prevented the lens's ability to cause hyperopic defocus [20].

This research has some limitations. First, it only measured SFCT. Secondly, the study did not compare the effects of myopic and hyperopic defocus on SFCT. Lastly, the current study does not take into account ocular biometry, which is crucial for controlling eye growth.

CONCLUSION

Exposure to shorter wavelengths induces an increase in SFCT that is independent of defocus. A significant increase in SFCT was noted after inducing hyperopic defocus. When assessing the combined effect of defocus and shorter wavelength after inducing hyperopic defocus, the effect of the shorter wavelength was found to be minimal.

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Zahra Batool: conceptualization, data collection, data analysis, manuscript drafting.

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Muqadas Shahzadi: data entry and statistical assistance.

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The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.