• Clinical Research •

Impact of LED exposure on contrast sensitivity and protective efficacy of blue-blocking lenses

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Abstract

● **AIM:** To measure the contrast sensitivity (CS) using computer-based Chart2020 software pre- and post-white light exposure with and without blue-blocking lenses (BBLs).

● **METHODS:** The study included participants aged 18 to 25y (*n*=30 eyes), where baseline CS was measured before the experiment. Following this, the participants were exposed to two white light-emitting diodes (LEDs; 450 lx each), placed at a 45-degree angle from the participant's eye and 80 cm from the light source. All participants were randomly divided into three groups (BBL1- Placebo lens, BBL2- Crizal Prevencia, BBL3- Duravision) by sequential randomisation, which was double-blinded. Post-light exposure, the CS was measured monocularly with a calibrated computer-based CS Chart-2020 software at different log units.

● **RESULTS:** CS measured using Chart-2020 software at 0.8, 1.5, 6, 12, and 18 cpd pre- and post-white LED exposure with and without BBLs showed a significant difference (P<0.05) in contrast threshold and log contrast at 6 cpd and 18 cpd (P<0.05) and showed no significant differences in 0.8, 1.5, 12 cpd (P>0.05).

● **CONCLUSION:** This study shows that exposure to white LEDs can diminish CS, while BBLs may ameliorate these negative effects.

KEYWORDS: white light-emitting diodes; circadian rhythm; retinal toxicity; blue-blocking lenses; contrast sensitivity

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INTRODUCTION

The accelerated development of light-emitting diodes (LEDs) in the market and their advantages have led to the usage of LEDs as the primary light source in recent years. These light sources have greater efficiency, a narrow spectrum and are long-lasting compared to incandescent and fluorescent lamps[1-2]. LEDs are versatile and wavelength-specific, with a peak emission range of ~250 to ~760 nm[2]. Although LEDs are more advantageous than other light sources, such as fluorescent lamps and incandescent bulbs, cumulative exposure to LEDs results in photophobia, headaches, and dry eye symptoms.

In the visible spectrum (380-700 nm), blue light ranges from 400-495 nm. Constant exposure to blue wavelength might impact both the image-forming and the non-image-forming vision. Specifically, the most harmful blue wavelength range is 415- 455 nm[3]. Exposure to blue light has been known to cause inimical effects on the retinal pigmented epithelium and photoreceptor through excessive reactive oxygen species (ROS) production[4-5]. It causes retinal photopic injury through photothermal, photochemical, and photomechanical mechanisms[6-8], photochemical damage being the standard type. Long-term exposure to blue light results in ocular conditions such as age-related macular degeneration (ARMD), cortical cataracts, digital eye strain, dry eyes and eye fatigue. Exposure to light during the night-time results in an interrupted circadian rhythm due to melatonin suppression[6,8-9].

The currently available blue-blocking lenses (BBLs) in the market, both in the form of spectacle lenses and intraocular lenses, claim to inhibit the transmission of the harmful blue wavelength range (415-455 nm) while preserving the beneficial range of blue wavelength. These BBLs claim to reduce eyestrain, enhance sleep quality, prevent retinal toxicity, slow the progression of ARMD, and partially protect the

degeneration of hippocampal and visual cortex neurons and behavioural deficits[10-11]. Lian *et al*[12], in a study, revealed that two different BBLs (15% and 30%) did not have a protective effect on contrast sensitivity (CS) when tested using the CSV-1000 CS test and sleep quality[13]. In a previous rodent model study, BBLs protected visual cortex pyramidal neurons against chronic exposure to high levels of short-wavelength LEDs[14]. However, it remains unclear how exposure to blue light affects CS. Our study focuses on filling a knowledge gap by evaluating the effects of high levels of blue light exposure on CS. We also investigated whether BBLs, such as Crizal Prevencia (CP) and Dura Vision Blue Protect (DV), can enhance CS measures after exposure to blue light.

PARTICIPANTS AND METHODS

Ethical Approval The Institutional Ethics Committee (IEC1:135/2022) at Kasturba Medical College, Manipal Academy of Higher Education in India, has approved this experimental cross-over study design. A standardised protocol was maintained, and the eligible participant was enrolled following written informed consent.

The participants included were required to fall in the age range of 18-25y with best corrected visual acuity (BCVA) of logMAR 0.00, stereopsis of ≤40 arc seconds without any ocular abnormalities were enrolled for the study and paradox to the inclusion criteria, that could be triggered or worsened by exposure to high-intensity light and subjects who underwent a refractive surgery were excluded.

A comprehensive ocular examination was performed, and the subjects were recruited for the study. The examination included testing for unaided distance visual acuity using logMAR chart and near vision using the N-notation, objective and subjective refraction, anterior and posterior segment examination using slit lamp (Haag-Strait USA), stereopsis using Frisby, intraocular pressure (IOP) using I-care tonometer (I-care Finland oy. Centervue S.p.A., I-care Finland oy and I-care USA Inc.)

Display Setting and Contrast Measurement The computer-based contrast sensitivity (chart 2020) and Spyder 4-Express 4.5.9 display calibration software were installed in the HP ProBook laptop [HP ProBook 440 G8 (HP, 2020)]. The display brightness and colour were calibrated to 85 cd/m^2 in a dark room to maintain the same testing luminance between each subject. The maximum display brightness was 250 cd/m^2, calibrated to 85 cd/m^2 in a dark room, and maintained at the same testing luminance between subjects. The display luminance calibration is performed for each subject to ensure consistent measurement across trials.

Following recruitment, the subjects [*n*=34 (eyes)] were dark adapted for 20min before beginning with the testing procedure for the absolute intensity threshold. Two white LEDs were placed at 45 degrees and 80 cm from the subject (Figure 1). Subjects were instructed to refrain from looking at the white LEDs. The baseline contrast sensitivity was measured using (chart-2020) software, and the grating was presented at 0.8, 1.5, 3, 6, 12, and 18 cycles per degree (cpd) at 1 m. Following this, the subjects were exposed to white LEDs for 10min. Post-exposure contrast sensitivity measurements were collected. A washout period of 10min, using amber lights was given for each subject, and they were given a reading task at 40 cm. Following the washout period, the subjects were again exposed to white LEDs for 10min with the reading task at 1 m (Figure 1). During the second exposure, the subjects were instructed to wear either of the lenses: type I (Placebo lens; PL), type II (CP), or type III (DV), according to sequential randomisation. Post-exposure, the contrast sensitivity was measured again. The baseline measurements were compared to the measurements acquired along with the three types of lenses to assess the protective efficacy of BBLs, if any. It was a double-blinded study, where both the examiner and the subjects were blinded.

Figure 1 Experimental setup, including light used and wraparound spectacle frame with blue light blocking lenses (BBL).

Statistical Analysis The statistical analyses were performed using GraphPad Prism software (Version 7.00; ©2023 GraphPad Software). The dataset was assessed for normality using the Kolmogorov-Smirnov test, confirming that the data followed a normal distribution. To evaluate differences in demographic variables among the three groups, a Chi-square test was conducted. For the normally distributed data, repeated measures analysis of variance (RM-ANOVA) was used to analyse variations across different spatial frequencies and log contrast sensitivity (logCS) within the groups, with post hoc comparisons conducted using Tukey's multiple comparison Tests. P<0.05 was considered statistically significant.

RESULTS

A total of 17 participants (*n*=34 eyes) were recruited for this study, and 2 participants were excluded from the study due to

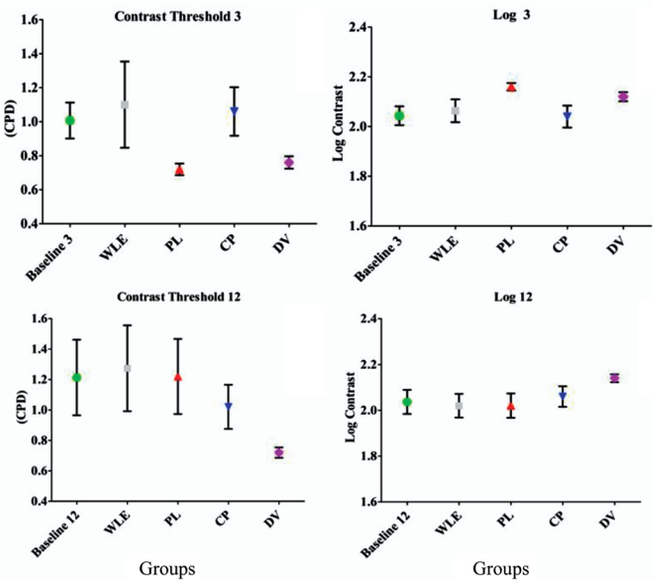

Figure 2 Contrast sensitivity threshold and log contrast measurements with and without BBL (blue blocking lenses) in the 3 to 12 log range PL: Placebo lenses; CP: Crizal Prevencia; DV: Duravision Blue; WLE: White light exposure. The Y-axis of the contrast threshold shows cycles per degree (cpd), while the X-axis serves as a baseline against other tested groups.

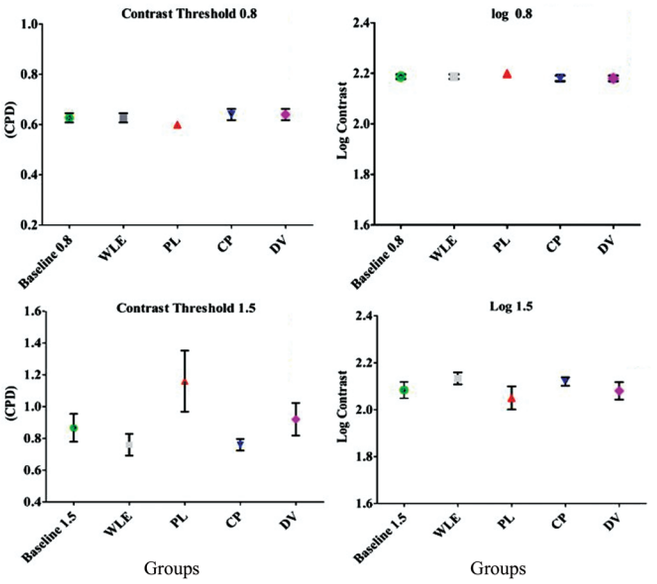

Figure 3 The contrast sensitivity threshold and log contrast are compared with and without blue blocking lenses (BBL), ranging from 0.8 to 1.5 log PL: Placebo lenses; CP: Crizal Prevencia; DV: Duravision Blue; WLE: White light exposure.

photophobia and migraine. Therefore, a total of 15 subjects (n=30 eyes) were included with a mean age of (21.27± 2.251), with five male subjects (n=10 eyes) and ten female subjects (n=20 eyes) with a spherical equivalent of ±0.50 D.

The contrast sensitivity measurements at various spatial frequencies (cpd) were compared across different groups. The results revealed no significant difference across the different groups including the exposure and the treatment (lens) group at 0.8, 1.5, 3, and 12 cpd (P>0.05, $F_{4,29}$=2.168) and logCS (P>0.05, $F_{4,29}$=1.242), 3.0 cpd (P>0.05, $F_{4,29}$=1.648) logCS (P>0.05, $F_{4,29}$=2.403) and 12.0 cpd (P>0.05, $F_{4,29}$=1.274) and logCS (P>0.05, $F_{4,29}$=1.2035) respectively (Figure 2). This shows the variation of logCS detected post-light exposure, light exposure with BBLs, and white light exposure (WLE) with PL, as shown in the experiment.

A one-way RM-ANOVA observed no significant effect of CP, DV and PL type ($F_{4,29}$=0.7838, P<0.000), indicating that logcpd depended on the type of BBLs. Post-hoc comparisons test (Tukey corrected for multiple comparisons assuming an α 0.05) showed that both the CP (mean difference, logcpd, P=0.00) and defocus blur (DB; mean difference, logcpd, P=0.00) lenses produced significantly lower CS than the PL. However, the BBLs and PL were not substantially different from the light exposure groups of 0.8 cpd. No significant difference was observed in the contrast threshold at 1.5, 3, and 12 cpd (Figure 3).

The 6.0 cpd, contrast sensitivity showed a significant difference (P=0.0041, $F_{4,29}$=4.051) with post-hoc between

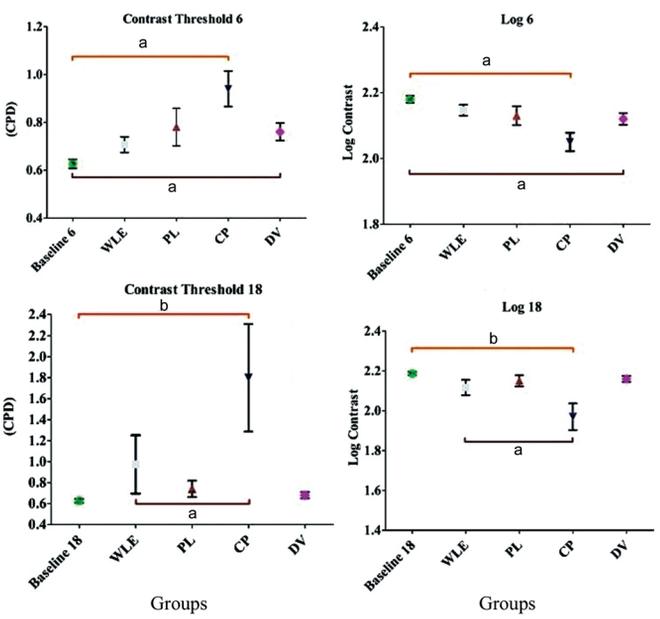

Figure 4 The contrast sensitivity threshold and log contrast are compared with and without blue blocking lenses (BBL), ranging from 6 to 18 log PL: Placebo lenses; CP: Crizal Prevencia; DV: Duravision Blue; WLE: White light exposure. [a]P<0.05; [b]P<0.01.

baseline (BL) 6.0 *vs* CP and BL 6.0 *vs* DV showed a significant difference (P<0.05; Figure 4) and no significance was found between (P>0.05) BL 6.0 *vs* WLE, BL 6.0 *vs* PL and WLE *vs* PL with multiple comparisons (Figure 4). At 18.0 cpd, it showed a significant difference in contrast threshold (P=0.009, $F_{4,29}$=3.489) and logCS (P=0.003, $F_{4,29}$=4.145). The post-hoc comparison showed a significant difference between BL 18.0 *vs* CP and WLE *vs* CP (P<0.05) and found no significance in contrast sensitivity between BL 18.0 *vs* WLE, BL 18.0 *vs* PL and another possible comparison (P>0.05; Figure 4).

DISCUSSION

Our study assessed the impact of two frequently prescribed BBLs (CP and DB)[15] on contrast sensitivity, measured both before and after exposure to white LEDs, and the results were compared with the control groups. Our findings indicate a significant reduction in contrast sensitivity at spatial frequencies of 6 and 18 cpd when comparing the WLE group to the BBLs group (CP and DB). In contrast, no significant differences were observed between the WLE and BBL groups at spatial frequencies of 0.8, 1.5 cpd, and 3 cpd. Pupillary size can influence contrast sensitivity as it negatively affects CS at both ends of the visible spectrum, and minimising the blue spectrum of light might reduce the contrast sensitivity[12,15] as a lower spectrum of light affects the pupillary size and modulation[16]. Furthermore, BBLs that transmit less blue light resulted in more significant decreases in colour contrast sensitivity and were found to influence colour contrast thresholds[17]. As the lower spectral (blue) wavelength influences the pupillary dynamics[16], this could also be one of the reasons for the reduction of CS at 1.5, 3 of the lower ends and 18 at the higher end. The contrast threshold and logCS measured with BBLs significantly reduced contrast sensitivity, increasing error at low and high spatial frequencies. The BBL lens with more than 70% blue light transmission properties showed no decrease in visual performance[18].

The CS worsens in an indoor environment with filters[12], and on the other hand, more exposure to white light in their daily life activities may perhaps cause retinal toxicity[19-20], disruption in circadian rhythm[21] and the suppression of melatonin[22] and further damage the visual cortex[23-24] with changes in contrast sensitivity; however, CS measurements were higher in amber light conditions as compared with white LED conditions this may be an adjusted ability to differentiate an object from the background under the ambient light compared to white LEDs. White LEDs have a higher blue component known to cause photobleaching that could temporarily reduce contrast sensitivities.

The BBLs protect the human eye and maintain a regular biological clock from short wavelengths of light[25]. However, these lenses degrade an individual's visual performance while maintaining average physiological performance by decreasing the amount of light entering the eye, eye strain, symptoms related to dry eye and increasing melatonin secretion, and degradation of visual performance depends on the yellow colour of the lens, material used and contrast of an individual[7]. Since this pilot study was done in a pre-clinical setting, the significance of this study may not apply in all situations, so further study is required to understand the effect of BBLs on contrast sensitivity, particularly in real-world conditions on real-world objects.

In conclusion, we observed that exposure to white LEDs for 20min might decrease contrast sensitivity. However, this effect can be significantly mitigated by using either BBLs or PL. It is also worth noting that high-quality spectacle lenses can help reduce the potential negative impacts of LED exposure on contrast sensitivity.

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Data Availability Statement: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: Monterio D, None; **Kumar EOAM,** None; **Ghosh M,** None; **Poojary R,** None; **Jose J,** None; **Jathanna JS,** None; **Bhandarkar M,** None; **Theruveethi N,** None.

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