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ORIGINAL ARTICLE

Effect of blue cut glasses on color discrimination and contrast sensitivity in young emmetropes

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ABSTRACT

Objectives: To evaluate the effects of blue-cut glasses on visual functions, specifically color discrimination (CD) and contrast sensitivity (CS), in young emmetropes.

Methods: This interventional study was conducted at Hayatabad Medical Complex and Pakistan Institute of Community Ophthalmology, Peshawar, Pakistan, from 10-09-2022 to 10-04-2023. A total of 80 emmetropes aged 18–30 years with 6/6 vision were included, while individuals with ocular or systemic conditions affecting vision were excluded. Visual functions were assessed using the Ishihara test for color blindness, Pelli-Robson chart for contrast sensitivity, and FM 100 Hue test for color discrimination. Participants were tested with and without blue-cut glasses in randomized sessions to avoid fatigue or memorization effects. Data were analyzed using paired t-tests, with a p-value of <0.05 considered statistically significant.

Results: A total of 80 participants (55% male, 45% female) with a mean age of 25.37±2.99 years were included. Mean color discrimination (CD) score was 27.35±26.99 with non-blue-cut glasses and 34.05±28.33 with blue-cut glasses, showing a statistically significant difference (p = 0.004). The mean contrast sensitivity (CS) score was 1.92 ± 0.07 without blue-cut glasses and 1.91±0.08 with blue-cut glasses, with no statistically significant difference (p = 0.117). These findings indicate that blue-cut glasses negatively affect color discrimination but have no significant impact on contrast sensitivity.

Conclusion: Blue-cut glasses negatively impact color discrimination while showing no significant effect on contrast sensitivity in young emmetropes. These findings highlight the importance of evaluating the trade-offs between the protective and visual effects of blue-cut glasses.

Keywords: Blue-cut glasses (Non-MeSH); Color vision (MeSH); Color discrimination (Non-MeSH); Contrast (MeSH); Contrast Sensitivity (MeSH).

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INTRODUCTION

In 2021, there were approximately six billion smartphone users worldwide, a number projected to rise to eight billion by 2026. [1] During the COVID-19 pandemic, around one billion people began remote learning, while an estimated 300 million transitioned to working from home. [2] This surge in digital device usage has significantly increased the global demand for blue-cut lenses, as these are believed to offer subjective visual comfort and mitigate the potential hazards of blue light exposure. [3,4]

Short-wavelength blue light (415–455 nm) within the visible spectrum is associated with eye damage. Primary sources include sunlight and artificial light from digital screens and light-emitting devices, often producing blue light near international exposure limits.[5] Blue-filtering lenses are designed to protect against blue light, which is implicated in disrupting neuronal functions,[6,7] damaging photoreceptors,[8] and increasing the risk of age-related macular degeneration.[9] With the widespread use of blue-rich LED display devices such as smartphones, tablets, and computers, our eyes are now exposed to more blue light than ever before. To address potential photochemical harm, innovative ophthalmic aids like intraocular and spectacle lenses have been developed.[10] These lenses employ filtering elements or surface coatings to limit the transmission of short wavelengths (400-460 nm).[11]

However, a critical challenge with blue-light-blocking lenses is balancing the reduction of harmful wavelengths with the preservation of essential visual functions such as contrast sensitivity and color discrimination. Blue light plays a vital role in visual tasks like color perception and night vision.[12,13] This emphasizes the need to evaluate the potential benefits and unintended effects of blue-light-blocking optical instruments.

While high-energy blue light poses risks to the eyes, some blue wavelengths are necessary for normal vision. Studies indicate that the unintended impact of blue-cut lenses on visual functions like contrast sensitivity and color discrimination has not been fully assessed.[14,15] This gap in knowledge is particularly critical given the rapid rise in screen time across diverse age groups. Young emmetropic individuals, who often experience optimal vision without correction, are an ideal population for investigating how blue-cut lenses may alter key visual functions. This study, therefore, aimed to evaluate the effects of blue-cut glasses on contrast sensitivity and color discrimination in young emmetropes, addressing a significant gap in the understanding of their benefits and limitations.

METHODS

This interventional study was conducted at the Ophthalmology Department of Hayatabad Medical Complex and Pakistan Institute of Community Ophthalmology, Peshawar, Pakistan, from September 10, 2022, to April 10, 2023. Ethical approval was obtained from the Hospital Research and Ethics Committee of Hayatabad Medical Complex (HMC) under reference number 903, vide letter # HMC-QAD-F-00 dated September 6, 2022. The sample size was calculated using "statulator.com" based on an expected mean difference of 8%, standard deviation (SD) of 20, power of 90%, and a two-sided significance level of 5%. This resulted in a required sample size of 70 participants per group, accounting for a 10% dropout rate, leading to a total sample size of 80 participants.[16] Non-probability convenience sampling was employed.

Inclusion and exclusion criteria: Participants were emmetropic individuals aged 18–30 years with 6/6 vision. Exclusion criteria included individuals with ocular diseases, opacities, congenital or acquired color vision deficiencies, a family history of color vision deficiency, PPK (primary phakic keratopathy) patients, elevated intraocular pressure (IOP), or systemic diseases.

Procedures: Participants underwent visual acuity testing using the Snellen visual acuity chart at 6 meters and the LogMAR chart at 4 meters, tested monocularly. The Ishihara test was performed to detect congenital color blindness, and refractive error assessments were conducted using automated refractive error testing and retinoscopy. Fundoscopy was performed by an ophthalmologist to identify any pathology affecting color vision or contrast sensitivity. Detailed medical histories were also recorded.

Contrast sensitivity measurement: Contrast sensitivity (CS) was measured binocularly using the Pelli-Robson contrast sensitivity chart at a 1-meter distance. The "Letter-by-Letter" scoring method was employed, with each correct letter assigned a value of 0.05 log. The endpoint was defined as two or more incorrect letters in a triplet. Changes in contrast sensitivity were categorized as mild (0.5 log), moderate (0.10 log), and severe (>0.10 log). Results were recorded using the standard Pelli-Robson contrast sensitivity (PR) sheet.

Color discrimination assessment: Color discrimination was evaluated using the Farnsworth-Munsell (FM) 100 Hue test under standard conditions at a 50 cm distance and a 60° viewing angle. The total error score (TES) was calculated, with TES categorized as superior (0–20), average (21–100), and low (>100). 17

Lens selection and testing: A survey of commonly available and prescribed blue-cut lenses was conducted, and a lens with a 60% blue-light-blocking capability was selected. The blue light transmission properties of the lenses were confirmed using the Supare LM800 auto lens meter. To ensure consistency, the same lens type and material were used for both blue-cut and non-blue-cut filters. Participants were provided with blue-cut and plano glasses for testing, and their color discrimination and contrast sensitivity were assessed using the FM 100 Hue test and Pelli-Robson contrast sensitivity chart, respectively.

Study protocol: Participants were randomized to avoid memorization or fatigue that could influence the results. Both contrast sensitivity and color discrimination were assessed on separate days to minimize bias. Blue-cut and plano glasses were provided to all participants, and measurements were taken using the Pelli-Robson contrast sensitivity test and FM 100 Hue test for both lens conditions. The mean differences in contrast sensitivity and color discrimination with and without blue-cut lenses were calculated and statistically analyzed.

RESULTS

A total of 80 participants were included in the study, with 44 (55%) males and 36 (45%) females. The mean age of participants was 25.37 ± 2.99 years (Table I).

Color discrimination: Without blue-cut glasses, 40 (50%) participants demonstrated superior total error scores (TES), 39 (48.8%) had average TES, and 1 (1.2%) had low TES. With blue-cut glasses, 34 (42.5%) participants had superior TES, 42 (52.5%) had average TES, and 4 (5%) had low TES. A paired t-test revealed a statistically significant difference in color discrimination scores between conditions, with blue-cut glasses showing a mean improvement (p = 0.004; 95% CI, Table II).

Contrast sensitivity: For contrast sensitivity (CS), without blue-cut glasses, 70 (87.5%) participants had

Table I: Descriptive statistics for continuous data

	Age of subjects (years)	Color discrimination without blue-cut glasses	Color discrimination with blue-cut glasses	Contrast sensitivity without blue-cut glasses	Contrast sensitivity with blue-cut glasses
Mean	25.37	27.35	34.05	1.92	1.91
Median	25.50	17.00	22.00	1.95	1.95
Mode	24.00	8.00	12.00	1.95	1.95
Std. D	± 2.99	± 26.99	± 28.93	± 0.07	± 0.08
Minimum	19.00	0.00	4.00	1.65	1.65
Maximum	30.00	92.00	128.00	1.65	2.00

Table II: Comparing means of color discrimination, contrast sensitivity of no filter glasses, with blue cut glasses

Variables	Mean	SD	SEM	CI 95%		T	p value
				Lower	Upper		
CD without and with blue cut glasses	6.650	20.178	2.256	02.159	1.14	2.94	0.004
CS without and with blue cut glasses	0.0100	±0.0564	0.0063	-0.0025	0.0225	0.584	0.117

CD: color discrimination; CS: contrast sensitivity; SD: Standard deviation; SEM: Standard Error of Mean

normal scores, 6 (7.5%) had mildly reduced scores, and 4 (5%) had severely reduced scores. With blue-cut glasses, 66 (82.5%) participants had normal CS scores, 8 (10%) had mildly reduced scores, and 6 (7.5%) had severely reduced scores. Statistical analysis showed no significant difference in CS scores between the two conditions (p = 0.117; 95% CI, Table II).

DISCUSSION

This study evaluated the effects of blue-cut glasses on color discrimination and contrast sensitivity in young emmetropes. The findings revealed a statistically significant improvement in color discrimination with blue-cut glasses (p = 0.004), as the mean total error score (TES) increased from 27.45 ± 26.99 without blue-cut glasses to 34.05 ± 28.93 with them. However, the effect of blue-cut glasses on contrast sensitivity was minimal and not statistically significant. These results suggest that blue-cut lenses selectively enhance specific visual functions, such as color discrimination, while having a negligible impact on others. This highlights the importance of further research to comprehensively understand their benefits and limitations in visual performance.

According to the normative data for color discrimination on the FM-100 Hue test, a total error score (TES) of 29 is considered the standard deviation (SD) for normal subjects.[18] This aligns with the SD observed in our study. In the present study, a significant improvement in color discrimination was noted with blue-cut glasses compared to the control group (p = 0.004, 95% CI). Similar findings were reported in a previous study where a significant effect on photopic color discrimination was observed using a blue and navy sock color-sorting task.[12] Another study noted a tritan-like (blue-yellow) color defect associated with blue-light-blocking lenses.[19] Similarly, a 2020 study involving five healthy participants aged 23–39 found that blue-blocking lenses impaired color contrast, particularly for blue hues in low-contrast conditions, concluding that such lenses can affect color perception.[20] Additional research has also reported similar findings under low illumination conditions.[21] A pilot study evaluating the long-term use of eight different blue-filtering lenses showed deterioration in blue and yellow color vision using both FM-100 Hue and CAD tests.[22] These findings collectively suggest that while blue-cut lenses may improve certain aspects of visual performance, they can also introduce specific color perception challenges.

Some previous studies have observed no effect on color discrimination when lenses with blue light transmittance reductions of 12-40% were used, finding no significant changes.[23] Similar results were reported in studies that utilized lenses with the lowest blue-blocking abilities.[24] In contrast, our study used lenses that caused a 60% reduction in blue light, which could explain the differences in findings. This observation aligns with a study that reported a direct correlation between higher blue-blocking ability and greater color reduction.[25] Another study, which used the FM-100 Hue test with a TES threshold of 29 as the significance level, found no significant changes in color perception, supporting this variability.[26]

In terms of contrast sensitivity, our study did not show any statistically significant differences between the two groups (p = 0.117, 95% CI). This is consistent with findings from other studies, such as one using the Mars Contrast Sensitivity Chart, where clinical significance was defined as a 0.11-log unit difference and no significant changes were observed.[27] Additionally, studies comparing contrast sensitivity within the same patients28-31 and between different patient groups,[26,32] similarly reported no statistically significant differences.

Conversely, some researchers have reported reductions in contrast sensitivity. For instance, a study conducted in Milan, Italy, noted a reduction in contrast sensitivity when comparing lenses blocking wavelengths at 450 nm.[33] Another study observed improved contrast acuity at low and middle spatial frequencies with glare-reducing tinted lenses.[34] These variations highlight the complex and multifaceted effects of blue-light-blocking lenses on visual performance, emphasizing the need for further investigation.

Limitations of the study and future directions

This study had some limitations. The small sample size and focus on young emmetropes limit the generalizability to other populations. The assessment of short-term effects under controlled conditions does not reflect real-world variability or long-term impacts. Additionally, using a single lens type with 60% blue-light-blocking capability restricted comparisons with other designs, and the study focused solely on color discrimination and contrast sensitivity, omitting other visual parameters.

Future research should include diverse populations, examine long-term effects, and explore the impact of blue-cut lenses in real-world settings. Comparative studies with lenses of varying blue-blocking capabilities are needed to optimize their benefits while preserving visual functions. Expanding the scope to include parameters such as glare sensitivity, night vision, and visual acuity, as well as investigating protective effects against ocular conditions like macular degeneration, will provide a more comprehensive understanding of their utility.

CONCLUSION

This study demonstrates that blue-cut glasses significantly enhance color discrimination as evidenced by improved total error scores on the FM-100 Hue test, but have no notable effect on contrast sensitivity. The findings highlight that blue-cut lenses, particularly those blocking more than 60% of blue wavelengths, can alter hue discrimination. Eyecare providers should consider these effects when prescribing blue-cut glasses to ensure they align with the patient's visual needs and tasks. Further research is needed to explore the long-term effects and practical implications of blue-cut lenses, particularly in diverse lighting and visual task conditions.

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AUTHORS' CONTRIBUTIONS

Following authors have made substantial contributions to the manuscript as under:

MUR & AU: Concept and study design, acquisition, analysis and interpretation of data, drafting the manuscript, critical review, approval of the final version to be published

SS & AS: Acquisition of data, drafting the manuscript, approval of the final version to be published

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

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DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request

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