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ORIGINAL ARTICLE

The Effect of Blue Light Exposure on Retinal Health and Visual Function: A Clinical Study of 160 Patients

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ABSTRACT

Background: Blue light, a high-energy visible light emitted by digital screens and LED lighting, has gained attention for its potential effects on retinal health and visual function. Prolonged exposure to blue light may cause oxidative damage to retinal cells, contributing to conditions such as age-related macular degeneration (AMD), digital eye strain, and myopia progression. While the scientific community has explored the impact of blue light on retinal health in laboratory settings, clinical data on human populations remain sparse.

Methodology: This cross-sectional study involved 160 patients (aged 18-65) who were categorized based on their screen exposure time (high exposure: ≥6 hours/day, low exposure: 3-6 hours/day). Retinal health was assessed using Optical Coherence Tomography (OCT), visual acuity was measured using Snellen charts, and the Computer Vision Syndrome (CVS) questionnaire was used to assess digital eye strain symptoms. The refractive error was measured with autorefractors to track myopia progression. Statistical analysis was performed using independent t-tests and chi-square tests to evaluate the differences between high and low exposure groups.

Results: The results showed a significant association between prolonged blue light exposure and retinal damage, including increased retinal nerve fiber layer thickness and foveal thickness in the high exposure group. Visual acuity was significantly reduced in the high exposure group (0.4 ± 0.3 logMAR) compared to the low exposure group (0.1 ± 0.2 logMAR). The prevalence of digital eye strain was higher in the high exposure group (65%) compared to the low exposure group (42%). Furthermore, myopia progression was observed in 35% of high exposure participants, compared to 12% in the low exposure group. The findings were statistically significant ($p < 0.05$).

Conclusion: Prolonged exposure to blue light is associated with retinal damage, reduced visual acuity, digital eye strain, and accelerated myopia progression. These findings highlight the need for preventive measures such as screen time management, blue light filtering glasses, and regular eye health assessments to mitigate the potential risks associated with prolonged blue light exposure.

Keywords: Blue light, Retinal health, Visual function, Age-related macular degeneration, Digital eye strain, Myopia progression, Ophthalmology, Eye health, Screen time, Blue light filtering.

INTRODUCTION

The increasing use of digital devices and artificial lighting has led to higher exposure to blue light, a high-energy visible light with wavelengths between 400-500 nm[1]. Blue light is a part of the natural spectrum of sunlight, but the widespread use of LED screens and energy-efficient lighting has significantly increased artificial blue light exposure. While blue light regulates circadian rhythms and enhances alertness, concerns have emerged regarding its long-term effects on retinal health and visual function[2,3].

The retina, especially the retinal pigment epithelium (RPE) and photoreceptors, is vulnerable to oxidative stress induced by blue light exposure[4]. Oxidative damage can lead to retinal degeneration, a key contributor to age-related macular degeneration (AMD)[5]. Additionally, prolonged exposure to digital screens has been linked to digital eye strain, a condition characterized by symptoms like dry eyes, blurred vision, and headaches[6]. Furthermore, emerging evidence suggests that extended screen time and blue light exposure may contribute to the progression of myopia, particularly in younger populations[7,8].

While numerous laboratory studies have demonstrated the harmful effects of blue light on retinal cells, clinical studies examining these effects in human populations are still limited[9].

This study aims to explore the impact of blue light exposure on retinal health and visual function in a cohort of 160 patients, using retinal imaging, visual acuity tests, and subjective assessments of eye strain and myopia progression.

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METHODOLOGY

This study is a cross-sectional observational clinical investigation conducted at a Northwest General Hospital, Hayatabad Peshawar from March 2023 to August 2023. A total of 160 patients aged between 18 and 65 years were recruited for the study. Patients were classified into two groups based on their daily screen exposure: the High Exposure Group (HEG) (≥6 hours/day) and the Low Exposure Group (LEG) (3-6 hours/day).

Inclusion Criteria:

1. Age between 18 and 65 years
2. Daily screen exposure of ≥3 hours
3. No history of ocular diseases (e.g., diabetic retinopathy, advanced glaucoma)
4. Written informed consent to participate

Exclusion Criteria:

1. History of eye surgery
2. Pre-existing retinal conditions
3. Use of ocular medications affecting retinal health

Procedures:

1. **Retinal Imaging:** Optical Coherence Tomography (OCT) was used to assess retinal thickness, nerve fiber layer, and foveal thickness.
2. **Visual Acuity:** Snellen charts were used to assess visual acuity.
3. **Digital Eye Strain Questionnaire:** The CVS questionnaire was administered to assess symptoms of digital eye strain.
4. **Myopia Progression:** Refraction measurements were taken using autorefractors, and myopia progression was measured over a six-month period.

Statistical Analysis: Data were analyzed using SPSS (Version 26). Descriptive statistics were used to summarize demographic information. Independent t-tests were applied to compare

continuous variables between the high and low exposure groups, while chi-square tests were used for categorical variables. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 160 patients participated in the study, with 85 patients in the High Exposure Group (HEG) and 75 in the Low Exposure Group (LEG). The average age of participants was 40.2 ± 12.5 years, with a male-to-female ratio of 1:1.2. The majority of participants in the HEG were working professionals (65%), followed by students (25%) and home workers (10%). In the LEG, most participants were students (40%), followed by working professionals (35%) and home workers (25%).

Table 1: Demographic Characteristics

Group	Age (years)	Male (%)	Female (%)	Occupation (%)
High Exposure Group	40.5 ± 13.2	42 (49%)	43 (51%)	Professionals (65%), Students (25%), Home workers (10%)
Low Exposure Group	39.8 ± 11.9	40 (53%)	35 (47%)	Students (40%), Professionals (35%), Home workers (25%)

The retinal images from the HEG showed significantly higher retinal nerve fiber layer (RNFL) and foveal thickness compared to the LEG. The RNFL thickness in the HEG was 0.23 ± 0.06 mm, significantly greater than the 0.18 ± 0.05 mm in the LEG ($p < 0.05$). Foveal thickness in the HEG was 280 ± 18 µm, compared to 265 ± 15 µm in the LEG ($p < 0.01$).

Table 2: Retinal Health and Visual Acuity

Group	RNFL Thickness (mm)	Foveal Thickness (µm)	Visual Acuity (logMAR)
High Exposure Group	0.23 ± 0.06	280 ± 18	0.4 ± 0.3
Low Exposure Group	0.18 ± 0.05	265 ± 15	0.1 ± 0.2

Patients in the HEG had reduced visual acuity (0.4 ± 0.3 logMAR) compared to the LEG (0.1 ± 0.2 logMAR), with a statistically significant difference ($p < 0.05$).

Table 3: Digital Eye Strain and Myopia Progression

Group	Digital Eye Strain (%)	Myopia Progression (%)
High Exposure Group	65%	35%
Low Exposure Group	42%	12%

The prevalence of digital eye strain was higher in the HEG group (65%) compared to the LEG group (42%) ($p < 0.01$). In the HEG group, 35% showed progression in myopia over 6 months, compared to 12% in the LEG ($p < 0.01$).

Table 3: Digital Eye Strain and Myopia Progression

Group	Digital Eye Strain (%)	Myopia Progression (%)
High Exposure Group	65%	35%
Low Exposure Group	42%	12%

A multiple regression analysis was conducted to evaluate the relationship between blue light exposure and retinal health, visual acuity, and myopia progression. The model revealed that blue light exposure significantly predicted increased retinal nerve fiber layer thickness ($\beta = 0.12$, $p < 0.05$), reduced visual acuity ($\beta = -0.34$, $p < 0.01$), and increased myopia progression ($\beta = 0.21$, $p < 0.05$).

Table 4: Regression Analysis for Blue Light Exposure

Outcome Variable	β (Standardized)	p-value
Retinal Nerve Fiber Layer	0.12	0.03
Foveal Thickness	0.09	0.08
Visual Acuity (logMAR)	-0.34	0.01
Myopia Progression	0.21	0.02

DISCUSSION

This study provides compelling evidence that prolonged blue light exposure significantly impacts retinal health, visual acuity, and myopia progression. The increase in retinal nerve fiber layer (RNFL) thickness and foveal thickness observed in the high exposure group (HEG) indicates a possible mechanism of retinal damage due to oxidative stress. Oxidative stress, a well-known contributor to retinal diseases such as age-related macular degeneration (AMD), may be exacerbated by blue light exposure[10,11]. The results align with previous research, which has indicated that blue light can induce retinal inflammation and increase the risk of retinal degeneration[4,5].

The reduction in visual acuity observed in the HEG group supports the hypothesis that digital eye strain, characterized by symptoms such as blurred vision and discomfort, is more prevalent among individuals with prolonged blue light exposure. The higher prevalence of digital eye strain in the HEG group (65%) compared to the low exposure group (42%) highlights the need for preventive strategies to manage prolonged screen time[6,7].

Our study also found a significant association between blue light exposure and the progression of myopia. Previous studies have indicated that increased near work, including screen time, is associated with accelerated myopia progression, particularly in children and adolescents[12,13]. Our findings suggest that blue light exposure, which is often linked to increased screen time, may exacerbate this progression in adults as well. This reinforces the importance of managing screen time to prevent myopia progression and related visual issues.

The regression analysis further supported these findings, with blue light exposure significantly predicting retinal damage, reduced visual acuity, and accelerated myopia progression. The effect of blue light on retinal health and myopia progression is consistent with the findings of prior research, which suggests that interventions, such as the use of blue light filtering glasses and regular eye breaks, may help mitigate these risks[14,15].

CONCLUSION

The study demonstrates that prolonged exposure to blue light is associated with retinal damage, reduced visual acuity, digital eye strain, and accelerated myopia progression. These findings emphasize the need for preventive strategies, such as limiting screen time, using blue light filtering glasses, and ensuring regular eye health assessments. Further longitudinal studies are necessary to explore the long-term effects of blue light on eye health and to develop effective interventions for reducing its impact.

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