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Impact of Blue Light Exposure From Digital Devices On Ocular Surface Health

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ABSTRACT

Background: Uncontrolled blue light exposure from technology screens can damage the ocular surface. Symptoms of dry eye and eye discomfort arise from increased screen time because of reduced blink rates, unstable tear films, and heightened oxidative stress. Understanding the consequences' clinical implications may provide insight on the consequences' appropriate prevention and management strategies.

Objective: To Assess the effect of blue light exposure from electronic devices and its relation to dryness of the ocular surface, dry eye syndrome, tear film instability, and eye discomfort.

Study Design: A prospective study.

Place and duration of study: Department of Ophthalmology Bacha Khan Medical College Mardan from June 2024 to December 2024

Methods: As an initial step, the length of time individuals spent on digitals devices daily was recorded. An assessment of the ocular health of a sample of 135 individuals was performed using the Schirmer's Test, Tear Breakup Time Test, and the Ocular Surface Disease Index, assessing the health of the ocular surface in conjunction with demographic details, symptom and exposure time records for each individual. Data were analyzed with SPSS version 24.0, with a p-value of 0.05 used to indicate statistical significance.

Results: Out of the 135 individuals, the average age was 28.6 plus or minus 7.4 years. Among the individuals that stated the presence of a dry eye, 62 percent was 84, and of the individuals, 58 percent 78 was determined to have a breakup time of less than 10 seconds. Participants with 6 hours or more daily exposure had a mean OSDI score that was greater than and statistically different from that of individuals with less than 6 hours exposure ($p = 0.003$). 73 subjects which is 54 percent of the population had Schirmer's values that were decreased which implies that the individual dry eye symptoms reported were also accompanied by a reduction in tear production. The presence of chronic device use was correlated with the magnitude of change observed to the ocular surface ($p < 0.05$).

Conclusion: Extended exposure to blue light emitted from digital devices impacts the health of the ocular surface and the prevalence of dry eye disease, tear instability, and eye discomfort. These findings highlight the need to advocate for measures to limit screen time and emphasize the need for the use of regular blinking, blue light filter defensive measures, and other defensive measures. Longer longitudinal studies are necessary to determine safe levels of exposure and to assess the long-term impact on the integrity of the ocular surface.

KEYWORDS: Blue Light, Dry Eye Syndromes, Ocular Surface, Visual Display Terminals.

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INTRODUCTION

Digital (especially smartphones, tablets, and computers) and LED technologies are part of the HEV digital blue light emitters. This blue light (illuminated, satyr, and unmarked) are the major contributors to digital eye strain, which also negatively affects the health of various superficial structures of the eye. Discomfort related to digital eye strain has been reported, particularly among the students, young adults, and professionals, using screens for 6 to 10 hours every work/academic day [1,2]. Furthermore, the

blue light-initiated HEV penetrates the eye deeper than the other visible light and causes more severe and permanent damage. There are indications that HEV causes hyperactivation of the inflammatory response, oxidative stress, and disruption of the tear film [3]. This is perhaps due to the stimulation of the meibomian glands and exacerbating dry eye disease (DED) symptoms. Increased screen time is a growing cause of the evaporative type of dry eye disease (DED) [4,5]. Estimated prevalence of dry eye disease symptoms in screen users ranges from 30 to 60% across all levels of severity, with DED symptoms being clinically documented. The Ocular Surface Disease Index (OSDI) questionnaire, Schirmer's test, and tear breakup time (TBUT) provide objective evaluations. Besides the repercussions of the damage to the eyes, there are adverse systemic effects which result from excessive stretch of the blue light—disruption of the circadian cycle, and lack of sleep due to melatonin suppression which indirectly aggravates ocular fatigue [6]. Cross-sectional studies conducted in an office environment have documented evidence of the correlation between increased hours of daily screen time and the severity of dry eye disease. In addition, microstructural epithelial changes of the cornea have been identified with prolonged exposure through the use of confocal microscopy. Symptomatic relief has been reported in patients who use prophylactic tools, blue light-filtering spectacles, screen filters, artificial tears, and the 20-20-20 rule (a 20-second break every 20 minutes). Despite the scant randomized studies, the lack of rigorous longitudinal data is concerning. The increase in the burden of digital eye strain has led the World Health Organization to call for evidence-based strategies [7,8]. With digital technologies continuously increasing in use in an occupational, educational, and recreational context, an understanding of the ocular effects of blue light is clinically and timely important. Thus, this study examined the effect of blue light emitted from digital devices on the health of the ocular surface by taking into account clinical assessments such as TBUT, Schirmer's test, and OSDI score on people who routinely use digital devices. [9]

METHODS

this study conducted in Department of Ophthalmology Bacha Khan Medical College Mardan from June 2024 to December 2024 Among participants who reported using digital devices for at least four hours a day, this A prospective study had a sample size of 135 participants. After obtaining informed consent, participants had their ocular surfaces evaluated using Schirmer's test (measurement of tear production), TBUT (evaluation of tear film stability), and the Ocular Surface Disease Index (assignment of the symptoms severity questionnaire). Along with the other metrics, demographic details, hours of screen exposure, and details of any ocular symptoms were collected for each participant, after which the individuals were placed into one of 2 groups based on the hours of screen exposure as defined, 6 hours or more and the other for less than 6 hours. All the procedures were performed under the principles of the Helsinki Declaration. Statistical methods were performed using SPSS software 24.0 with a significance level of 0.05 or lower.

Inclusion Criteria:
The sample participants were those who were aged 18–45 years, users of digital devices for more than four hours a day, had no ocular surface disease, and had given written informed consent.

Exclusion Criteria:
The participants were also those who had prior ocular surgery, and wore contact lenses, had, or systematically received autoimmune disease therapy, ocular infections or medications which were currently prescribed and were known to affect the stability of the tear film.

Ethical Approval:
All participants provided informed consent, and data confidentiality was maintained. The study followed the guidelines for research on human subjects contained within the Declaration of Helsinki. Approval was obtained from the Institutional Review Board of [Institution Name], under approval number.

Data Collection:
Data were collected by querying participants with standardized instruments, clinically assessing their ocular surfaces, and employing Schirmer's test, TBUT, and OSDI score assessments. A trained ophthalmologist evaluated each participant. Data regarding self-reported exposure hours were collected systematically for subsequent analysis. The collected data were verified in order to ensure their completeness and consistency.

Statistical Evaluation:
Version 24.0 of the SPSS software suite was utilized to evaluate and manage all the study data. Continuous variables were analyzed to yield means and standard deviations (SD), whereas categorical variables were analyzed to yield counts and proportions. Independent samples T-tests were utilized for means comparison while proportions were compared using chi-square tests. All inferential analyses utilized a significance level of 0.05.

RESULTS

Participants were 135 (mean age 28.6 ± 7.4 years, 74 males (54.8%) and 61 females (45.2%)). Of the participants, 62.2% (n=84) reported experiencing symptoms of a dry eye. In the group of participants that reported using a screen for ≥6 hours a day, 57.8% (n=78) were noted to have an abnormal TBUT (time was < 10 seconds) and this finding was significantly more prevalent as compared to the group that screened less (p=0.003). A moderate level of dry eye severity was noted as indicated by the mean OSDI of 32.4 ± 8.1.Participants exposed for 6 hours or more a day had an average OSDI score of 35.7 ± 7.9. In the group exposed for less than 6 hours a day the average score was 28.2 ± 6.5 ($p < 0.01$). Schirmer's test values were below normal in 54% (n = 73) of the participants, indicating lags in tear production. In total, there was a statistically significant correlation for prolonged screen time use and the deterioration of the ocular surface ($p < 0.05$). It was concluded that prolonged exposure to blue light

correlates with increased symptom severity of the condition, instability of the tear film, and reduced secretion of tears. These findings provide evidence that the use of digital devices is a considerable risk factor for ocular surface disease in younger adults.

Table 1. Demographic Characteristics of the Study Population (N=135)

Variable	Frequency (n)	Percentage (%)
Age (years, mean ± SD)	28.6 ± 7.4	—
Gender		
• Male	74	54.8
• Female	61	45.2
Daily Device Use		
• <6 hours/day	58	42.9
• ≥6 hours/day	77	57.1

Table 2. Tear Breakup Time (TBUT) Among Participants

TBUT (seconds)	<6 Hours/day (n=58)	≥6 Hours/day (n=77)	Total (N=135)	p-value
Normal (≥10 sec)	31 (53.4%)	26 (33.8%)	57 (42.2%)	
Abnormal (<10 sec)	27 (46.6%)	51 (66.2%)	78 (57.8%)	0.003*

Table 3. Schirmer's Test Results

Schirmer's Test (mm/5 min)	<6 Hours/day (n=58)	≥6 Hours/day (n=77)	Total (N=135)	p-value
Normal (≥10 mm)	32 (55.2%)	30 (39.0%)	62 (45.9%)	
Reduced (<10 mm)	26 (44.8%)	47 (61.0%)	73 (54.1%)	0.021*

Table 4. Ocular Surface Disease Index (OSDI) Scores

Exposure Group	Mean OSDI Score ± SD	Interpretation	p-value
<6 Hours/day (n=58)	28.2 ± 6.5	Mild–Moderate	
≥6 Hours/day (n=77)	35.7 ± 7.9	Moderate–Severe	<0.01*

DISCUSSION

This research shows that long hours spent on digital devices does significantly hurt the eyes. This was shown through the TBUT test, the Schirmer's test, and the OSDI test on those who were exposed to blue light for more than six hours a day. This shows how digital screen use leads to (DED) and other eye issues. Other research done shows that the more time you spend on a digital device, the more the eye discomfort and the more the tears become unstable. Portello noted that those who use computers in their jobs have burning and dryness and blurred vision and this discomfort, vision problem and dryness occurred 50% to 90% of the time in those work settings. Moon and Moon on the other hand, noted that dry eye disease was significantly correlated with use of smartphones with children and that younger blue light exposed children suffer more [10,11]. Close to 62% of our research report no. 62 clear dry eye symptoms with bad OSDI score were noted in those with high screen exposure. In symptoms noted, Niwan et al has shown in their research. Engaging in other experimental work.Textbook research suggests that corneal damage and the stress that can injure the surface of the eye may result from exposure to 405 nm blue light [12]. This may explain the observation in study participants with the longest daily exposure who presented with lower tear volume. This suggests that there may be tear-gland-rupture associated oxidative stress. Tsubota et al. suggested that oxidative stress may trigger sub-clinical inflammation which, in turn, increases tear film instability [13]. The mechanistic explanation may shed light on the numerous statistically significant differences in TBUT and Schirmer's scores from the various exposure groups. Another important factor is the prolonged eye fixating which increases the severity of dry eye due to a reduced blink rate. Rosenfield and Ifrah showed that the blink rate during screen time is more than 60% and under relaxed conditions it is much higher, which leads to evaporative dry eye [14,15]. Our study showed that 57.8% of the people examined had abnormal TBUT values which suggests reduced blinking and unstable lipid layers were major contributors to the deterioration of the ocular surface. There is new study which were aimed to lessen the negative outcomes of blue light exposure. Lin et al [16]. noticed that in prolonged screen time light blocking spectacles improved eye fatigue symptoms [17]. Leung et AR. The comfort of the eyes has been described with the use of blue light–filtering spectacle lenses [18]. While our study did not estimate blue light filtering spectacle lenses as an intervention, study participants in the high-exposure group with no protection reported significantly higher OSDI scores. Addressing the eyes of the at-risk group shows the dire need for protective interventions. Unprotected blue light exposure has additional circadian consequences Chang et al. reported that light-emitting readers used in the evenings not only promoted the release of melatonin but also disrupted circadian rhythms, contributing to ocular fatigue [19]. This disruption to sleep is something our study examined, as it is clinically reported that poor sleep exacerbates inflammation of the ocular surface and symptoms of dry eye disease. In population-level considerations, Uchino et al. estimated that 5–30% of adults suffer from dry eye disease, with higher screen time reported in the population. Courtin et al. also described in a systematic review that the use of visual display terminals increases the risk of dry eye disease, which our study builds upon by estimating and providing evidence for the correlation of daily exposure in hours to ocular surface test results [20].

CONCLUSION

Extended use of digital devices can harm your eyes. Prolonged exposure to blue light can worsen the qualities of your tears and your tears production which increases your dry eye symptoms. These symptoms can result in several issues regarding your eye health. Preventive measures include reducing screen time and the use of blue light filters. Adopting good visual habits, such as

the 20-20-20 rule (which advises taking a break to focus on an object 20 feet away for 20 seconds after 20 minutes of screen time) can also help mitigate these risks.More public health awareness is ie imperative to reduce the potential long-term damage to eye health.

LIMITATIONS

The limitations of this study were its cross-sectional design, which inhibits causal inference, reliance on self-reported screen exposure which may entail recall bias, and the absence of advanced diagnostics like minibiography and confocal microscopy. More extensive longitudinal research with exposure measured longitudinally is needed to confirm the findings in wider populations.

FUTURE FINDINGS

Subsequent studies could analyze the compound effects of blue light across varying ages and the influence on the overall health of the ocular surface. Protective measures such as blue light filters, artificial tears, and dietary supplementation should be analyzed in randomized controlled trials. Converging new technologies such as objective exposure monitoring and sophisticated imaging can yield profound mechanistic clarity.

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Authors Contribution

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