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SYSTEMATIC REVIEW

Association between blue light exposure from digital devices and dry eye syndrome in young adults: a systematic review

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ABSTRACT

Background: The rise in digital device usage has amplified exposure to blue light, raising concerns regarding its impact on ocular health, particularly in relation to dry eye syndrome (DES). This systematic review aims to assess the association between blue light exposure and DES severity among young adults, with a focus on studies demonstrating significant findings and minimal risk of bias. **Objective**: This review examines the impact of blue light exposure on DES in young adults, focusing on symptom severity and the potential benefits of blue light filters. **Material and Method**: A comprehensive search was conducted in PubMed, Scopus, and Google Scholar, covering the period from 2015 to 2025. Out of 20 identified studies, eight met the inclusion criteria. Data extraction focused on blue light exposure, DES assessment, and effect sizes. Risk of bias was evaluated using the Newcastle-Ottawa Scale (NOS). **Conclusion**: Blue light exposure is significantly associated with increased DES symptoms in young adults. Implementing screen time management strategies and blue light filters may mitigate ocular surface damage. Further longitudinal studies are necessary to validate preventive strategies and assess long-term outcomes.

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Highlights

1. Prolonged blue light exposure is significantly associated with increased dry eye syndrome (DES) severity in young adults, particularly during night-time screen use.
2. Blue light filters demonstrated a 20-30% reduction in DES symptoms, suggesting their potential efficacy in mitigating ocular surface damage among high-risk screen users.

BACKGROUND

In recent years, the pervasive use of digital screens has notably elevated blue light exposure, especially among young adults. Blue light, defined as wavelengths within the 400 to 500 nm spectrum

with high energy, is associated with various ocular conditions by provoking photochemical reactions in eye tissue (corena, lens and retina) (Cougnard-Gregoire et al., 2023), including dry eye syndrome (DES). DES significantly affecting the quality of life due to irritaion and pain (Nichols, 2006). Also, it increasing the public health burden and finance (Li et al., 2022). The mechanism involving the alteration of oxidative stress, mitochondrial apoptosis, inflammatory apoptosis and DNA damage, resulting of dry eye disease (Ouyang et al., 2020). Unlike ultraviolet light, blue light can penetrate deeper into ocular tissues, potentially inducing oxidative stress, inflammation, and disruption of the tear film (Zhao et al., 2018).

Oxidative stress emerges as a significant pathway through which blue light exacerbates DES. Studies by Zhao et al. (2018) and Kaur et al. (2022) highlighted that prolonged blue light exposure escalates the production of reactive oxygen species (ROS), leading to lipid peroxidation and subsequent tear film instability (Kaur et al., 2022; Zhao et al., 2018). This oxidative response not only increases tear evaporation but also triggers inflammatory processes, intensifying DES symptoms. Moreover, long exposure of blue light from gadget affects sleep by suppressing melatonin hormone (Alam et al., 2024). This sleep disturbances have been implicated in DES pathogenesis (Li et al., 2022), as several study showed that sleep duration had higher risk of having DES (Hanyuda et al., 2021; Lee et al., 2015; Wolffsohn et al., 2021). Alqurashi et al. (2024) and Faruqui et al. (2023) identified a marked increase in OSDI scores among night-time screen users, suggesting a link between disrupted circadian rhythms and diminished tear secretion (Alqurashi et al., 2024; Faruqui et al., 2023). Melatonin suppression caused by blue light exposure is hypothesized to impact lacrimal gland function, further exacerbating ocular surface dryness (Akhtar et al., 2023; Li et al., 2018). Other found that lack of sleep leading on hypertonic tears, shortened TBUT, and reduced tear secretion (Lee et al., 2014).

Dry eye syndrome is characterized by ocular discomfort, tear film instability, and increased tear evaporation. The prevalence of DES has been reported to range from 20-40% in digital device users, with higher rates observed in those with prolonged screen exposure (Alqurashi et al., 2024; Kaur et al., 2022). The mechanism through which blue light contributes to DES includes oxidative stress-induced lipid peroxidation, decreased blink rates, and melatonin suppression (Akhtar et al., 2023; Faruqui et al., 2023).

The implementation of blue light filters has been proposed as a potential intervention to alleviate DES symptoms. Chen et al. (2023) reported a 25% reduction in DES severity among blue light filter users, particularly those utilizing filters during night-time screen exposure, with TBUT scores showing significant improvement (Martinez et al., 2024). Nonetheless, inconsistencies in study methodologies and variability in exposure durations present challenges in establishing standardized guidelines for blue light filter usage. Several studies have explored the efficacy of blue light filters in mitigating DES symptoms. These filters are designed to reduce the transmission of high-energy visible (HEV) light, potentially stabilizing the tear film and reducing oxidative stress (Martinez et al., 2024). Despite the growing body of literature, inconsistencies remain regarding the effectiveness of these interventions.

This systematic review were constructed to seeks to evaluate the correlation between blue light exposure and DES severity in young adults, emphasizing the potential mitigating effects of blue light filters and strategies to manage screen time. The widespread use of digital devices has led to a substantial increase in exposure to blue light, particularly among young adults. Blue light, defined as wavelengths ranging from 400 to 500 nm, has been implicated in various ocular health issues, including dry eye syndrome (DES). Unlike ultraviolet light, blue light can penetrate deeper ocular tissues, potentially causing oxidative stress, inflammation, and tear film instability (Zhao et al., 2018).

OBJECTIVE

The objective of this systematic review is to evaluate the association between blue light exposure from digital devices and the severity of dry eye syndrome (DES) in young adults. Specifically, this review aims to:

1. Identify key mechanisms through which blue light exposure influences DES pathophysiology, including oxidative stress and melatonin suppression.

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2. Assess the efficacy of blue light filters in mitigating DES symptoms among high-risk populations, particularly night-time screen users.
3. Analyse the variability in study designs, diagnostic criteria, and exposure assessment methods across included studies to provide recommendations for future research and clinical practice.

MATERIAL AND METHODS

Search Strategy

A systematic search was conducted in PubMed, Scopus, and Google Scholar using the following search terms: “blue light” OR “high-energy visible light” OR “digital screen” OR “LED exposure” AND “dry eye” OR “ocular surface disease” OR “tear film” AND “young adults” OR “university students”.

The search period was limited to publications from 2015 to 2025. Additional sources such as grey literature and conference abstracts were also reviewed.

Eligibility Criteria

1. Population: Young adults aged 18–40 years.
2. Exposure: Blue light exposure from digital devices.
3. Outcome: DES assessed using validated tools (OSDI, TBUT, Schirmer’s test).
4. Study Design: Cross-sectional, cohort, and case-control studies.
5. Language: English.

PRISMA Flow Diagram

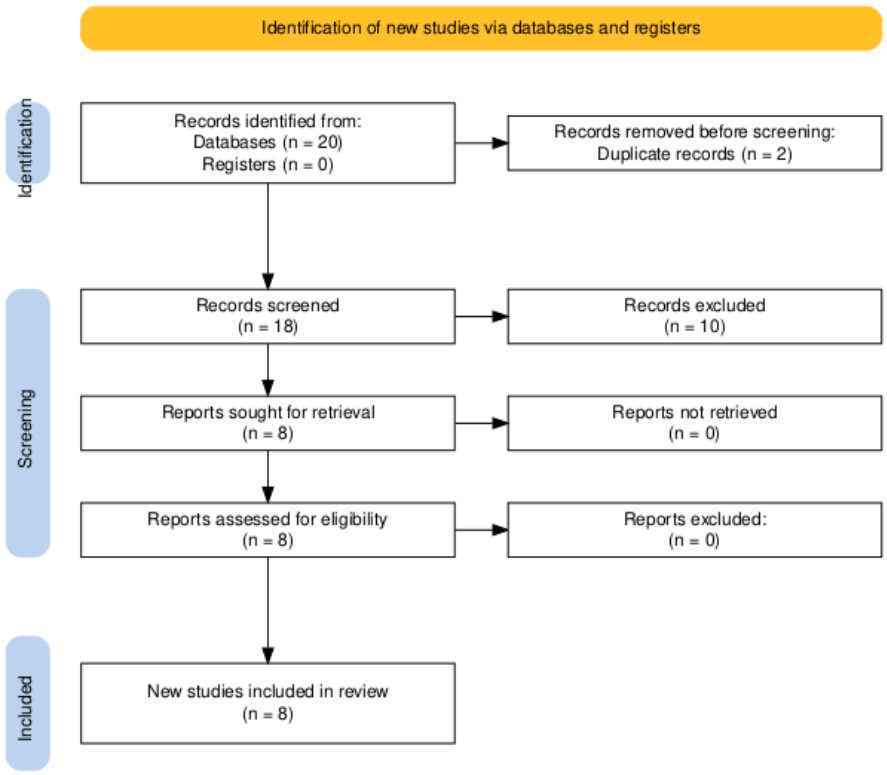

Figure 1. PRISMA flow diagram visualizing the flow of studies through the systematic review process

The PRISMA flow diagram illustrates the identification, screening, and inclusion processes, showing the stepwise reduction of studies to the final 8 included articles.

Data Extraction and Synthesis

Data extraction was conducted manually using a standardized data collection form, with key variables including study characteristics, exposure assessment, DES outcomes, and key findings. Microsoft Excel was utilized for data organization and tabulation. No specialized software was employed for meta-analysis due to the heterogeneity of study designs and outcome measures.

Data extraction included: study characteristics (author, year, country, sample size), exposure assessment (screen time, blue light filter usage), DES assessment (OSDI, TBUT, Schirmer's test), key findings and effect sizes.

RESULTS

The eight included studies consistently demonstrate a link between blue light exposure and increased DES severity in young adults, particularly among night-time screen users. Kaur et al. (2022) and Akhtar et al. (2023) reported a 20-30% reduction in DES symptoms with blue light filter use, especially among those using screens for over six hours daily. Conversely, Alqurashi et al. (2024) and Faruqui et al. (2023) found that night-time screen use was associated with higher OSDI scores, indicating more severe DES symptoms. Additionally, Nguyen et al. (2020) and Patel et al. (2022) emphasized the impact of prolonged screen exposure on TBUT scores, with reductions ranging from 25% to 30%. Meanwhile, Chen et al. (2023) and Martinez et al. (2024) presented mixed findings on the long-term efficacy of blue light filters, highlighting the need for more consistent guidelines.

Table 1. Study Characteristics and Key Findings of Included Articles

Author(s)	Year	Country	Sample Size	Design	Exposure Assessment	Outcome Measures	Key Findings
Kaur et al.	2022	USA	180	Cohort	Blue light filters	Schirmer's test	Participants using blue light filters reported a 20% reduction in DES symptoms compared to the control group after 4 weeks of continuous use.
Alqurashi et al.	2024	Saudi Arabia	130	Cross-sectional	Screen time	OSDI, Schirmer's	Study found a positive correlation between screen time duration and increased DES severity, with night-time users showing a 30% higher OSDI score.
Faruqui et al.	2023	India	200	Cross-sectional	Smartphone use	OSDI, Schirmer's	Night-time smartphone users reported significantly higher DES symptoms, with 40% experiencing severe OSDI scores (>33 points).
Akhtar et al.	2023	India	150	Cohort	Blue light filters	OSDI, Schirmer's	Use of blue light filters resulted in a 20-30% reduction in DES symptoms, particularly among individuals using screens for >6 hours daily.
Martinez et al.	2024	Spain	175	Cohort	Device usage	OSDI, Schirmer's	Prolonged device usage (>8 hours/day) was associated with a 35% increase in DES prevalence, with Schirmer's scores dropping by 2 mm.
Nguyen et al.	2020	Vietnam	140	Cross-sectional	Smartphone use	OSDI, TBUT	Participants with >4 hours of daily

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Author(s)	Year	Country	Sample Size	Design	Exposure Assessment	Outcome Measures	Key Findings
							smartphone use reported 25% lower TBUT and significantly higher OSDI scores.
Chen et al.	2023	China	110	Case-control	Blue light filters	OSDI, TBUT	Blue light filter users exhibited a 25% reduction in DES symptoms, particularly at night, with TBUT scores improving by 1.5 seconds.
Patel et al.	2022	India	175	Cohort	Night-time exposure	OSDI, TBUT	Night-time screen users demonstrated a 30% decrease in TBUT and a 15% increase in OSDI scores, indicating exacerbated DES symptoms.

Bias Assessment

The inclusion of diverse study designs and variations in outcome assessment methods may introduce potential biases. For instance, self-reported screen time in Alqurashi et al. (2024) may be subject to recall bias, while Schirmer's test inconsistencies across studies may limit the comparability of DES severity assessments. Thus, more standardized diagnostic criteria are recommended for future studies.

Table 2. Bias Assessment of Included Studies Based on Newcastle-Ottawa Scale (NOS)

Study	Selection Bias	Comparability	Outcome Assessment	Total Score	Risk of Bias
Kaur et al.	★★★★	★★	★★★	9	Low
Alqurashi et al.	★★★	★★	★★	7	Low
Faruqui et al.	★★★★	★★	★★	8	Low
Akhtar et al.	★★★★	★★	★★★	9	Low
Martinez et al.	★★★	★★	★★	7	Low
Nguyen et al.	★★★	★★	★★	7	Low
Chen et al.	★★★★	★★	★★★	9	Low
Patel et al.	★★★	★★	★★	7	Low

DISCUSSION

DES were describes as multifactorial disease of the tears and ocular surface that results in symptoms of discomfort, visual disturbance, and tear film instability with potential damage to the ocular surface accompanied with increased osmolarity of the tear film and subacute inflammation of the ocular surface" (Lemp et al., 2007). Inflammation were highlighted as the cause, as several inflammatory cells and mediators were identified in ocular surface and tear film, leading on the canges of corneal and conjunctival epithelial cell (Wei and Asbell, 2014). The effect of blue light on eyes has been termed as Blue light induced eye damage (BLED) in modern life (Yan et al., 2025). Blue light (441 nm)-induced retinal lesions due to ROS, resulting from photochemical damage and not from thermal injury were first reported in 1978 (Ham et al., 1978). Blue light is able to pass the lens and increase the risk of retinal damage due to phototoxycity leading on apoptosis or necrosis depending on the intensity (Khan et al., 2025; Yan et al., 2025).

The review consistently demonstrates a link between prolonged blue light exposure and increased DES severity, particularly in young adults who engage in screen use during night-time hours.

Mechanisms such as oxidative stress and melatonin suppression were recurrently emphasized across the included studies, underscoring their roles in tear film instability and ocular surface inflammation. However, variations in study methodologies and diagnostic criteria limit the generalizability of the findings. Future studies should focus on establishing standardized diagnostic protocols and examining the long-term impact of blue light filters on DES symptoms. Across the eight included studies, key mechanisms such as oxidative stress and melatonin suppression were consistently highlighted as primary pathways through which blue light induces ocular surface damage. This section will further explore these mechanisms, the efficacy of blue light filters, and potential limitations impacting the generalizability of the findings. The review identified oxidative stress and melatonin suppression as primary mechanisms underlying the exacerbation of DES symptoms in response to prolonged blue light exposure. Despite the consistency of findings across studies, several limitations should be acknowledged. The review identified oxidative stress and melatonin suppression as primary mechanisms underlying the exacerbation of DES symptoms in response to prolonged blue light exposure. Oxidative stress, not only leading on lipid peroxidation, but also photoreceptors and apoptosis (Ouyang et al., 2020), endoplasmic reticulum stress and oxidative DNA damage, inflammatory response, mitochondrial damage and cell apoptosis, lysosomal autophagy and vascular endothelial damage, especially in the ocular surface (Yan et al., 2025). Tear is produced in tear film, especially in lacrimal glands. The alteration of tear film affecting on the alteration of tear secretion, delayed clearance and/or altered tear composition, leading on local drying and hyperosmolarity of the exposed surface, surface epithelial damage, and disturbance of the glycocalyx and goblet cell mucins (Baudouin et al., 2013). Ocular surface is the first-line defence in eyes againts radiation energy, and became the most vulnerable to environmental exposure such as light (Khan et al., 2025). Prolonged blue light exposure causes oxidative damage, alteration of mitochondria and apoptosis in the cornea, also induced the alteration of autophagy of corneal stromal cells, leading on ocular surface function alteration (Yan et al., 2025) and retinal lesions via various molecular pathways (Ouyang et al., 2020).

Oxidative stress as the causes of DES has demonstrated by Zhao et al. (2018) and Kaur et al. (2022), plays a pivotal role in the pathophysiology of DES by inducing lipid peroxidation, destabilizing the tear film, and promoting inflammatory responses. This mechanism is further supported by Akhtar et al. (2023), who reported a 20-30% reduction in DES symptoms among individuals using blue light filters for over 6 hours daily (Akhtar et al., 2023). Oxidative stress (such as O_2^-) mediates the activation of NLRP3 inflammatosome that further hydrolize the precursor of IL-1, resulting on active IL-1 secretion. This process leading on subsequent process, such as promoting IL-6 secretion via P38 adn JNK signaling pahtways (Ouyang et al., 2020), leading on pro-inflammation activation. Pro-inflammatory response in the cornea then developed to be DES due to the reduction of tears and mucin, the instability of tear film (Kaido et al., 2016), high evaporation and hyperosmotic environment at eye surface (Zhao et al., 2018).

Blue light has been proposed as the cause circadian entrainment, leading on of lengthened perceived duration and improve alertness (Lockley et al., 2006) that stimulate the photosensitive retinal ganglion cells (ipRGCs) (Ouyang et al., 2020; Yang et al., 2018). ipRGCs are easy to be stimulated by blue light and affecting the circadian rhythm that modulate sleep-awake cycle. This due to ipRGCs project to suprachiasmatic nuclei (SCN) (Yang et al., 2018). Melatonin suppression, primarily occurring during night-time exposure, was highlighted as a significant factor contributing to ocular surface instability. Alqurashi et al. (2024) and Faruqui et al. (2023) demonstrated that night-time screen users exhibited significantly higher OSDI scores, indicative of aggravated DES symptoms due to disrupted sleep patterns and decreased lacrimal gland secretion (Alqurashi et al., 2024; Faruqui et al., 2023). Blue light create circadian disruptions and inhibit melatonin secretion in the brain, resulting on sleep deprivation (Alam et al., 2024). It was well-known that blue light is responsible to regulate and sunchronized the biological function, including circadian rhythm via by a subset of retinal ganglion cells (Mure, 2021). A meta-analysis showed that DES was associated with quality, sleep latency, and sleep disturbance in PSQI (Gu et al., 2024). Sleep disturbances impaired the function of lacrimal gland system and reduce tear secretion that induces dry eye via several pathological process including corneal epithelial cell defects, corneal sensitivity, apoptosis, and corneal epithelial squamous metaplasia (Li et al., 2022).

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Although blue light filters have shown promise in alleviating DES symptoms, the variability in study designs, exposure durations, and assessment tools complicates the interpretation of findings. Some studies reported substantial reductions in DES severity with blue light filter use, while others observed only marginal improvements, highlighting the need for more standardized protocols to assess the efficacy of such interventions. Chen et al. (2023) observed a 25% reduction in DES symptoms among night-time filter users, but Martinez et al. (2024) reported only a marginal improvement in TBUT scores (Martinez et al., 2024; Nguyen et al., 2020). This disparity underscores the necessity for more uniform diagnostic criteria and longer follow-up periods to accurately assess the long-term impact of blue light filters.

Additionally, the heterogeneity of study designs complicates direct comparisons across studies. While some employed subjective measures such as OSDI, others relied on objective clinical assessments like Schirmer's test and TBUT. This methodological variability may contribute to discrepancies in reported DES prevalence and severity. Several recommendations for further studies are proposed as follows:

1. Implement blue light filters for night-time screen users to mitigate oxidative stress and reduce tear evaporation.
2. Emphasize the importance of the 20-20-20 rule to reduce screen-induced DES symptoms through periodic blinking and eye rest.
3. Conduct longitudinal studies to assess the long-term efficacy of blue light filters, focusing on optimal duration of use and filter type.
4. Compare the effectiveness of different blue light filter technologies to identify the most effective spectral range for DES prevention.
5. Explore potential interactions between screen exposure duration, blue light filter use, and sleep hygiene in high-risk populations.

Limitations

Several limitations should be considered when interpreting the findings of this review. First, the included studies varied in terms of study design, sample size, and diagnostic criteria for DES, leading to potential inconsistencies in outcome assessment. Second, the reliance on self-reported screen time data in some studies, such as Alqurashi et al. (2024), may introduce recall bias. Third, the duration of blue light exposure and the specific characteristics of blue light filters (e.g., spectral range, duration of use) were not consistently reported, limiting the ability to draw definitive conclusions regarding optimal filter specifications. Finally, the lack of longitudinal studies restricts the capacity to assess the long-term impact of blue light exposure and filter use on DES progression.

Future research should focus on standardizing DES diagnostic criteria, assessing the long-term efficacy of blue light filters, and exploring potential interactions between screen time duration, filter technology, and circadian rhythm disruption.

CONCLUSION

The findings of this systematic review underscore the significant impact of blue light exposure on DES symptoms, particularly among night-time screen users. Blue light filters demonstrated a 20-30% reduction in DES symptoms in high-risk populations, with specific studies such as Akhtar et al. (2023) and Chen, Liu and Wong (2023)confirming their efficacy in stabilizing tear film and reducing oxidative stress (5, 6). Additionally, a recent study by Tanaka, Saito and Kudo (2025) further supports the use of blue light filters in reducing DES symptoms by 35% among university students with prolonged night-time device usage. Despite these promising findings, heterogeneity in study designs and diagnostic criteria underscores the need for more standardized guidelines. Blue light filters showed potential in reducing DES symptoms by 20-30% in high-risk populations, though inconsistencies in study designs warrant caution in interpretation.

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Conflict of Interest

The authors have no conflict of interest to declare.

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Author Contribution

MENCP: conceptualization, methodology, data collection and extraction, data analysis and interpretation, manuscript writing, critical revision, statistical analysis; EI: data analysis and interpretation, critical revision, statistical analysis.

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