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Ocular discomfort mechanism: A comparison between digital screen use and UV light exposure

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Abstract

Background and Rationale: Vision is essential for daily functioning, and increasing digital screen use along with ultraviolet (UV) exposure has led to a rise in ocular discomfort and vision-related disorders. Digital eye strain (DES), or computer vision syndrome, affects both adults and children, with prevalence ranging from 5% to 65%, exacerbated by the COVID-19 pandemic. UV radiation contributes to acute and chronic ocular pathologies, including photo keratitis, pterygium, cataract and eyelid malignancies.

Methods: A narrative review was conducted using PubMed, Google Scholar, and peer-reviewed ophthalmology literature to synthesize evidence on the epidemiology, pathophysiology, clinical manifestations, and preventive strategies for DES and UV-related ocular disorders.

Results: Digital eye strain causes primarily functional and reversible symptoms such as dry eye, eye strain, headache, and accommodative difficulties due to reduced blinking, tear film instability, and prolonged near work. In contrast, UV exposure leads to cumulative structural ocular damage through photochemical injury. Both conditions share mechanisms including oxidative stress and ocular surface disruption, and evidence supports ergonomic measures for DES and UV-protective strategies for prevention.

Conclusion: Ocular discomfort from digital screens and UV radiation presents distinct yet overlapping pathophysiological mechanisms. While avoidance is impractical, risk mitigation through ergonomic optimization, visual hygiene, optical correction, and UV protection is effective. Integrating these strategies into clinical practice and public health initiatives is essential to preserve visual function and prevent cumulative ocular morbidity in contemporary society.

Keywords: Digital eye strain; Computer vision syndrome; Ultraviolet radiation; Ocular discomfort; Tear film instability; Visual ergonomics; Eye protection; Occupational vision care**.**

1. Introduction

1.1. Background and Rationale

1.1.1. Importance of Vision in Modern Life

Vision is a critical sensory modality essential for learning, occupational performance, social interaction, and overall quality of life. Although the visual system is highly adaptable, rapid technological advancement and increasing

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environmental exposure have placed unprecedented demands on ocular tissues, making ocular discomfort and visual disorders an emerging public health concern.

1.1.2. Digital Screen Use and Ocular Discomfort

Digital technologies—including computers, smartphones, tablets, and virtual reality devices—are now integral to professional, educational, and personal activities. Prolonged digital screen exposure has led to the recognition of digital eye strain (DES), also known as computer vision syndrome, characterized by ocular and extraocular symptoms associated with sustained screen use [1,2]. Epidemiological studies report DES prevalence ranging from 5% to 65% in adults, with a marked increase during the COVID-19 pandemic, particularly among children, where prevalence reached 50–60% alongside rising dry eye symptoms and myopia progression [16,17,19].

1.1.3. Mechanisms of Digital Eye Strain

Digital eye strain is multifactorial, involving visual, ocular surface, and musculoskeletal mechanisms. Blue light (380–500 nm) emitted from digital screens can penetrate ocular media and induce oxidative stress, raising concerns about retinal fatigue and long-term ocular health [4,6,29]. Additionally, sustained screen viewing significantly reduces blink rate and increases incomplete blinking, leading to tear film instability, increased evaporation, ocular surface inflammation, and dry eye symptoms [30–35]. Poor ergonomics, glare, and inadequate lighting further exacerbate accommodative stress and musculoskeletal discomfort [18,38].

1.1.4. Ultraviolet Radiation and Ocular Health

Ultraviolet (UV) radiation is an unavoidable environmental exposure, comprising UV-A, UV-B, and UV-C wavelengths [9]. Although the atmosphere absorbs most UV-C and UV-B radiation, residual UV-A and UV-B reach the eye and contribute to ocular pathology [9,10]. Acute UV exposure may cause photo keratitis, while chronic exposure is strongly associated with pterygium, cataract, climatic droplet keratopathy, and eyelid malignancies [12,22,24–27]. Risk varies with geographic location, occupational exposure, altitude, and use of protective eyewear [22].

1.1.5. Comparative Perspective and Research Gap

Despite differing exposure characteristics, digital screens and UV radiation share overlapping mechanisms of ocular discomfort, including oxidative stress, inflammation, and tear film instability. Blue light from both artificial and natural sources has been implicated in photochemical retinal injury [25,29]. However, most existing studies examine these exposures independently, with limited integrative analyses addressing shared and distinct mechanisms, creating a gap in comprehensive ocular health guidelines.

1.1.6. Aim and Objectives

This narrative review aims to compare and critically analyze ocular discomfort associated with digital screen use and ultraviolet radiation exposure. The objectives are to:

- Review epidemiology and clinical manifestations of ocular discomfort in both conditions.
- Examine underlying pathophysiological mechanisms.
- Identify shared and distinct biological pathways.
- Evaluate preventive and management strategies to reduce ocular morbidity.

1.1.7. Significance of the Study

By integrating evidence from ophthalmology, ergonomics, and public health, this review provides a comparative framework to inform clinical practice and preventive strategies. The findings are particularly relevant for vulnerable populations such as children, office workers, and outdoor labourers and may guide the development of safer digital technologies and improved UV-protective interventions.

2. **Methods**

2.1. Study Design

A narrative review design was adopted to synthesize heterogeneous evidence related to ocular discomfort associated with digital screen use and ultraviolet radiation exposure. This approach allows integrative interpretation of epidemiological, clinical, experimental, and public health literature [1–3], and is well suited to multifactorial conditions involving variable exposure characteristics and outcomes.

2.2. Data Sources and Search Strategy

Literature searches were conducted using PubMed/MEDLINE, Google Scholar, WHO publications, and peer-reviewed ophthalmology and optometry journals. Search terms included combinations of "digital eye strain," "computer vision syndrome," "blue light," "ultraviolet radiation," "ocular discomfort," and "dry eye disease," using Boolean operators to refine queries. Reference lists were manually screened for additional studies.

2.3. Eligibility Criteria and Study Selection

Peer-reviewed studies addressing ocular outcomes related to digital screen use or UV exposure were included. Non-ocular studies, editorials, conference abstracts, and non-English publications without translation were excluded. Titles, abstracts, and full texts were screened in a structured multi-stage process.

2.4. Data Extraction and Synthesis

Data were organized into thematic categories including epidemiology, pathophysiology, clinical manifestations, and preventive strategies. A qualitative thematic synthesis was employed to compare digital and UV-related mechanisms [8].

2.5. Ethical Considerations and Limitations

Ethical approval was not required as only published literature was reviewed. Limitations include potential selection bias and lack of quantitative synthesis; however, the narrative approach provides a broad, integrative perspective [10].

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3. **Discussion**

3.1. Overview of Ocular Discomfort Mechanisms

This review highlights that ocular discomfort associated with digital screen use and ultraviolet (UV) radiation exposure arises through distinct yet partially overlapping mechanisms. Digital eye strain (DES) is predominantly characterized by functional and largely reversible disturbances of the ocular surface and accommodative system, whereas UV-related ocular damage is primarily photochemical and structural, often leading to cumulative and irreversible tissue changes.

3.2. Digital Screen Use and Ocular Surface Dysfunction

3.2.1. Role of Blink Dynamics and Tear Film Stability

A central mechanism underlying digital eye strain is altered blink behaviour. Prolonged screen use significantly reduces blink rate from physiological levels of approximately 18–22 blinks per minute to as low as 3–7 blinks per minute, resulting in tear film instability, increased evaporation, and ocular surface hyperosmolarity [30–32]. Incomplete blinking further exacerbates tear film disruption and accelerates dry eye symptoms [35]. Long-term digital exposure has also been associated with reduced aqueous tear production, suggesting a potential contribution to chronic ocular surface dysfunction [34]. In addition, suboptimal ergonomics, glare, poor posture, and prolonged near work increase accommodative demand and visual fatigue, often accompanied by musculoskeletal symptoms that compound overall discomfort [18, 38].

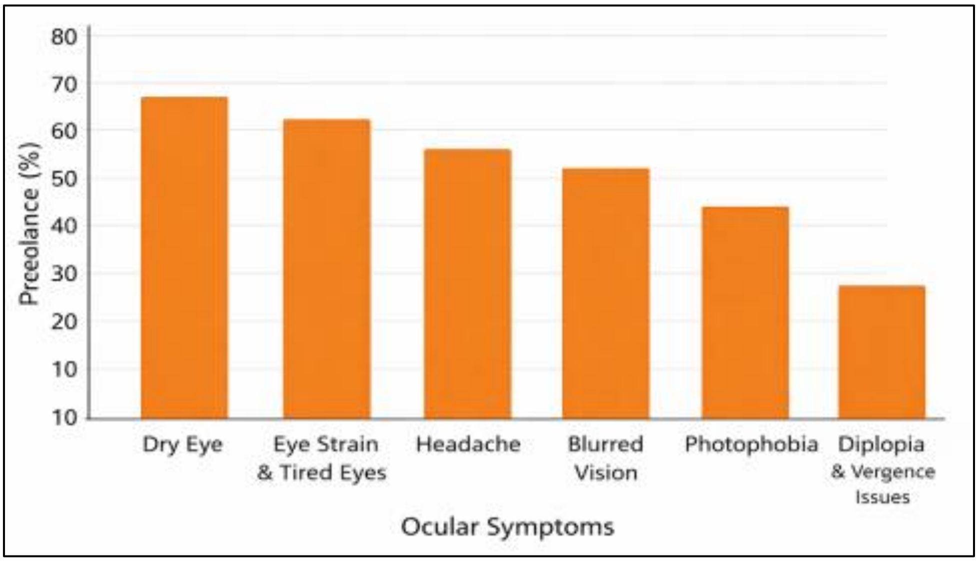

Figure 1 Prevalence of Common Ocular Symptom Associated with Prolonged Digital Screen Use

3.2.2. Visual, Ergonomic, and Ultraviolet Radiation–Related Ocular Damage

Beyond ocular surface alterations, digital eye strain involves significant visual and musculoskeletal components. Improper viewing distance, suboptimal screen height, poor posture, glare, and inadequate ambient lighting increase accommodative demand and visual fatigue. These ergonomic factors frequently coexist with ocular symptoms and contribute to extraocular complaints such as neck, shoulder, and back pain, collectively reducing work efficiency and overall comfort [18,38].

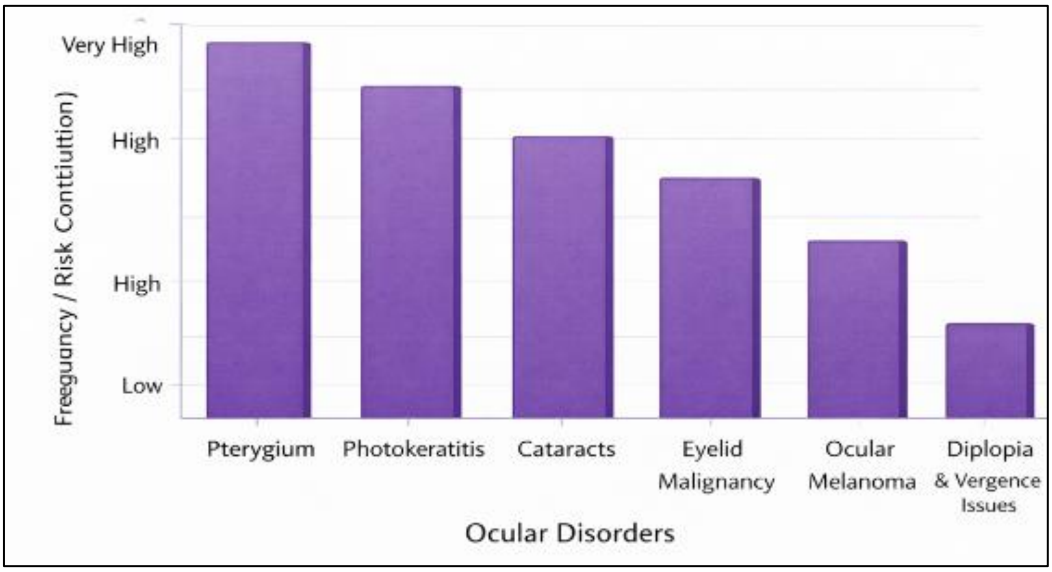

Figure 2 Relative Frequency of Ocular Disorder Associated with Chronic Radiation Exposure

Ultraviolet (UV) radiation exposure represents a distinct yet important contributor to ocular morbidity. As solar radiation passes through the Earth's atmosphere, all UV-C and approximately 90% of UV-B radiation are absorbed, leaving predominantly UV-A and a smaller but biologically significant UV-B component to reach the ocular surface [9]. In addition to natural sunlight, artificial sources—particularly welding arcs—pose substantial occupational hazards, as even brief exposure can result in intense UV-B and UV-C–induced ocular injury [36]. Ozone layer depletion has further increased ground-level UV-B exposure, amplifying the global burden of UV-related ocular disease [36].

Acute high-intensity UV exposure may cause photo keratitis, characterized by corneal epithelial damage, photophobia, tearing, and ocular pain [24]. Repeated or chronic exposure is strongly associated with structural ocular disorders, including pterygium, climatic droplet keratopathy, cortical cataract, and eyelid malignancies such as basal cell and squamous cell carcinoma [12, 22,25–27]. Unlike digital eye strain, which is largely functional and reversible, UV-induced ocular conditions often involve cumulative and irreversible tissue damage, underscoring the critical importance of preventive strategies.

3.3. Comparative Perspective: Digital Screens versus UV Exposure

Despite differing exposure characteristics, both digital screen use and UV radiation share overlapping pathogenic pathways. Visible blue light (400–500 nm), emitted by digital devices and sunlight, has been implicated in oxidative stress and inflammatory damage to ocular tissues, particularly the retinal pigment epithelium in experimental models [25,29]. Additionally, tear film instability and Meibomian gland dysfunction appear to be common contributors to ocular discomfort in both conditions.

Table 1 Comparison of Ocular Discomfort Mechanisms Associated with Digital Screen Use and Ultraviolet Radiation Exposure

Feature	Digital Screen Use	Ultraviolet (UV) Radiation Exposure
Source of exposure	Computers, smartphones, tablets, digital displays	Sunlight, welding arcs, artificial UV sources
Primary wavelength	Visible blue light (380–500 nm)	UV-A (315–400 nm), UV-B (280–315 nm)
Nature of exposure	Prolonged, close-range, repetitive	Environmental, occupational, cumulative
Key mechanism	Reduced blink rate, incomplete blinking, accommodative stress	Photochemical tissue damage, oxidative stress
Tear film impact	Tear film instability, increased evaporation	Tear instability, Meibomian gland involvement
Ocular surface effects	Dry eye, irritation, burning sensation	Photo keratitis, conjunctival degeneration
Retinal involvement	Blue-light–induced oxidative stress	Minimal UV retinal exposure; blue light contributes
Reversibility	Largely functional and reversible	Often structural and irreversible
Major risk group	Office workers, students, children	Outdoor workers, welders, high-altitude populations

3.3.1. Management, Prevention, and Public Health Implications

Effective mitigation of ocular discomfort related to digital screen use and ultraviolet (UV) radiation exposure relies on integrated behavioural, ergonomic, and optical strategies. Prevention of digital eye strain includes limiting prolonged screen time where feasible, optimizing workstation ergonomics (appropriate viewing distance, screen height, lighting, contrast, and luminance), and adopting regular visual breaks such as the 20–20–20 rule [2,37–39]. Correction of refractive errors and the use of anti-reflective or blue-light–filtering lenses further reduce accommodative stress and visual fatigue. In children, parental monitoring of screen use and promotion of outdoor activities are particularly important to minimize prolonged near-work demands.

Protection against UV-induced ocular damage requires consistent use of UV-filtering spectacles or contact lenses, certified UV-blocking sunglasses, wide-brimmed hats, and protective eyewear in high-reflectivity or occupational settings [40,41]. Limiting exposure during peak sunlight hours remains a simple yet effective preventive measure.

Collectively, these findings underscore the importance of integrating ocular ergonomics, behavioural counselling, and protective interventions into routine eye care. Targeted education and public health policies promoting safe digital practices and UV protection are essential to reduce cumulative ocular morbidity and preserve visual health across vulnerable populations, including children, office workers, and outdoor labourers.

Table 2 Preventive and Management Strategies for Digital Eye Strain and UV-Induced Ocular Disorders

Category	**Digital Eye Strain Prevention**	**UV Exposure Protection**
Behavioral measures	Reduce screen time (<4 h/day), frequent breaks	Limit peak sunlight exposure
Ergonomic strategies	Proper screen distance (≈20 inches), posture	Shade use, wide-brimmed hats
Visual hygiene	20-20-20 rule, screen brightness adjustment	Avoid reflective surfaces
Optical aids	Anti-reflective and blue-light filtering lenses	UV-filtering spectacles and contact lenses
Pediatric measures	Screen monitoring, outdoor activities	Eye protection education
Occupational protection	Workstation optimization	Welding goggles, UV safety eyewear
Public health role	Digital use awareness programs	UV index awareness and policies

4. Conclusion

In contemporary society, complete avoidance of digital screen use and ultraviolet (UV) radiation exposure is neither practical nor feasible, given their integral roles in daily life and occupational activities. This review demonstrates that digital screen exposure predominantly results in functional and reversible ocular discomfort, including dry eye, eye strain, and accommodative dysfunction, largely driven by altered blink dynamics, tear film instability, and sustained near-vision demands. In contrast, UV radiation exposure is associated with cumulative photochemical injury leading to structural and often irreversible ocular pathologies such as photo keratitis, pterygium, cataract, and eyelid malignancies.

Despite these differences, both exposures share common pathogenic mechanisms, notably tear film instability, Meibomian gland dysfunction, and oxidative stress mediated by visible blue light. Given the inevitability of exposure, emphasis should shift from avoidance to risk mitigation through evidence-based preventive strategies. Behavioral modification, ergonomic optimization, appropriate optical correction, and consistent use of UV-protective measures are effective in reducing ocular morbidity and preserving visual function. Integrating these interventions into clinical practice and public health initiatives is essential to safeguard ocular health in an increasingly digital and environmentally exposed world.

Compliance with ethical standards

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Disclosure of conflict of interest:

No conflict of interest to be disclosed.

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