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REVIEW ARTICLE

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Computer vision syndrome: a comprehensive literature review

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ABSTRACT

Computer Vision Syndrome is a growing health concern in the digital age, with a reported prevalence of 69.0%. It is caused by screen-related, environmental, ergonomic, and physiological factors, affecting diverse demographics. The COVID-19 pandemic significantly amplified CVS due to increased screen time for remote work, online learning, and social media use, with studies reporting symptoms in up to 74% of individuals. Unique visual challenges from digital screens, including reduced clarity and glare, exacerbate symptoms like dry eyes and discomfort, especially in those with uncorrected vision. Understanding CVS is crucial for mitigating its impact through effective prevention and management strategies. This study explores the causes, diagnosis, management, and prevention strategies of CVS by synthesizing recent findings from optometry, occupational health, digital health, and ergonomics. It also highlights emerging trends such as AI, wearables, and augmented reality while providing practical management strategies. A narrative review of literature from 2014 to 2024 was conducted, focusing on PubMed-indexed, peer-reviewed articles, including meta-analyses and systematic reviews, with priority given to recent, highly cited studies.

ARTICLE HIGHLIGHTS

Introduction

- Computer Vision Syndrome (CVS), also known as digital eye strain, affects 69% of the population, with prevalence influenced by gender, region, and income.
- The COVID-19 pandemic has intensified CVS symptoms due to increased screen time for remote work and online learning.

Definition and Symptoms of Computer Vision Syndrome (CVS)

- CVS encompasses a range of ocular and extraocular symptoms, including eyestrain, headaches, blurred vision, and neck pain.
- Symptoms are exacerbated by the unique visual demands of digital screens, such as imprecise letter clarity and reduced contrast.

Prevalence and Demographic Analysis of Computer Vision Syndrome

- A 2023 meta-analysis highlights a higher prevalence of CVS among females and in regions like Africa and Asia.
- University students report the highest prevalence rates due to increased screen time and inadequate ergonomic practices.

Risk Factors and Visual Demands in Computer Vision Syndrome

- Prolonged screen time, poor ergonomic setups, and uncorrected vision are significant risk factors for CVS.
- The role of blue light in CVS remains controversial, with ongoing debates about its impact on visual fatigue.

Prevention, Management, and Treatment Strategies

- Wearable technologies and AI are emerging as innovative tools for CVS prevention, offering real-time feedback on eye health and ergonomics.
- Despite their popularity, blue light-blocking spectacles and multifocal lenses show limited efficacy in reducing CVS symptoms.

Innovative Technologies in CVS Prevention

- Smart glasses equipped with near-eye tracking technologies can monitor blink rates and provide reminders to reduce eye strain.
- AI-based ergonomic assessments have shown promise in improving posture and awareness in professional settings.

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KEYWORDS

Artificial intelligence (AI) in eye health; computer vision syndrome; digital health; prevalence; prevention and management; risk factors; symptoms; wearable technologies

Current Guidelines for CVS Prevention

- Public awareness campaigns emphasize the importance of ergonomic practices, regular eye exams, and balanced device use.
- Workplace interventions and educational initiatives are crucial for a holistic approach to CVS management.

Future Perspective

- The future of CVS management will rely on evidence-based interventions, innovative technologies, and public education.
- Addressing the unique needs of diverse groups, including children and older adults, is essential for effective CVS mitigation.

1. Introduction

In the contemporary digital age, Computer Vision Syndrome (CVS), commonly known as digital eye strain, has become a prevalent concern, with recent meta-analysis research in 2023 revealing a nuanced prevalence of 69.0%, influenced by factors such as gender, region, income group, and population categories, thereby highlighting the widespread nature of CVS across different demographic segments [1].

The COVID-19 pandemic significantly amplified the issue of CVS, as the global shift to online learning and remote work increased screen time across all age groups, with studies reporting a notable rise in CVS symptoms; a 2024 systematic review highlighted that 74% of participants experienced CVS, underscoring the impact of pandemic-induced lifestyle changes [2–5]. Beyond facilitating remote work and online learning, the pandemic also heightened screen time on social media platforms [6,7]. For example, a study in China found that social media usage increased by 3.2 hours per week during the pandemic compared to pre-pandemic levels [6]. Research indicates that social media use likely increased CVS symptoms, such as dry eyes, burning, and itching, due to reduced blinking, with prolonged mobile phone use—characterized by small screens and extended viewing times—and factors like age and social media habits significantly influencing CVS prevalence [8]. Additionally, a study among Thai university students found a 12% increase in CVS risk for every additional hour of screen time, further linking extended digital engagement to eye strain [9]. The distinctive visual demands of digital screens contribute significantly to CVS, as they present challenges like imprecise letter clarity, reduced contrast, reflections, and problematic viewing distances and angles, all of which strain the visual system and impair performance [10]. These effects are intensified by screen factors such as resolution, contrast, refresh rates, and ambient glare, with bright peripheral illumination during computer use further exacerbating symptoms [11].

Screen time exceeding two hours daily has been consistently linked to a higher risk of CVS [12]. The average American worker, for instance, spends seven hours per day on computers, making them especially prone to symptoms such as headaches, eyestrain, blurred vision, dry eyes, and neck and shoulder pain [10]. A study in the UK and Ireland reported that 89.5% of workers experienced CVS symptoms, with 34.4% experiencing them regularly, and identified key predictors such as being 35 years or older, prolonged daily computer use of six or more hours, and the use of corrective eyewear [13]. The impact of excessive screen time extends beyond the workplace, affecting various age groups, with CDC data showing children aged 8 to 10 average six hours daily on screens, those aged 11 to 14 average nine hours, and teenagers aged 15 to 25 average seven and a half hours, including television use [14].

Diagnosis requires a comprehensive eye examination focusing on computer-related visual requirements, enabling eye care professionals to recommend suitable treatments [12]. In the evolving digital landscape, understanding CVS becomes crucial for eye health, especially in the context of challenges in the modern work environment and the escalating reliance on digital screens. This literature review aims to contribute to the discourse on eye health in the digital era by exploring the complexities of CVS, including its causes, risk factors, symptoms, diagnosis, treatment, and prevention. It provides a comprehensive synthesis of the most recent findings from multiple disciplines, addressing physiological, ergonomic, and environmental factors. The review also highlights emerging trends such as the use of AI and wearables in prevention, and augmented reality as a new risk factor. By offering practical prevention and management strategies, it bridges research from optometry, occupational health, digital health, and ergonomics, making it a valuable resource for both research and real-world application.

2. Methods

A narrative review of literature from 2014 to 2024 was conducted, focusing exclusively on PubMed-indexed, peer-reviewed articles. The review encompassed meta-analyses, systematic reviews, and primary research studies related to computer vision syndrome.

- **Search Strategy:** Studies were identified through the PubMed database using keywords such as "Computer Vision Syndrome," "prevalence," "ergonomic factors," and "management strategies."
- **Inclusion Criteria:** Preference was given to the newest papers to ensure the inclusion of the most current findings. Highly cited and methodologically robust studies were prioritized for their relevance and impact on key review themes. Information from the American Optometric Association and the Centers for Disease Control and Prevention was included to supplement peer-reviewed literature with expert guidelines and statistics.
- **Exclusion Criteria:** Non-English studies, non-peer-reviewed articles, and papers unrelated to CVS were excluded.
- **Synthesis Approach:** Studies were thematically categorized into sections addressing prevalence, physiological and ergonomic factors, and evidence-based prevention and management strategies.

3. Definition and symptoms of computer Vision Syndrome (CVS)

Computer Vision Syndrome (CVS), also known as Digital Eye Strain (DES), is a term that encompasses a range of ocular and extraocular problems [11]. This condition, as described by the American Optometric Association (AOA), manifests as a collection of visual abnormalities associated with extended use of video display terminals (VDTs), such as computers, tablets, e-readers, and cell phones [12].

Ocular symptoms characteristic of CVS include vision blurring, dryness, headache, eye redness, watering/tearing of the eyes, burning sensation in the eyes, double vision, eye pain, itching, intolerance to light, difficulty in near vision, heaviness in the eyelids, foreign body sensation, excessive blinking, colored halos, vision worsening, eye strain and fatigue, and eye irritation, while extraocular symptoms, directly linked to poor posture and the positions adopted during computer-related activities, include sleep disturbance and discomfort or pain in the neck, shoulders, and back [1,11,12]. The ocular and musculoskeletal symptoms associated with CVS significantly impact psychological well-being, often leading to increased stress and discomfort, which are linked to higher rates of depression and anxiety [15,16]. Moreover, research indicates that CVS can hinder academic activities and cognitive functions due to its association with insomnia, as blue light from digital devices, particularly in the 440-550nm range, suppresses melatonin production—disrupting circadian rhythms and leading to difficulties in falling asleep and maintaining restful sleep [17,18]. Additionally, CVS symptoms like visual fatigue and dry eyes further impede performance during remote learning or work, which is particularly concerning for students and professionals who heavily depend on computer use [19]. Eyestrain, often accompanied by headaches, can be attributed to various factors, including muscle spasms around the orbit, impairment in accommodation, and convergence issues. This underscores the intricate interplay of physiological factors contributing to the manifestation of CVS symptoms [20].

Furthermore, the severity of ocular CVS symptoms is closely related to visual acuity and the specific demands of a task, such as rapid transitions between light and dark environments. These transitions can cause transient visual impairments due to photopigment bleaching in the retina, illustrating how environmental and task-related factors affect visual performance [10]. Additionally, factors like uncorrected vision, poor office ergonomics, and visually demanding tasks exacerbate these issues by increasing strain on the visual system. For example, frequent focus adjustments between the screen, keyboard, and other elements when using a computer further contribute to CVS symptoms [10,12]. Symptoms such as asthenopia and visual fatigue develop gradually and take longer to resolve, often persisting with continued task exposure [10]. Moreover, extended computer use reduces blinking, which in turn leads to dry eyes and poorer tear film quality, further contributing to eye fatigue [10,12].

Posture-related symptoms in CVS, recognized as musculoskeletal symptoms, are most commonly manifested as neck, shoulder, and back pain, with a study on bank employees in Cape Coast Metropolis, Ghana, revealing a strikingly high prevalence of 79.1% for neck pain, 69.8% for shoulder pain, and 82.7% for back pain [21].

Similarly, research among undergraduate students in Chennai revealed a significant prevalence of these musculoskeletal symptoms [22].

Another study conducted among medical students at the University of Khartoum, Sudan, involving 149 participants, yielded comparable findings, with neck and shoulder pain being the most commonly reported symptom (78.5%) [23]. The noteworthy frequency of these musculoskeletal issues is hypothesized to be linked to inadequate viewing angles and distances associated with computer use [12]. **Figure 1. And Figure 2.** summarizes the most common CVS symptoms with their prevalence according to Ccami-Bernal F et al. findings [1].

Prevalence and demographic analysis of computer vision syndrome

The comprehensive investigation into the prevalence of CVS conducted through a systematic meta-analysis study in 2023, covering research from 2011 to 2023, offers valuable insights into the nuanced landscape of this visual health concern. The overall prevalence of CVS across 103 studies was 69.0% (95% CI: 62.2 to 75.4) [1].

A gender-based analysis revealed that females exhibited a higher prevalence at 71.4% (95% CI: 61.4 to 80.5), compared to males at 61.8% (95% CI: 51.0 to 72.1) [1]. Dry eye, a key component of CVS, is influenced by hormonal fluctuations in females, which can disrupt tear production and increase dryness [24]. This effect is further exacerbated by the use of eye cosmetics, which can migrate to the ocular surface and destabilize the tear film lipid layer, leading to worsened evaporative dry eye symptoms [25]. Additionally, increased screen time and improper adoption of ergonomic practices may contribute to this disparity, though further research is needed to confirm these factors.

The study highlighted regional disparities in prevalence rates, with Africa (71.2%, 95% CI: 64.0 to 77.8) and Asia (69.9%, 95% CI: 60.5 to 78.6) exhibiting higher rates compared to Europe (61.4%, 95% CI: 54.2 to 68.3) and Latin America (66.6%, 95% CI: 57.6 to 74.9) [1]. The high prevalence rate in Africa can be attributed to various factors, like poor ergonomic practices, suboptimal workplace setups, and a lack of awareness about proper ergonomics. For example, a Study in Ghana shows that 79.5% of workstations had poor ergonomic practices, with 73.5% of respondents using incorrect screen angles and 99.0% experiencing suboptimal lighting [26]. Similarly, in Ethiopia, 78.6% of participants had poor setups, with 61.1% exceeding recommended viewing angles and 55.7% working under inadequate lighting [27]. In Nigeria, despite high educational levels

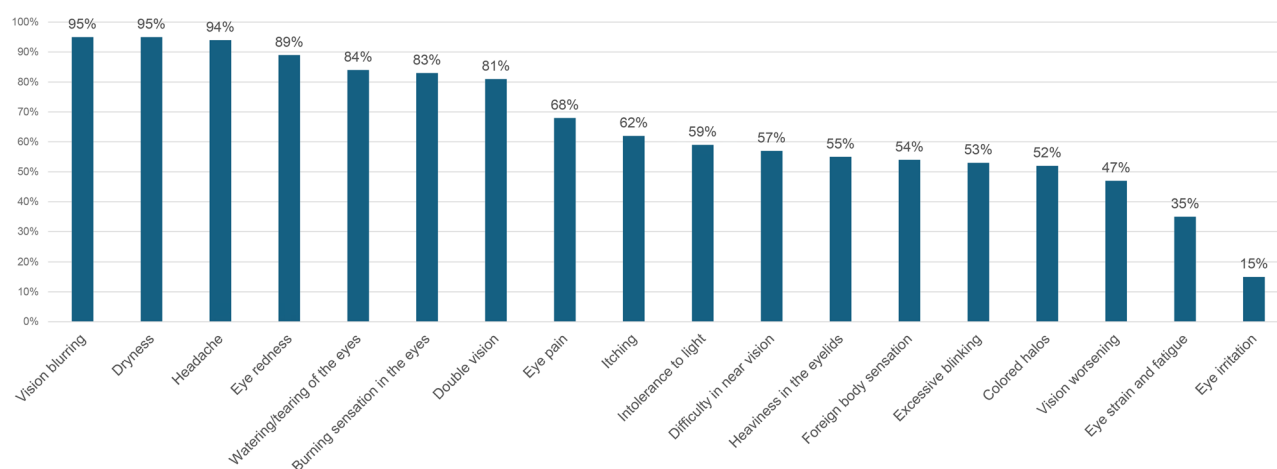


Figure 1. Ocular Symptoms Prevalence.

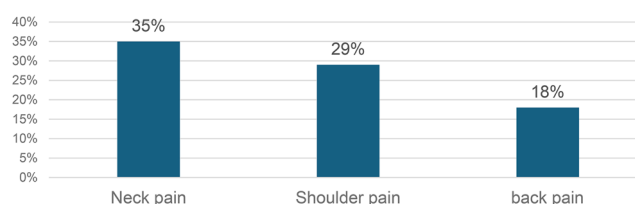


Figure 2. Extraocular Symptoms Prevalence.

among medical laboratory scientists, only 25.5% were aware of ergonomics, and fewer than 30% of those understood its benefits or associated risks [28]. Weather factors, such as low humidity in hot, sunny, and dry climates, may also contribute to the high prevalence of CVS in Africa, as dry eyes, a key component of computer vision syndrome, are more common in these conditions [29,30]. The findings highlight the need for ergonomic training, improved workplace setups, and environmental adaptations to address the high prevalence of CVS in Africa, while also emphasizing the importance of awareness campaigns and policy interventions to reduce its impact.

Income group analysis revealed that lower-middle-income countries reported the highest prevalence at 71.3% (95% CI: 65.2 to 77.0), followed by low-income countries (69.3%, 95% CI: 59.5 to 78.3), high-income countries (68.0, 95% CI: 60.3 to 75.2), and upper-middle-income (66.1, 95% CI: 49.1 to 81.2) [1]. This data suggests that CVS is a pervasive issue across all income levels, highlighting the potential influence of workplace practices, awareness, and access to preventive measures rather than economic factors alone.

Population-specific nuances were evident, ranging from 50.5% prevalence (95% CI: 29.3 to 71.6) among children and adolescents to 76.1% (95% CI: 70.7 to 81.2) among university students. While in broader categories, the general population and workers reported prevalence rates of 67.9% (95% CI: 56.7 to 78.3) and 69.2% (95% CI: 64.7 to 73.6), respectively [1]. The high prevalence of CVS among university students is linked to variations in screen time, ergonomic practices, and awareness of proper eye care, as they frequently spend long hours on multiple digital devices for study, online classes, research, and social activities—especially after the pandemic-driven shift to virtual learning—often without proper ergonomic setups or adequate breaks, leading to increased rates of CVS symptoms [2–4,9,31–34].

Social media dominates teenagers' and young adults' daily lives, linking excessive use to high-risk behaviors and poor academic performance [35,36]. This issue has been further amplified by the COVID-19 pandemic, which drove adolescents toward increased digital interactions, contributing to health problems such as CVS [3,37]. Alongside social media, gaming has also been a significant contributor to screen time in teenagers and young adults. While it can enhance cognitive skills and social interaction, excessive gaming often leads to increased screen exposure, a risk factor for CVS [38]. Similarly, augmented reality (AR), which blends digital elements with the real world, is increasingly being integrated into entertainment, healthcare, and education [39,40]. However, extended use of AR for gaming raises additional concerns about ocular health, particularly due to phenomena like vergence-accommodation conflict, where the eyes must simultaneously converge on a virtual object's perceived depth while accommodating to the fixed distance of the physical screen. This mismatch disrupts the natural coupling of these processes, leading to visual discomfort, particularly during rapid changes in depth cues [41,42]. These issues are particularly concerning among teenagers and young adults, who, according to the Entertainment Software Association (ESA) in 2019, account for 40% of video game players. This age group, specifically adolescents aged 12 to 18 years, spends the most time gaming, with an average of 11.89 hours per week [43].

On the other hand, children and adolescents may have lower screen exposure due to individual preferences for physical activity, effective parental guidance, and social engagement, which collectively promote a lifestyle favoring active participation over screen-based activities, as many young individuals prefer outdoor play and sports, thereby reducing their screen time [44]. Parental influence is crucial, as studies show that parents who set screen time limits can significantly decrease their children's screen usage [45]. Additionally, when parents engage in activities with their children, it often results in less screen time, highlighting the importance of active involvement [46]. Social engagement in school settings plays a key role in reducing screen time, as children who feel connected to their school community are more likely to participate in activities that limit screen use, whereas loneliness and social isolation are linked to increased screen usage, highlighting the importance of social connections [47].

Notably, the choice of diagnostic criteria played a role in prevalence rates, with CVS-Q studies reporting 61.3% prevalence (95% CI: 50.7 to 71.4), while other criteria yielded a higher 75.4% prevalence (95% CI: 71.3 to 79.4) [1]. This variation highlights the need for standardized diagnostic criteria in CVS studies to ensure consistent results. Broader criteria may identify more cases, while specific criteria like the CVS-Q may report fewer cases compared to more inclusive definitions, affecting prevalence estimates and public health strategies [48].

These findings underscore the intricate interplay of demographic, diagnostic, and population-specific factors influencing the prevalence of CVS. The detailed breakdown of prevalence across various subgroups enhances

our understanding of the multifaceted nature of CVS and highlights the need for tailored interventions based on demographic and contextual considerations. Figure 3. presents the prevalence of Computer Vision Syndrome across different demographics according to Ccami-Bernal F et al. findings [1].

Risk factors and visual demands in computer vision syndrome

Extended use of computers or digital screens poses unique challenges that increase the risk of CVS, as the visual demands differ from traditional tasks, with distinct viewing distances and angles stressing eye focusing and movement, while screen resolution, contrast, refresh rates, and glare further contribute to eye symptoms [12].

Among the potential factors, blue light emitted from digital screens has drawn considerable attention. Proponents argue that blue light may increase visual fatigue and discomfort, with some researchers linking it to symptoms of CVS [49]. Studies indicate that prolonged exposure to blue LEDs in mice is linked to apoptosis and oxidative damage to the cornea, with similar effects like reduced cell viability and increased reactive oxygen species observed in human corneal and conjunctival cells, potentially leading to ocular surface inflammation, worsening dry eye disease, and exacerbating CVS symptoms; additionally, animal and cell culture studies show retinal damage from prolonged exposure to bright blue light, raising concerns that chronic exposure in humans could contribute to retinal diseases, including age-related macular degeneration [50,51]. However, the role of blue light in CVS remains controversial. Several organizations, including the American Optometric Association, does not consider blue light a factor that causes CVS [52]. Some researchers propose that blue light from screens may be a risk factor of eye strain, while others argue that the symptoms are more likely the result of a combination of screen-related factors, along with environmental and ergonomic influences [12,51,53,54].

As a result, the scientific community continues to debate the true impact of blue light on CVS, calling for further research to clarify its role and effectiveness in mitigating symptoms.

Uncorrected vision significantly contributes to the risk of developing CVS [10,55]. Research indicates that individuals with uncorrected refractive errors, presbyopia, accommodative disorders, and vergence disorders, are particularly susceptible to CVS due to the increased visual strain required to focus on screens for extended periods [11]. These individuals may also find their prescriptions unsuitable for computer screen distances, leading to uncomfortable postures like tilting the head or bending forward. Such postures can result in muscle spasms or pain in the neck, shoulders, or back [10]. This underscores the importance of regular visual assessments to detect these conditions, particularly in adults, as they become more susceptible to age-related visual impairments after the age of 40, further emphasizing the need for early diagnosis and intervention [12].

The American Optometric Association (AoA) underscores that spending two or more continuous hours at a computer or using digital screen devices daily places individuals at the greatest risk for developing CVS. This

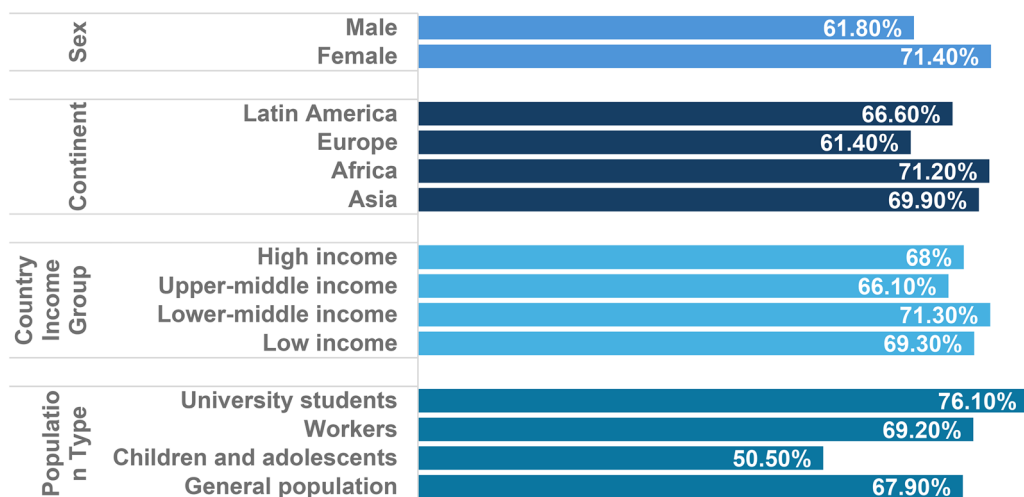


Figure 3. The Prevalence of Computer Vision Syndrome Across Different Demographics.

prolonged screen time surpasses the visual capacities of individuals, contributing to the manifestation of CVS symptoms [12].

In essence, understanding these multifaceted risk factors is essential for developing effective preventive strategies. Symptoms of CVS often arise when the visual demands of the task surpass an individual's visual capabilities. By being aware of both individual and environmental contributors, practices that promote optimal visual health can be fostered in our technology-driven era [10,12].

Prevention, management and treatment strategies

Current guidelines for CVS prevention [12]

The following recommendations are grounded in current guidelines for the prevention and management of CVS by the American Optometric Association. These guidelines emphasize the importance of a comprehensive approach, including a thorough eye examination that considers an individual's medical history, prescription usage, and environmental conditions that may exacerbate eye strain. In this context, occupational and environmental health professionals play a pivotal role, particularly in the workplace, by disseminating knowledge to staff members and supervisors regarding effective strategies to alleviate eye strain.

The positioning of the computer screen is crucial for comfort and ergonomics. Users typically find it more comfortable when their eyes naturally look downward toward the screen. For optimal positioning, the screen should be set 15 to 20 degrees below eye level, with the center of the screen positioned about 4 to 5 inches below eye level and at a distance of 20 to 28 inches from the eyes. Additionally, the placement of reference materials plays an important role. Ideally, they should be located above the keyboard and below the monitor to reduce the need for frequent head movements. If this setup is not practical, using a document holder positioned next to the monitor is a suitable alternative. Figure 4 provides a visual representation of these ergonomic guidelines, illustrating the correct sitting posture, the recommended screen angle and distance, and the optimal placement of reference materials.

Equally important is the consideration of lighting conditions, where efforts should be made to position the computer screen to avoid glare, particularly from overhead lighting or windows. The use of blinds or drapes on windows and lower-wattage bulbs in desk lamps can aid in reducing glare. In cases where glare remains an issue, the use of anti-glare screens or filters is recommended to decrease the reflected light from the screen. Suggestions for symptomatic workers include the use of single-vision lenses with a computer-adjusted focal length to balance ergonomic practices and visual comfort.

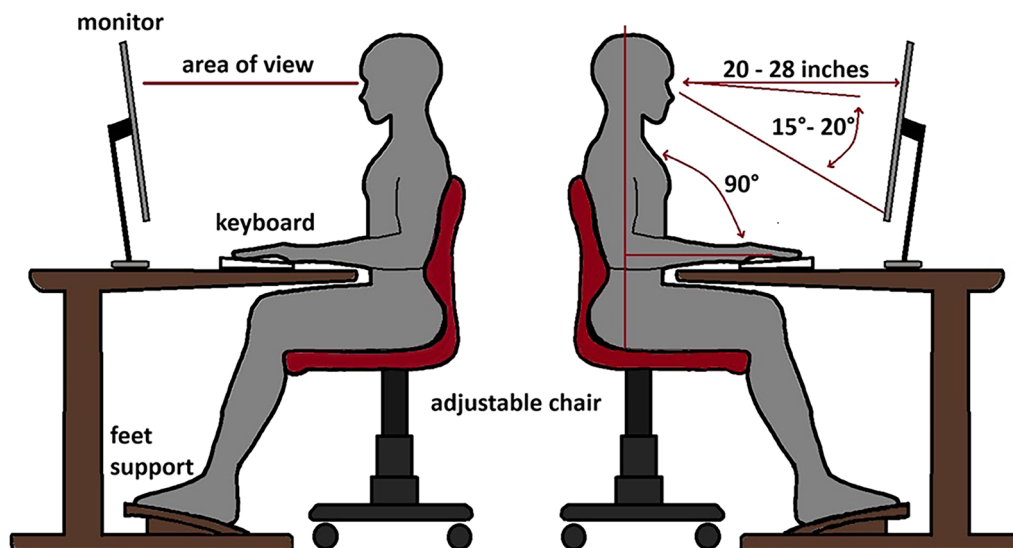


Figure 4. The Correct Ergonomic Sitting Posture.

The seating position is another vital aspect, emphasizing the need for comfortably padded chairs that conform to the body. Chair height should be adjusted to ensure that feet rest flat on the floor, with adjustable armrests providing support while typing, and wrists kept off the keyboard during typing.

To alleviate eyestrain, incorporating rest breaks into computer usage is advised. Users should aim to rest their eyes for 15 minutes after two hours of continuous computer use. Blinking frequently is recommended to minimize the risk of developing dry eyes during prolonged computer use, as blinking helps keep the front surface of the eyes moist.

Innovative technologies in CVS prevention

The integration of wearable technologies and artificial intelligence (AI) in monitoring eye health and promoting ergonomic practices is gaining significant attention, particularly with the advent of smart glasses and other innovative devices, as highlighted by several studies exploring advancements and applications of these technologies in health-related fields. One such study, "Wearable Near-Eye Tracking Technologies for Health: A Review" by Zhu et al., highlights the role of near-eye tracking (NET) technologies in health. Published in 2024, the review examines approximately 70 related articles from the past two decades, with a focused analysis on 30 studies from the preceding five years.

These wearable devices utilizing NET technologies, such as Video Oculography (VOG) and Electrooculography (EOG), provide real-time insights into eye movements and behaviors; for instance, smart glasses equipped with NET sensors can monitor blink rates and eye strain, offering timely reminders to blink or take breaks, thereby reducing digital eye strain and promoting healthier screen time habits, while also enhancing personal health management through continuous, non-intrusive monitoring and encouraging ergonomic practices by alerting users to adjust posture or take necessary breaks [56].

Additionally, Donisi et al. have highlighted the use of wearable sensors combined with AI to enhance physical ergonomics. This approach can be adapted to develop personalized solutions for computer users, where wearable devices track posture and screen time, using AI to provide real-time feedback and suggest adjustments to prevent CVS [57].

A similar concept was adapted by Hamilton et al. in their study, which demonstrated that AI-based real-time video ergonomic assessment can improve posture and awareness among surgical residents. The residents improved their ergonomic scores in the neck and right shoulder angles. They also expressed increased awareness of ergonomics based on the session content and AI information, proving the intervention effective [58]. As these technologies continue to evolve, they demonstrate the transformative potential of wearable technologies and AI in managing eye health and promoting ergonomic practices. By offering personalized feedback and interventions, these innovations can prevent CVS and significantly enhance overall well-being.

. A 2021 review emphasized the need for effective interventions to reduce screen time and prevent CVS, examining studies from 2011 to 2019 found in MEDLINE, COCHRANE LIBRARY, and CINAHL, which focused on reducing screen use among children and adolescents. Out of 933 publications, 11 studies were included, featuring diverse approaches like school programs, smartphone apps, counseling, and educational materials. Notably, the ATLAS app significantly reduced recreational screen use at 8 and 18 months, while programs like Fit 5 Kids and the Melbourne InFANT Program successfully cut TV viewing time. However, challenges such as the short-term impact of interventions and difficulty identifying the most effective components highlight the need for further research into long-term strategies using new technologies to reduce digital exposure and mitigate CVS risk [59].

Device manufacturers can help mitigate CVS risks related to screen resolution, contrast, refresh rates, and glare by incorporating features like glare-reduction technologies, adjustable brightness modes, and optimized refresh rates, with collaboration between healthcare professionals and technology developers fostering innovative solutions to enhance user experience and safeguard eye health [12].

Recognizing the pivotal role of eye practitioners, there is a call to educate the public about maintaining optimal visual health through adherence to established visual and ergonomic standards. A holistic CVS-related educational campaign is strongly recommended, encompassing aspects of computer usage, ergonomic practices, CVS symptoms, management options, and preventive approaches, thus empowering individuals to proactively safeguard their visual well-being [10,12,60].

Management and treatment [61]

Navigating the intricacies of CVS management demands a nuanced and multifaceted approach, as underscored by insights derived from an exhaustive systematic review and meta-analysis by Singh et al., titled "Interventions for the Management of Computer Vision Syndrome: A Systematic Review and Meta-analysis," published in the Journal of the American Academy of Ophthalmology. Encompassing data from 45 randomized controlled trials (RCTs) and involving a robust cohort of 4,497 participants, this comprehensive examination provides a foundation for evidence-based recommendations to inform clinical practice. Currently, there are no established clinical guidelines to assist practitioners in offering evidence-based advice on CVS treatments. This systematic review and meta-analysis aim to bridge that gap by guiding best practices for eye care providers. The following encapsulates the key findings unearthed by these studies [61].

1. Optical Aids

- **Multifocal Lenses:** The study found no significant improvement in visual fatigue scores when using multifocal lenses compared to single-vision lenses, with a standardized mean difference (SMD) of 0.11. Additionally, there was very low certainty evidence for no difference in amplitude of accommodation. No significant differences were observed in dry eye symptoms or adverse event rates. Multifocal lenses are often prescribed to provide optimal refractive correction at intermediate and near distances. However, the findings suggest they may not effectively alleviate CVS symptoms.
- **Blue Light-Blocking Spectacles:** Despite their popularity, blue light-blocking spectacles did not show a significant reduction in visual fatigue symptoms compared to non-blue light-blocking lenses. There was also no significant difference in critical flicker-fusion frequency (CFF). Moderate certainty evidence indicated no improvement in dry eye symptoms. The study questions the use of CFF as a measure of visual fatigue and calls for more rigorous studies to determine the true efficacy of blue light-blocking lenses. This ongoing debate raises questions about the validity of current recommendations regarding blue light exposure and the use of protective eyewear.

2. Oral Supplements

- **Berry Extracts:** The study found no significant improvement in visual fatigue or CFF with berry extracts, such as bilberry and maqui berry. There was also no improvement in dry eye symptoms. The proposed mechanisms of action for these supplements are unclear, and the study populations did not have dietary deficiencies that might justify supplementation.
- **Omega-3 Fatty Acids:** Low certainty evidence suggested that omega-3 fatty acids might improve dry eye symptoms, although there was high statistical heterogeneity and potential adverse events like gastric intolerance, especially at higher doses. Omega-3s are thought to enhance ocular surface health by modulating tear homeostasis. While they may be beneficial, further research is necessary to confirm their efficacy and safety.
- **Carotenoids:** The study found very low certainty evidence for an improvement in CFF with carotenoid supplementation. The clinical significance of this finding is unclear, and the potential mechanism of action is unknown. Carotenoids, such as lutein and zeaxanthin, are believed to support eye health, but more research is needed to explore their benefits for CVS.
- **Combination Supplements:** These supplements often include a mix of vitamins, minerals, and other nutrients. However, there was very low certainty evidence for no significant effects of combination supplements on visual fatigue, accommodation amplitude, and blink rate. Adverse events reported were unrelated to the intervention.
- **Other Supplements:**

Green Tea Extracts: Often marketed for their antioxidant properties, the study found very low certainty evidence for no significant difference in visual fatigue or CFF with green tea extracts compared to placebo.

Probiotics: Thought to support overall health, including eye health, there was very low certainty evidence for no significant difference in visual fatigue, dry eye symptoms, or CFF with probiotics.

Taurine: Taurine is sometimes included in eye health supplements, but the study found very low certainty evidence for no significant difference in CFF with taurine compared to placebo.

3. Artificial Tears

Commonly used to alleviate dry eye symptoms, the study found very low certainty evidence for the efficacy of artificial tears in managing CVS symptoms, with different dosing regimens tested. No significant reduction in symptoms was observed compared to no intervention, and secondary outcomes and adverse events were not reported.

4. Environmental Modifications

- **Moist Cool Air Devices (Humidifiers):** These devices are thought to improve air quality by adding moisture to the air to increase humidity levels. The study found very low certainty evidence for no significant difference in visual fatigue or dry eye symptoms with moist cool air devices.
- **Computerized Risk Assessment Systems:** Systems typically involving software, used to analyze and optimize workplace ergonomics. The study found very low certainty evidence for mixed results in reducing visual fatigue with workplace modification advice generated by computerized risk assessment systems.
- **Ergonomic Adjustments:** Commonly recommended to reduce CVS symptoms, the study found no evidence for the efficacy of ergonomic adjustments in managing CVS symptoms, as no outcomes were measured or reported.

5. Visual Hygiene

20-20-20 Rule: A popular recommendation for reducing eye strain. However, the study found limited evidence for its efficacy, showing no significant improvement in visual fatigue symptoms compared to a placebo, such as advice to drink water. There was also limited evidence for its effect on reducing dry eye symptoms.

6. Other Interventions

- **Yoga:** Thought to reduce stress and improve overall well-being, the study found very low certainty evidence for some reduction in visual fatigue with yoga, but similar interventions and comparators in studies raise caution in conclusions.
- **Supplementary Workplace Rest Breaks:** Recommended to reduce eye strain and fatigue, the study found very low certainty evidence for some reduction in visual fatigue with supplementary workplace rest breaks, but no numeric data were provided.

The study underscores the pressing need for further research to identify effective treatments for established CVS. Despite evaluating a wide range of interventions, the evidence supporting their efficacy remains limited and often inconclusive. Future studies should focus on rigorous methodologies, standardized outcome measures, and larger sample sizes to better assess the potential benefits and safety of various treatments. This continued research is crucial for developing effective evidence-based strategies to manage CVS and improve patient outcomes.

Future perspective

The landscape of Computer Vision Syndrome (CVS) is set for significant transformation in the next decade, driven by advancements in technology, research, and awareness. With the widespread use of digital devices, innovative prevention and management strategies are increasingly critical. Future research will likely establish standardized diagnostic criteria to assess CVS prevalence and inform public health strategies.

Emerging technologies, such as AI and wearable devices, offer potential personalized interventions, including smart glasses and ergonomic applications. These tools could provide real-time feedback to reduce CVS symptoms and improve visual health.

Recent systematic reviews of interventions—including optical, nutritional, ergonomic, and environmental approaches—show limited and often inconclusive evidence of effectiveness. For example, blue light-blocking glasses and multifocal lenses have demonstrated minimal to no success, highlighting the need for further research to identify alternative management strategies and update current recommendations accordingly.

Additionally, CVS may manifest differently in specific populations, such as children with neurodevelopmental disorders, individuals with visual or neurological conditions, and older adults with age-related changes. Research is needed to explore how these groups experience CVS differently in terms of symptom patterns,

severity, and impacts on daily life compared to those without these conditions. Understanding these distinctions will be crucial for developing tailored diagnostic criteria and targeted interventions.

Public awareness campaigns emphasizing ergonomic practices, regular eye exams, and balanced device use are critical. These efforts, alongside workplace interventions and educational initiatives, must be integrated into a holistic approach that also addresses the unique challenges faced by diverse groups.

Further research is also needed to clarify the role of blue light and other environmental factors in CVS and to evaluate innovative treatments, such as advanced optical aids, nutritional supplements, and ergonomic solutions tailored to individual needs.

In summary, advancing the diagnosis, prevention, and management of CVS will require a combination of evidence-based interventions, improved diagnostic tools, public education, and innovative technologies. By addressing these priorities, including the unique needs of special populations, we can effectively mitigate CVS's impact and promote better visual health for all.

Authors' contributions

F.K. conceptualized the study, and wrote the study protocol, F.K., A.A., and A.T. participated in the design and did a literature search, F.K., and A.A. wrote the manuscript, F.K. supervised the study. All authors read and approved the final draft.

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No potential conflict of interest was reported by the author(s).

Ethical and transparency statements

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Reference

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This recent systematic review is highly relevant to the current literature review as it provides the most up-to-date estimate of the prevalence of Computer Vision Syndrome (CVS), assessing data up to February 2023. The review consolidates findings from 103 studies with over 66,000 participants, providing an important benchmark for understanding the global scope of CVS, with a prevalence of 69.0%. It also breaks down prevalence by demographic factors such as gender, age, and geography, which offers valuable insights into population-specific trends. Additionally, the use of meta-regression to identify factors influencing CVS prevalence adds depth to the understanding of potential risk factors, making this reference essential for evaluating the current state of CVS prevalence and the need for standardized definitions and preventive strategies.

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This systematic review and meta-analysis is highly relevant to the current literature review, as it focuses on the prevalence of Computer Vision Syndrome (CVS) specifically during the COVID-19 pandemic. With a combined prevalence rate of 74% across 18 studies chosen out of 192, this paper provides an important perspective on how the global health crisis has exacerbated the prevalence of CVS, particularly in developing countries. The subgroup analysis also reveals notable variations in prevalence by country and study group, offering valuable insights into the impact of the pandemic on different populations. This reference contributes to understanding the effects of the COVID-19 pandemic on the prevalence of Computer Vision Syndrome (CVS), emphasizing the need for targeted interventions during periods of increased screen time and changing work environments.
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This systematic review is valuable for the literature review as it highlights the potential of wearable sensors combined with artificial intelligence (AI) in improving physical ergonomics, which is closely related to the prevention of musculoskeletal disorders (MSDs) and potentially to Computer Vision Syndrome (CVS). The integration of AI with wearable sensors for monitoring biomechanical load and posture offers promising avenues for improving worker health and preventing physical strain. This reference is particularly relevant to understanding how emerging technologies, like AI and wearable devices, could contribute to better ergonomic assessments, enhancing preventive measures for CVS. It also explores how these innovations can refine risk assessments and workplace designs, which are crucial for reducing CVS-related strain.

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This review is relevant to the literature on Computer Vision Syndrome (CVS) as it addresses the growing public health concern of excessive screen time, particularly in children, and the effectiveness of interventions to reduce screen exposure. The study highlights the negative effects of early and prolonged screen use, including potential risks for mental, physical, and cognitive health. Given that CVS is associated with prolonged screen use, this reference contributes valuable insights into intervention strategies that could help mitigate screen-related health issues, including CVS, by reducing screen time. The review's findings emphasize the need for multifaceted and scalable intervention programs, which could be directly applied to prevent CVS in both children and adults.

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This comprehensive systematic review and meta-analysis focuses on the efficacy and safety of various interventions for managing Computer Vision Syndrome (CVS). It evaluates evidence from 45 randomized controlled trials involving 4,497 participants, offering insights into the effectiveness of therapies such as blue light-blocking glasses, omega-3 supplementation, artificial tears, and ergonomic adjustments. The findings highlight the limited high-certainty evidence supporting specific interventions, though some treatments, such as omega-3 supplements for dry eye symptoms, show promise.

This reference is integral to a literature review on CVS, as it synthesizes clinical trial data, identifies gaps in existing research, and emphasizes the need for evidence-based recommendations for practitioners. It underscores the importance of further research into effective treatments and highlights commonly used interventions, offering a foundation for exploring novel approaches to CVS management.

QUESTIONNAIRE

I5(26)

Computer vision syndrome: a comprehensive literature review

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- Some questions may have more than one correct answer; in which case you must mark all the correct answers.

Introduction

Question 1: Which of the following factors, beyond remote work and online learning, exacerbated the symptoms of Computer Vision Syndrome (CVS) during the COVID-19 pandemic?

- A: The transition to larger digital screens
- B: Increased screen time on social media platforms
- C: The widespread use of blue light blocking glasses
- D: Reduced exposure to natural sunlight indoors

Definition and symptoms of Computer Vision Syndrome (CVS)

Question 2: A 24-year-old student reports chronic difficulty falling asleep after late-night studying on a tablet. Which physiological mechanism most likely explains this sleep disturbance associated with Computer Vision Syndrome?

- A: Extended computer use reduces the blink rate and tear film quality
- B: Rapid transitions between light and dark environments cause photopigment bleaching
- C: Increased accommodation effort triggers spasms around the orbit
- D: Blue light in the 440-550 nm range suppresses melatonin production

Question 3: Which of the following accurately describes the relationship between task demands and transient visual impairments in CVS?

- A: Rapid transitions between light and dark environments cause photopigment bleaching
- B: Frequent focus adjustments between screens reduce the blink rate
- C: Muscle spasms around the orbit impair accommodation and convergence
- D: High ambient glare causes permanent retinal photoreceptor damage

Prevalence and demographic analysis of computer vision syndrome

Question 4: True or False: Male computer users exhibit a higher prevalence of Computer Vision Syndrome than female users due to greater occupational exposure to digital screens.

- A: TRUE
- B: FALSE

Question 5: A clinical researcher is analyzing the high incidence of dry eye symptoms among office workers in Africa. Which environmental factor most likely contributes to this regional prevalence?

- A: High atmospheric pressure in elevated regions
- B: Increased exposure to artificial indoor heating
- C: Low humidity in hot, sunny and dry climates
- D: Poor indoor air circulation in modern offices

Question 6: Why might children and adolescents demonstrate lower screen exposure compared to teenagers and young adults?

- A: Strict school regulations limiting in-class device usage
- B: Lower dependency on digital networks for peer communication
- C: A preference for physical activity and outdoor play
- D: Reduced access to personal digital devices at home

Risk factors and visual demands in computer vision syndrome

Question 7: What physiological impact has prolonged exposure to blue LEDs demonstrated in animal models?

- A: Apoptosis and oxidative damage to the cornea
- B: Permanent alteration of the retinal pigment epithelium
- C: Increased intraocular pressure and glaucoma risk
- D: Severe degradation of the optic nerve myelin sheath

Question 8: Which of the following is LEAST likely to be an underlying visual condition making an individual particularly susceptible to Computer Vision Syndrome?

- A: Enhanced accommodative amplitude
- B: Uncorrected refractive errors
- C: Untreated presbyopia
- D: Pre-existing vergence disorders

Question 9: A 45-year-old patient complains of neck and shoulder pain after working on a computer. They have uncorrected presbyopia. What is the most likely mechanical cause of their musculoskeletal symptoms?

- A: Reduced blinking leading to compensatory head movements
- B: Increased photopigment bleaching causing muscle spasms
- C: Sustained convergence effort straining the extraocular muscles
- D: Adopting uncomfortable postures like tilting the head forward

Current guidelines for CVS prevention

Question 10: According to the American Optometric Association, what is the optimal vertical positioning for a computer screen to maximize user comfort?

- A: Elevated 10 to 15 degrees above natural eye level
- B: Positioned exactly parallel to the user's forward gaze
- C: Set 15 to 20 degrees below the horizontal eye level
- D: Angled 25 to 30 degrees upward from the desk surface

Question 11: TRUE or FALSE: To maintain proper workplace ergonomics and prevent musculoskeletal strain, users should rest their wrists directly on the keyboard while typing.

- A: TRUE
- B: FALSE

Innovative technologies in CVS prevention

Question 12: A hospital implements a new AI-based, real-time video monitoring system in its surgical department. Based on recent studies, what is the most likely primary benefit for the surgical residents using this technology?

- A: Reduced blue light exposure from the surgical monitors
- B: Decreased ambient glare from the operating room lights
- C: Automatic adjustment of visual focal length during surgery
- D: Improvement in ergonomic scores for the neck and shoulder

Management and treatment

Question 13: Which proposed mechanism explains how omega-3 fatty acid supplementation might improve dry eye symptoms in patients with Computer Vision Syndrome?

- A: By decreasing the photopigment bleaching in the retina
- B: By reducing the frequency of accommodative muscle spasms
- C: By directly filtering high-energy blue light emissions
- D: By modulating tear homeostasis to enhance ocular surface health

Environmental Modifications

Question 14: Which of the following interventions is LEAST likely to provide a significant, evidence-based improvement in visual fatigue or dry eye symptoms for a patient with CVS?

- A: Setting the computer screen 15 to 20 degrees below eye level
- B: Implementing AI-based real-time video ergonomic assessments
- C: Utilising moist cool air devices to increase room humidity
- D: Adjusting chair height so feet rest flat on the floor

Future perspective

Question 15: What key priority is emphasized for advancing the future management and mitigation of Computer Vision Syndrome?

- A: Clarifying the role of blue light and environmental factors
- B: Mandating strict governmental limits on daily screen time
- C: Eliminating all blue light emissions from digital devices
- D: Developing universal surgical interventions for presbyopia

THE END



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ANSWER SHEET

15(26)

Computer vision syndrome: a comprehensive literature review

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2						9						
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