

A Review of Digital Eye Strain Studies

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Introduction:

The increasing reliance on digital devices for education, work, and leisure has led to a surge in digital eye strain (DES), also known as computer vision syndrome (Gammoh, 2021). This condition encompasses a range of ocular symptoms, including eye fatigue, dryness, blurred vision, headaches, and neck pain (AlQarni, A. M. et al 2023). The COVID-19 pandemic, with its shift to online learning and remote work, further exacerbated this issue (Munsamy, A. J. et al 2022). This review critically analyzes several studies investigating DES prevalence, risk factors and impact, highlighting their strengths and weaknesses.

Research Gap:

While numerous studies have explored DES, variations exist in the populations studied (students, general population, specific professions), the assessment tools used (questionnaires, clinical measurements), and the specific digital activities investigated. This creates a research gap in terms of generalizability and comparability of findings. Furthermore, a deeper understanding of the long-term effects of prolonged digital device use on ocular health, particularly in vulnerable populations like children and adolescents, is still needed. The interplay between DES and other factors like sleep quality, mental health, and ergonomic setup also requires further investigation.

The reviewed studies collectively identify several key research gaps in the understanding and management of digital eye strain (DES):

Longitudinal Impact: The predominantly cross-sectional nature of the research limits insights into the long-term effects of prolonged digital device use on ocular health.

Longitudinal studies are needed to track changes in ocular function and DES symptoms over time, particularly in vulnerable populations like children and adolescents (e.g., Mohan et al., 2021; Aldukhayel et al., 2022). This would help determine if DES is a transient issue or if it leads to more permanent ocular damage.

Objective Measures: The heavy reliance on self-reported questionnaires introduces subjectivity and potential bias. A major research gap is the integration of objective measures of ocular health, such as tear film break-up time, Schirmer's test, corneal topography, and accommodation amplitude (Jakhar et al., 2023). Correlating subjective symptoms with objective findings would provide a more comprehensive and accurate assessment of DES.

Intervention Effectiveness: While many studies identify risk factors, there is a lack of rigorous research evaluating the effectiveness of interventions designed to prevent and manage DES. Studies are needed to assess the impact of ergonomic modifications, eye exercises, blue light filters, and educational programs on DES symptoms and ocular function.

Specific Population Focus: While several studies focus on university students (e.g., Gammoh, 2021; AlQarni et al., 2023; Munsamy et al., 2022; Huyhua-Gutierrez et al., 2023; Sawaya et al., 2020; Almudhaiyan et al., 2023), more research is needed on other populations, including children (Mohan et al., 2021; Aldukhayel et al., 2022), older adults, and individuals with pre-existing ocular conditions. Furthermore, research focusing on specific professions with high digital device use (e.g., office workers, gamers) is also warranted.

Multifactorial Approach: DES is likely influenced by a combination of factors, including digital device use,

environmental factors, individual characteristics and lifestyle habits. Future research should adopt a more holistic approach, examining the complex interplay between these factors. For example, studies should consider the combined effects of screen time, lighting, ergonomics, sleep quality (Rana et al., 2023), and mental health (Rana et al., 2023; Alzahrani, 2024) on DES.

Mechanism of Action: The underlying mechanisms by which digital device use leads to DES are not fully understood. More research is needed to investigate the physiological changes that occur in the eye and visual system during prolonged digital screen time.

This could lead to the development of more targeted and effective interventions.

Dependent and Independent Variables In the context of these DES studies, the following general framework for dependent and independent variables can be identified:

Dependent Variables: These are the outcomes being measured or studied. In DES research, the primary dependent variable is typically digital eye strain, which can be operationalized in various ways:

- **Subjective Symptoms:** These are measured using questionnaires and include symptoms like eye fatigue, dryness, blurred vision, headache, neck pain, and difficulty focusing.
- **Objective Measures of Ocular Function:** These include measures like tear film break-up time, Schirmer's test results, corneal topography, accommodation amplitude, and blink rate. (Note: Many of the studies reviewed primarily focus on subjective symptoms.)

Independent Variables: These are the factors that are thought to influence or be associated with the dependent variable (DES). These can be categorized as:

o **Digital Device Use: This includes factors like:**

- **Screen Time:** Duration and frequency of digital device use.

- Type of Device: Smartphone, computer (desktop; laptop), tablet, etc.
- Viewing Distance: Distance between the eyes and the screen.
- Breaks Taken: Frequency and duration of breaks during digital device use.

o **Environmental Factors:**

- Lighting: Ambient lighting conditions.
- Ergonomics: Workstation setup, chair height, screen position.
- Humidity: Environmental humidity levels.

o **Individual Factors:**

- Pre-existing Eye Conditions: Dry eye syndrome, refractive errors, etc.
- Age
- Gender
- Sleep Quality
- Mental Health: Stress, anxiety, depression.
- Smartphone Addiction

o **Other Factors:**

- COVID-19 Pandemic/Online Learning: This acts as a contextual independent variable in several studies, representing a period of increased digital device use for educational purposes.

Methodology:

The reviewed studies predominantly employed cross-sectional survey designs, relying on self-reported questionnaires to assess DES symptoms. Several studies, like Gammoh (2021),

AlQarni et al. (2023), Munsamy et al. (2022), Huyhua-Gutierrez et al. (2023), Lotfy et al. (2022), Sawaya et al. (2020), Mohammed et al. (2021), Alzahrani (2024), Almudhaiyan et

al. (2023), Aldukhayel et al. (2022), Jakhar et al. (2023), and Rana et al. (2023), followed this approach.

While this method allows for efficient data collection from large samples, it is susceptible to recall bias and may not accurately reflect the severity of DES. Objective measures of ocular function, such as tear film break-up time, Schirmer's test, and accommodation amplitude, were largely absent, limiting the ability to correlate subjective symptoms with objective findings. Only Kaur et al. (2022) provided a comprehensive review of DES, summarizing existing literature.

Mohan et al. (2021) focused specifically on children and their online learning.

Discussion:

This collection of studies provides valuable insights into the prevalence and risk factors of digital eye strain (DES) across diverse populations, primarily university students, during a period marked by increased digital device use, particularly due to the COVID-19 pandemic. While variations in prevalence exist, a consistent theme emerges: DES is a significant health concern, especially among young people engaged in extended digital learning.

Prevalence and Demographics: The reported prevalence of DES varies considerably across studies. This heterogeneity likely stems from several factors, including differences in study populations (e.g., Gammoh, 2021, focusing on Jordanian university students; Aldukhayel et al., 2022, examining children in Saudi Arabia), the specific assessment tools employed, and the intensity of digital device use within the studied cohorts. Studies conducted during the pandemic, such as AlQarni et al. (2023), Munsamy et al. (2022), and Mohammed et al. (2021), often capture a period of heightened online learning, potentially contributing to higher reported prevalence rates compared to studies conducted before the pandemic. Furthermore, variations in how "screen time" and "DES" are defined and measured across studies (e.g., self-reported estimates versus device usage data) complicate direct comparisons. Concerning demographics, some studies suggest female students may report higher DES prevalence

(e.g., Rana et al., 2023), possibly due to hormonal influences, differences in device usage patterns, or reporting biases, though more research is needed to confirm these observations.

Risk Factors and Their Significance: Prolonged screen time consistently emerges as a significant risk factor for DES across the reviewed literature. However, the precise relationship between screen time and DES severity remains complex. While increased screen time generally correlates with increased DES symptoms, the specific type of digital activity, breaks taken, and individual susceptibility also play crucial roles. Near work, not exclusively digital, also contributes to eye strain. Studies focusing solely on digital screen time might underestimate the cumulative effect of all near visual tasks. Environmental factors, including lighting, ergonomics, and humidity, while acknowledged as potential contributors, are not always thoroughly investigated in these studies. Individual factors like pre-existing eye conditions, refractive errors, and dry eye syndrome are important confounders. Jakhar et al. (2023) specifically explored the overlap between dry eye symptoms and DES, highlighting the potential for these conditions to exacerbate each other. The COVID-19 pandemic and the rapid shift to online education clearly impacted DES. Studies conducted during this period (e.g., AlQarni et al., 2023; Mohammed et al., 2021; Munsamy et al., 2022) suggest a potential increase in both prevalence and symptom severity.

Methodology and its Impact: The reliance on cross-sectional survey designs and self-reported data represents a significant methodological limitation across the majority of studies.

While these methods allow for efficient data collection from larger samples, they are inherently susceptible to recall bias and limit the ability to establish causal relationships. The lack of objective measures of ocular function (e.g., tear film break-up time, accommodation amplitude) further weakens the conclusions about the severity and nature of DES. Sample sizes and demographic characteristics vary, impacting the generalizability of findings. Furthermore, the specific questionnaires used to assess DES symptoms differ across studies, which can make comparing results difficult. Kaur

et al. (2022) provide a valuable comprehensive review, but it highlights the need for more standardized DES assessment tools.

Comparing Specific Studies: While all studies contribute to our understanding of DES, some offer unique perspectives. Alzahrani (2024) specifically investigated the association between smartphone addiction and DES, a relevant area of inquiry given the increasing use of smartphones. Rana et al. (2023) explored the relationship between DES, sleep quality, and loneliness, suggesting a potential interplay between physical and mental health factors. Mohan et al. (2021) focused specifically on children and the impact of online learning, a population particularly vulnerable to the effects of digital device use.

Future Directions: These studies underscore the need for more rigorous research on DES. Longitudinal studies employing both subjective and objective measures of ocular health are essential to understand the long-term effects of digital device use and establish causal relationships between risk factors and DES. Standardized DES assessment tools and consistent definitions of key variables (e.g., screen time, DES symptoms) are crucial for improving the comparability of findings across studies. Furthermore, intervention studies evaluating the effectiveness of various strategies for preventing and managing DES (e.g., ergonomic interventions, eye exercises, blue light filters) are needed to inform best practices and protect the ocular health of digital device users.

The studies consistently reported a high prevalence of DES among their respective populations, particularly students. Factors associated with DES included prolonged screen time, inadequate breaks, poor lighting, and uncorrected refractive errors (Huyhua-Gutierrez et al 2023). The COVID-19 pandemic and the subsequent increase in online activities were identified as a significant contributing factor in many studies (Lotfy et al 2022). Some studies, like AlQarni et al. (2023), specifically linked DES to virtual learning (Sawaya et al 2020). The association between DES and other factors, such as sleep quality (Rana et al., 2023), smartphone addiction (Alzahrani, 2024), and dry eye symptoms (Jakhar et al., 2023),

was also explored. However, the cross-sectional nature of the studies limits the ability to establish causal relationships.

Limitations:

The primary limitation of the majority of the reviewed studies is their reliance on self-reported questionnaires, which are prone to subjective bias. The lack of objective clinical assessments of ocular function is a significant weakness. The cross-sectional design also limits the ability to draw causal inferences (Mohammed et al 2021). Furthermore, the sample sizes and demographics of the study populations varied, affecting the generalizability of the findings.

Some studies focused on specific student populations (e.g., medical students, nursing students), making it difficult to extrapolate the results to other groups. Recall bias might have influenced the accuracy of reported screen time and symptom duration.

Conclusion:

DES is a prevalent and growing concern, particularly with the increasing reliance on digital devices (Alzahrani, 2024). The reviewed studies highlight the need for increased

awareness of DES risk factors and the implementation of preventive measures, such as regular breaks, ergonomic workstation setup, and proper lighting (Mohammed et al 2021). Future research should focus on employing more objective measures of ocular function, utilizing longitudinal study designs to investigate the long-term effects of digital device use, and exploring the interplay between DES and other health factors. Interventions aimed at reducing DES, such as educational programs and ergonomic modifications, should be evaluated for their effectiveness. A more comprehensive and multi-faceted approach is needed to address the complex issue of DES and mitigate its impact on individuals' health and well-being.

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