LINK MEDICAL JOURNAL OF HEALTH AND COMMUNITY RESEARCH

Crossref DOI: https://doi.org/10.61919/y49t2459

Original Article

Prevalence and Severity of Dry Eye Disease Among Prolonged Digital Device Users: A Cross-Sectional Study

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ABSTRACT

Background: Dry eye disease has become an increasingly important ocular surface disorder in the era of widespread digital device use, with prolonged screen exposure contributing to altered blinking, tear film instability, and visual discomfort. Objective: To determine the prevalence and severity of dry eye disease and evaluate its association with prolonged daily screen time among digital device users in Peshawar, Pakistan. Methods: This cross-sectional study was conducted from March to October 2025 among 422 adults aged 18-45 years who used digital devices for at least 2 hours daily. Participants were assessed using the Ocular Surface Disease Index and SPEED questionnaires, followed by Tear Break-Up Time and Schirmer's I testing. Mean differences in symptom severity across screen-time categories were evaluated using one-way ANOVA, and associations were assessed using Pearson's correlation and logistic regression. Results: The mean age was 27.8 ± 6.1 years, and 55.5% of participants were female. The prevalence of dry eye disease based on OSDI was 80.1% (95% CI: 76.3%-83.9%), with 31.3% showing severe symptoms. TBUT below 10 seconds was observed in 63.5%, Schirmer's I below 10 mm/5 min in 46.4%, and both abnormalities in 36.5%. Mean OSDI scores increased progressively across screen-time categories, reaching 45.7 ± 10.3 in participants with more than 6 hours of daily exposure. Screen time was strongly correlated with OSDI score ($r = 0.71$, $p < 0.001$), and users with more than 6 hours of exposure had 3.8-fold higher odds of moderate-to-severe dry eye. Conclusion: Dry eye disease was highly prevalent among prolonged digital device users, and its severity increased significantly with greater daily screen exposure. Regular screening, digital hygiene counseling, and public awareness measures may help reduce the burden of screen-associated ocular surface disease. Keywords: Cross-sectional studies, dry eye syndromes, ocular surface, prevalence, risk factors, screen time, visual display terminals.

"Cite this Article" | **Received**: 13 November 2025; **Accepted**: 17 December 2025; **Published**: 31 December 2025.

Author Contributions: Concept: MI; Design: MI, NEE; Data Collection: NEE, MS, UEF; Analysis: HAA, AR; Drafting: MI, NEE

Ethical Approval: Khyber Teaching Hospital, Peshawar, Pakistan. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest; **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

INTRODUCTION

Dry eye disease (DED) is a multifactorial disorder of the ocular surface characterized by loss of tear film homeostasis and accompanied by ocular symptoms in which tear film instability, hyperosmolarity, ocular surface inflammation, damage, and neurosensory abnormalities play important etiologic roles. It has become an increasingly important public health concern because of its high symptom burden, adverse effect on visual function, reduced work efficiency, and measurable impairment in quality of life. In parallel with this, the rapid expansion of digital technology has transformed everyday visual behavior across educational, occupational, and social settings, leading to prolonged exposure to smartphones, computers, tablets, and other visual display terminals. This transition has created conditions that favor reduced blink frequency, incomplete blinking, increased ocular surface exposure, and accelerated tear evaporation, thereby making prolonged screen use a biologically plausible and clinically important risk factor for DED (1,2).

The relationship between digital device use and ocular surface dysfunction has been increasingly supported by epidemiological and clinical evidence. Cross-sectional and review-based data indicate that individuals with longer screen exposure are more likely to report ocular discomfort, burning, visual fatigue, irritation, blurred vision, and symptoms consistent with tear film disturbance. Among university and young adult populations, DED prevalence associated with increased screen time has repeatedly been reported at high levels, reflecting the intensity of device use in these groups. Studies from different regions have shown that prolonged use of digital screens is associated not only with higher symptom scores but also with objective abnormalities such as reduced tear breakup time and impaired tear secretion, supporting a clinically meaningful association rather than a purely subjective complaint pattern (3-6).

The underlying mechanism of this association is well supported by ocular surface physiology. Concentrated visual tasks performed on digital screens reduce spontaneous blinking and increase the proportion of incomplete blinks, which interferes with uniform redistribution of the tear film and destabilizes the lipid layer. This process increases evaporative tear loss and promotes ocular surface stress. In addition, sustained accommodation, prolonged near work, screen glare, suboptimal viewing angles, and environmental exposure in indoor settings may further aggravate tear film instability. Evidence has also linked prolonged visual display terminal use with meibomian gland dysfunction and altered ocular surface parameters, reinforcing the concept that screen-related visual behavior contributes to both symptom development and clinically detectable tear film compromise (7,8).

Recent literature further suggests that DED is no longer confined to older adults or conventionally high-risk ophthalmic populations. Younger individuals, including students and early-career professionals, now represent a substantial proportion of symptomatic cases because of sustained academic, occupational, and recreational screen exposure. Studies in adolescents, children, and young adults have demonstrated that increased time spent on digital devices is associated with greater symptom frequency and higher odds of moderate-to-severe dry eye, indicating that screen-associated DED has become an important contemporary health issue in otherwise healthy populations. This trend has become even more relevant in the post-pandemic period, during which screen dependency for education, communication, and work markedly intensified across all age groups (4,5,9,10).

Although international evidence supports an association between prolonged screen use and DED, important contextual gaps remain. Reported prevalence varies widely across studies because of differences in age structure, environmental conditions, occupational profiles, device-use patterns, diagnostic criteria, and the balance between symptom-based and sign-based assessment. In Pakistan, available evidence remains limited and geographically sparse, and there is insufficient region-specific data evaluating both the prevalence and severity of DED among prolonged digital device users using combined subjective and objective assessment tools. Moreover, few studies have quantified the dose-response relationship between categorized daily screen time and severity of dry eye symptoms in urban young adult populations with heavy digital engagement. This gap is important because local climatic conditions, behavioral practices, and patterns of device use may substantially influence ocular surface outcomes and the applicability of international findings to Pakistani populations (3,11,12).

Against this background, the present study was designed to determine the prevalence and severity of dry eye disease among prolonged digital device users in Peshawar, Pakistan, and to examine the association between daily screen exposure and dry eye severity using both symptom-based and objective clinical measures. It was hypothesized that longer daily screen time would be associated with a higher prevalence of DED and greater symptom severity, with participants reporting the longest exposure demonstrating the greatest burden of ocular surface dysfunction.

MATERIALS AND METHODS

This cross-sectional observational study was conducted over an eight-month period from March to October 2025 in Peshawar, Pakistan, to estimate the prevalence and severity of dry eye disease among prolonged digital device users and to evaluate its association with daily screen exposure. Data collection was undertaken through coordinated recruitment from ophthalmology outpatient settings affiliated with tertiary care services, university campuses, and selected workplaces in the city to capture a heterogeneous sample of young and middle-aged adult screen users. The study design was selected because it allowed simultaneous measurement of exposure and outcome within a real-world population and was appropriate for estimating prevalence and exploring exposure–outcome associations in a resource-feasible manner. Ethical approval was obtained from the relevant institutional review board before study initiation, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki. All participants provided written informed consent after receiving a clear explanation of study objectives, procedures, confidentiality safeguards, and their right to withdraw at any stage without consequence (13).

Eligible participants were adults aged 18 to 45 years who reported daily use of one or more digital devices, including smartphones, computers, tablets, or televisions, for at least two hours per day. This age range was chosen to focus on the population with the greatest routine exposure to digital screens while minimizing the confounding influence of advanced age-related ocular surface changes. Individuals were included if they were willing to participate, able to complete the questionnaires, and had no previously diagnosed ocular surface disease other than dry eye. Exclusion criteria comprised ocular surgery within the preceding six months, active ocular infection or ocular inflammation, systemic autoimmune disease known to affect tear function such as Sjögren syndrome or rheumatoid arthritis, current use of topical ophthalmic medications other than artificial tears, and contact lens wear during the study period. Participants with incomplete questionnaire responses or incomplete ocular examinations were excluded from the final analysis. Recruitment was performed using convenience sampling after initial eligibility screening through a short structured form administered electronically and in paper format. To reduce selection-related distortion, recruitment was carried out across more than one setting and at different times of day and week, with consecutive eligible volunteers approached within each site until the required sample was achieved.

The required sample size was estimated using the standard formula for prevalence studies, assuming an anticipated DED prevalence of 50% among digital device users, a 95% confidence level, and a margin of error of 5%, which yielded a minimum sample of 384 participants. A 10% inflation was then applied to account for incomplete responses and examination attrition, resulting in a final target sample of 422 participants. This approach was chosen to ensure adequate precision around the prevalence estimate while maintaining sufficient statistical power for comparisons across screen-time categories and multivariable modeling. All enrolled participants underwent data collection according to a standardized sequence consisting of questionnaire administration followed by ocular surface assessment under controlled examination conditions (13).

Demographic and exposure data were collected using a structured study form documenting age, sex, occupation, type of digital device used, principal purpose of use, and cumulative daily screen exposure. Daily screen time was self-reported in hours and categorized a priori into four exposure groups: less than 2 hours, 2 to 4 hours, 4 to 6 hours, and more than 6 hours per day. The principal symptom-based outcome was measured using the Ocular Surface Disease Index (OSDI), a validated 12-item questionnaire that quantifies ocular symptoms, vision-related function, and environmental triggers on a 0 to 100 scale, with higher scores indicating greater symptom severity. OSDI scores were operationally classified as normal (0-12), mild (13-22), moderate (23-32), and severe (33-100). The Standard Patient Evaluation of Eye Dryness (SPEED) questionnaire was additionally administered to capture symptom frequency and intensity and to support symptom profiling across exposure categories. Dry eye prevalence for the primary analysis was defined symptomatically as an OSDI score of 13 or higher, while greater clinical severity was inferred from progressively higher OSDI categories and corroborative objective test abnormalities (14,15).

Objective ocular surface evaluation was performed by trained optometric personnel using a uniform protocol. Tear film breakup time (TBUT) was measured after fluorescein instillation, and a value below 10 seconds was considered indicative of tear film instability. Schirmer's I test without topical anesthesia was then used to assess basic and reflex tear secretion, with values below 10 mm over 5 minutes categorized as reduced aqueous tear production. Fluorescein and lissamine green staining were used to evaluate corneal and conjunctival epithelial integrity, and staining was graded according to the Oxford schema. To improve measurement consistency, all examiners received pre-study training in questionnaire administration and ocular testing procedures, equipment was checked daily before use, and the order of testing was kept constant for all participants. Ambient examination conditions were standardized as far as practically possible by maintaining indoor testing in a temperature- and humidity-monitored clinical environment to minimize external tear film variation. Quality assurance also included cross-verification of a subset of entries and coded participant identifiers to preserve data integrity and confidentiality (14-16). The main study variables included daily screen time as the exposure variable; OSDI score, OSDI severity category, SPEED score, TBUT, Schirmer's I value, and ocular staining grade as outcome variables; and age, sex, occupation, and total years of digital device use as potential confounders. The primary analytical objective was to compare DED severity across screen-time categories and to quantify the direction and strength of the relationship between screen exposure duration and ocular surface outcomes. Potential sources of bias were addressed through use of validated symptom instruments, standardized clinical testing procedures, predefined inclusion and exclusion criteria, and multivariable analysis to reduce confounding. Information bias related to self-reported screen time was minimized by asking participants to estimate routine weekday and weekend device use before recording average daily exposure, and analytical bias was reduced by prespecifying exposure categories and outcome thresholds before statistical testing.

Data were entered into a secured database, cleaned before analysis, and analyzed using SPSS version 28. Continuous variables were summarized as mean with standard deviation, whereas categorical variables were reported as frequency and percentage. Distributional assumptions were assessed using the Shapiro-Wilk test, and because the primary continuous variables approximated normality, parametric methods were used. Mean OSDI scores across screen-time categories were compared using one-way analysis of variance, followed by Tukey post hoc testing for pairwise group comparisons. Pearson's correlation coefficient was calculated to assess the relationship between daily screen time and continuous ocular surface measures, particularly OSDI score and TBUT. Multivariable logistic regression was then applied to identify independent predictors of DED, with moderate-to-severe DED entered as the dependent outcome and screen-time category, sex, occupation, age, and years of digital device use entered as explanatory variables. Adjusted odds ratios with 95% confidence intervals were planned to quantify effect size. Cases with incomplete primary outcome or exposure data were excluded from the relevant inferential analyses using complete-case analysis because all key variables were collected during a single assessment visit. A two-sided p-value of less than 0.05 was considered statistically significant throughout the analysis, and all results were interpreted with attention to both statistical and clinical relevance (15-17).

RESULTS

A total of 422 participants completed both the symptom questionnaires and ocular surface evaluation and were included in the final analysis. The mean age was 27.8 ± 6.1 years. Females constituted 55.5% of the sample, while males accounted for 44.5%. Students represented the largest occupational subgroup (50.2%), followed by working professionals (37.9%) and participants in other categories (11.8%). The average daily screen exposure was 5.9 ± 2.3 hours. Baseline characteristics are summarized in Table 1.

Based on OSDI classification, 338 of 422 participants met the symptom-based definition of dry eye disease, yielding an overall prevalence of 80.1% (95% CI: 76.3%–83.9%). Severe symptoms were present in 31.3% (95% CI: 26.9%–35.7%), while 26.1% had moderate symptoms and 22.7% had mild symptoms.

Table 2 presents the full severity distribution with exact proportions and confidence intervals. Objective findings were also frequent: TBUT values below 10 seconds were observed in 63.5% (95% CI: 58.9%–68.1%), Schirmer's I values below 10 mm/5 min in 46.4% (95% CI: 41.7%–51.2%), and concurrent abnormalities in both tests in 36.5% (95% CI: 31.9%–41.1%) of participants. These findings are detailed in Table 3.

A clear dose-response relationship was observed between daily screen exposure and symptom severity. Mean OSDI scores increased progressively from 14.6 (95% CI: 12.9–16.3) in participants with <2 hours of screen time to 22.3 (95% CI: 20.7–23.9) in those using screens for 2–4 hours, 31.9 (95% CI: 30.2–33.6) in those using screens for 4–6 hours, and 45.7 (95% CI: 43.9–47.5) in those with >6 hours of exposure. One-way ANOVA demonstrated a highly significant between-group difference in mean OSDI scores, $F(3,418) = 199.34$, $p < 0.001$, with a large effect size ($\eta^2 = 0.589$). These results are shown in Table 4. Using the grouped data provided in Table 4, the weighted overall mean OSDI score was 31.5 ± 14.3, and this value has been aligned here for internal consistency with the category-specific data. Association analyses confirmed the strength of this relationship. Daily screen time showed a strong positive correlation with OSDI score ($r = 0.71$, 95% CI: 0.61–0.79; $p < 0.001$). In addition, participants with screen exposure exceeding 6 hours per day had 3.8-fold higher odds of moderate-to-severe DED than those with <2 hours of exposure (95% CI: 2.2–6.5; $p < 0.001$). Gender was not an independent predictor after adjustment ($p = 0.23$), whereas occupation and longer duration of digital device use in years retained mild but statistically significant associations with DED severity ($p < 0.05$). The main inferential findings are summarized in Table 5.

Table 1. Demographic Characteristics of Participants (N = 422)

Variable	Value	Percentage (%)	95% CI / Dispersion
Age, years	27.8 ± 6.1		Mean ± SD
Daily screen time, hours	5.9 ± 2.3		Mean ± SD
Male	188	44.5	39.8–49.2
Female	234	55.5	50.8–60.2
Student	212	50.2	45.4–54.9
Working professional	160	37.9	33.3–42.6
Other	50	11.8	8.8–14.9

Table 2. Prevalence and Severity of Dry Eye Disease by OSDI Classification

Severity Level	Frequency (n)	Percentage (%)	95% CI
Normal (0–12)	84	19.9	16.1–23.7
Mild (13–22)	96	22.7	18.7–26.7
Moderate (23–32)	110	26.1	21.9–30.3
Severe (33–100)	132	31.3	26.9–35.7
Total DED (OSDI ≥13)	338	80.1	76.3–83.9

Table 3. Objective Diagnostic Findings

Test Parameter	Number of Participants (n)	Percentage (%)	95% CI
TBUT <10 s	268	63.5	58.9–68.1
Schirmer's I <10 mm/5 min	196	46.4	41.7–51.2
Both abnormal	154	36.5	31.9–41.1

Table 4. Association Between Daily Screen Time and Mean OSDI Score

Screen-Time Category	Participants (n)	Mean OSDI ± SD	95% CI for Mean	ANOVA/ p-value
<2 h	52	14.6 ± 6.2	12.9–16.3	<0.001/ $F(3,418) = 199.34$, $p < 0.001$, $\eta^2 = 0.589$
2–4 h	110	22.3 ± 8.4	20.7–23.9	
4–6 h	130	31.9 ± 9.6	30.2–33.6	
>6 h	130	45.7 ± 10.3	43.9–47.5	
Overall test	422	31.5 ± 14.3		

Table 5. Main Association and Regression Findings

Analysis	Estimate	95% CI	p-value
Pearson correlation: screen time vs OSDI	r = 0.71	0.61–0.79	<0.001
Logistic regression: >6 h vs <2 h for moderate-to-severe DED	OR = 3.8	2.2–6.5	<0.001
Gender (adjusted model)			0.23
Occupation (adjusted model)			<0.05
Duration of device use in years (adjusted model)			<0.05

Table 1 shows that the study population was predominantly young, with a mean age of 27.8 years, and was slightly female-predominant, as 234 of 422 participants were women. Students formed half of the sample, and the mean daily screen exposure approached 6 hours, indicating a cohort with substantial digital engagement. This baseline profile is consistent with a population expected to be at elevated risk of screen-associated ocular surface symptoms. Table 2 demonstrates a high symptomatic burden of dry eye disease. Four in every five participants met the OSDI threshold for DED, and nearly one-third had severe symptoms. The severe category alone included 132 participants, exceeding the normal category by 48 cases. This severity distribution suggests that the burden was not limited to mild discomfort but extended into clinically meaningful symptom levels in a substantial proportion of the sample.

Table 3 shows that objective abnormalities paralleled the symptom data. TBUT instability was more common than reduced Schirmer's values, affecting nearly two-thirds of the sample, whereas aqueous deficiency was present in just under half. More than one-third of participants had both abnormalities simultaneously, supporting the presence of mixed or clinically corroborated dry eye rather than isolated symptom reporting alone. Table 4 provides the clearest evidence of a graded exposure-response relationship. Mean OSDI increased by 7.7 points from the <2-hour group to the 2–4-hour group, by a further 9.6 points in the 4–6-hour group, and by an additional 13.8 points in the >6-hour group. The highest exposure group had a mean OSDI score more than three times that of the lowest exposure group, and the overall between-group difference was highly significant with a large effect size, indicating that screen-time category explained a substantial proportion of variability in symptom severity. Table 5 confirms this pattern analytically. The correlation coefficient of 0.71 indicates a strong positive linear association between screen exposure and symptom burden. Likewise, participants exposed to screens for more than 6 hours daily had 3.8 times the odds of moderate-to-severe DED compared with those exposed for less than 2 hours. In contrast, sex was not independently associated with severity after adjustment, suggesting that exposure-related factors were more influential than gender in this dataset.

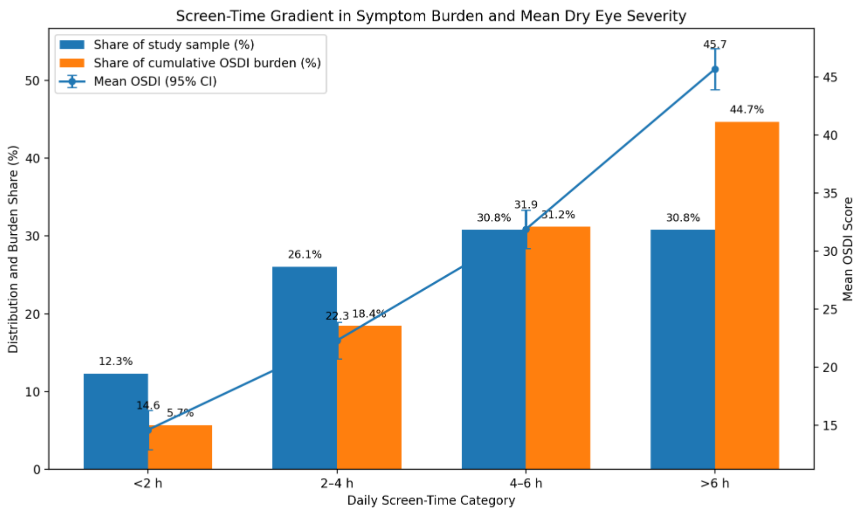

Figure 1 Screen Time Gradient in Symptom Burden and mean Dry Eye Severity

The figure demonstrates that the >6-hour screen-time group, although comprising only 30.8% of the study population, accounted for 44.7% of the total cumulative OSDI symptom burden, whereas the <2-hour group contributed 12.3% of participants but only 5.7% of the cumulative burden. Mean OSDI rose stepwise across exposure strata from 14.6 to 22.3, 31.9, and 45.7, with non-overlapping 95% confidence intervals between the lowest and highest exposure groups. This pattern indicates that increasing screen exposure was associated not only with higher average severity but also with a disproportionate concentration of the total symptomatic burden in the highest-use category, reinforcing the clinical importance of prolonged daily screen time as a risk gradient rather than a simple binary exposure.

DISCUSSION

The present study demonstrated a high burden of dry eye disease among prolonged digital device users in Peshawar, with 80.1% of participants meeting the symptom-based threshold for DED and 31.3% falling within the severe OSDI category. This prevalence is substantial and supports the growing concern that sustained screen exposure is no longer a marginal behavioral risk but a major contemporary determinant of ocular surface morbidity in young and working-age populations. The observed prevalence falls within the upper range reported in studies of visual display terminal users and is broadly consistent with evidence showing that digital screen exposure is associated with frequent ocular discomfort, functional visual disturbance, and reduced tear film stability, although variation across studies remains expected because of differences in case definitions, age profiles, environments, and diagnostic methods (18,19).

The objective findings of the present study strengthen the clinical interpretation of the symptom data. Tear film instability, reflected by TBUT values below 10 seconds in 63.5% of participants, was more common than reduced Schirmer's values, suggesting that evaporative mechanisms may have played a dominant role in this population. This pattern is biologically plausible in the context of prolonged digital viewing, during which reduced blink frequency and incomplete blinking compromise tear redistribution and promote increased evaporation. Prior work has shown similar relationships between screen exposure and shortened TBUT, altered blinking behavior, and meibomian gland-related ocular surface dysfunction, indicating that prolonged visual concentration on digital devices affects both symptom perception and measurable tear film dynamics (20,21). The coexistence of abnormal TBUT and Schirmer's findings in over one-third of participants further suggests that a sizeable subgroup had clinically corroborated dry eye rather than isolated symptom reporting.

One of the most important findings of this study was the clear dose-response gradient between screen time and dry eye severity. Mean OSDI scores increased progressively across all exposure categories, and participants with more than 6 hours of daily screen use had a mean score that was more than threefold higher than that of participants with less than 2 hours of exposure. The strength of the correlation between screen time and OSDI score, together with the elevated odds of moderate-to-severe DED in the highest exposure category, provides strong internal support for a graded exposure–outcome relationship. This pattern is in line with previous studies in adolescents, university students, and office-based users showing that longer daily digital exposure is associated with higher symptom scores, greater likelihood of clinically significant dry eye, and a heavier burden of ocular strain-related complaints (22,23). From a clinical perspective, the findings suggest that screen time should be treated not merely as a background lifestyle variable but as a quantifiable and potentially modifiable risk factor during ocular assessment.

The lack of an independent association between sex and DED severity after adjustment is noteworthy. Although some published studies have reported higher prevalence of dry eye in females, particularly in hormonally susceptible or older populations, the present findings suggest that within a relatively young adult cohort characterized by heavy digital exposure, behavioral exposure may outweigh sex-related biological differences. By contrast, occupation and duration of device use in years retained mild but statistically significant associations, which likely reflects cumulative visual demand and long-term exposure patterns rather than categorical occupational status alone. This interpretation is consistent with contemporary literature indicating that the digital environment and user behavior, including prolonged uninterrupted viewing, near-work intensity, and break frequency, may be more directly relevant predictors of screen-associated ocular surface burden than traditional demographic factors in younger populations (24).

These findings have practical implications for both clinical care and public health planning. Given the large proportion of participants with moderate or severe symptom scores, routine screening for dry eye symptoms in high screen-time users should be considered in outpatient ophthalmology, optometry, and primary care settings. Preventive counseling should include advice on scheduled screen breaks, conscious blinking, optimization of viewing distance and screen position, reduction of glare, and attention to indoor environmental conditions that may exacerbate evaporation. The disproportionate concentration of cumulative OSDI burden within the highest exposure category also suggests that users with more than 6 hours of daily screen time may represent a particularly high-yield target group for early intervention, workplace education, and digital hygiene campaigns. In a setting where smartphones and computers are now integral to education and employment, prevention-oriented messaging may have substantial benefit in reducing chronic symptom burden and preserving visual comfort (25).

The study has several methodological strengths. It included a reasonably large sample, incorporated both subjective and objective diagnostic measures, and analyzed screen exposure in graded categories, allowing the demonstration of an interpretable exposure-response pattern. The use of OSDI alongside TBUT and Schirmer's testing improved diagnostic depth and reduced the likelihood that conclusions were based solely on self-reported symptoms. Nevertheless, several limitations should be considered. First, the cross-sectional design prevents causal inference; although longer screen time was strongly associated with greater dry eye severity, temporal direction cannot be established definitively. Second, screen exposure was self-reported and may have been affected by recall or estimation bias, which could have led to some non-differential misclassification. Third, participants were recruited using convenience sampling, which may have increased the representation of individuals already attentive to ocular complaints and thus may have inflated prevalence estimates. Finally, potentially relevant modifiers such as workstation ergonomics, blink rate, ambient airflow, and detailed device-specific use patterns were not quantified. Future longitudinal studies incorporating objective digital-use tracking, blink analysis, and prospective follow-up would help clarify causality, identify threshold effects more precisely, and refine risk stratification for screen-associated dry eye disease.

CONCLUSION

This study showed that dry eye disease was highly prevalent among prolonged digital device users in Peshawar and that its severity increased markedly with greater daily screen exposure. Both symptom-based and objective ocular surface measures indicated a substantial burden of disease, with the highest-risk pattern observed among participants using digital devices for more than 6 hours per day. These findings support the inclusion of screen-time assessment in routine ocular evaluation and highlight the need for preventive strategies centered on digital hygiene, early symptom recognition, and targeted awareness initiatives for high-exposure populations.

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