• Clinical Research •

Predictive analysis of dry eye diagnosis and digital screen usage: a cross-sectional study

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Abstract

● **AIM:** To characterize the ocular surface characteristics in the Nepalese population across all age groups who have used digital screens for extended durations over several years.

● **METHODS:** In a cross-sectional, observational study, 144 digital screen users were assessed for dry eye disease (DED) using subjective and objective measures. The Ocular Surface Disease Index (OSDI) Questionnaire evaluated symptoms, followed by clinical assessments, including slit lamp biomicroscopy, tear breakup time (TBUT), Oxford Scheme grading, and Schirmer I test. DED was diagnosed if a patient had an OSDI score over 13 and at least two clinical signs (OSDI, Schirmer I test, or ocular staining). The prevalence of DED was calculated based on the proportion of patients meeting these criteria.

● **RESULTS:** Of the 144 participants (mean age: 34.6±15.2y), 78 (54.2%) were female. The use of digital screens varied between 2-8h (mean duration: 4.1±2.7h) per day. The mean OSDI score, TBUT score, and the Schirmer I scores were 22.7±10.5 (max-min: 24.4-20.9), 6.8±4.2s (max-min: 7.5-6.1), and 12.3±4.6 mm (max-min: 13.1-11.5) respectively with 95% confidence interval (β=1.96), and a two-tailed statistical significance level of 5% (α=0.05). With increased screen use, TBUT shortened and OSDI scores increased significantly (P<0.01), though Schirmer I scores were unaffected (P>0.05). The prevalence of DED ranged from 6.3% to 22.9% in those using screens for more than 2h, with an overall prevalence of 67.4% among digital screen users.

● **CONCLUSION:** There is a significant association between prolonged use of digital screens and clinical markers of dry eye signs and symptoms.

● **KEYWORDS:** digital devices; digital eye strain; screen time; blinking; tear film stability

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INTRODUCTION

The use of digital screens has seamlessly integrated into our daily routines; however, their excessive use has led to an increase in the number of individuals with ocular complaints such as ocular pain/discomfort and visual disturbances, collectively known as computer vision syndrome. A recent study involving 11 875 children aged 9-10y revealed that, on average, 3.5h per day were spent on screen for various activities such as watching TV, playing video games, texting, chatting, and using social media[1]. The COVID-19 pandemic has also contributed to an increased use of digital screens[2-3]. Literature suggests an association of screen time with several conditions, including reduced physical activity, dry eye disease (DED), and learning disabilities[4-6]. A literature indicates that, due to absence of specific guidelines for discretionary screen time for adults, or older adults, the use of digital screens has increased exponentially over the years, for example there has been a high proportion increase of Americans (72%) and Canadians (76%) now own smartphones and similar ownership rates are seen in many other countries around the world [*e.g.*, South Korea (88%), Australia (77%), and Israel (74%)][7]. Increased use of digital screens can lead to various changes on the ocular surface. Therefore, the purpose of the present study was to investigate the association between screen time and ocular surface characteristics in Nepalese population along with prevalence of DED. Understanding this prevalence will

help evaluate changes in digital screen usage patterns over the years.

A commonly accepted hypothesis regarding the connection between digital screen use and DED is that prolonged screen exposure alters the blinking dynamics, resulting in ocular surface dryness[8]. A Meta-analysis involving data from 11 365 people estimated an overall prevalence of dry eye symptoms at 49.5%, ranging from 9.5% to 87.5%, primarily affecting computer users[9]. Moon *et al*[10] found a significant correlation between smartphone usage and the prevalence of paediatric DED.

Since the use of digital screens has been rapidly increasing, the present study aimed to investigate the association between screen usage, frequency of dry eye symptoms, and the factors that aggravate patient symptoms which include duration, environmental conditions, screen brightness, brightness, screen breaks, blink rate, and so on.

PARTICIPANTS AND METHODS

Ethical Approval It was a hospital-based, prospective, observational, cross-sectional study, that was conducted at the Nepal Eye Hospital, Tripureshwor, between July 2023 and January 2024. The protocol was approved by an independent ethical review board, National Academy of Medical Sciences (Approval number: 184/2080/81). All the participants, aged 10 to 75y, were informed of the study procedures, associated risk and benefits, study objectives, and future implications of the study, and informed consent was obtained. The principals of the Declaration of Helsinki were followed, which primarily addressed obtaining informed consent, protecting participants' rights, conducting risk-benefit assessments, and maintaining confidentiality. The participants had the right to withdraw their consent at any time during the study.

Participants A total of 144 participants who reported working in front of digital screens for their main job were included in the study using the non-probability convenience sampling approach wherein the participants were selected based on their ease of accessibility and availability to the researcher. The exclusion criteria included the history of ocular surgeries, current medications that are known to interfere with ocular surface (*e.g.*, anti-histamines and oral contraceptive agents), contact lens wear at the time of assessment, history of dry eye treatments in the past and at present such as LipiFlow, light therapy, thermal therapy, *etc.*, or any ocular infections. The participants were asked to mention the average duration of their digital screen usage per day for their main job. The sample was then categorized based on the number of hours spent on digital screens.

Measurements Participants were evaluated at a single site, and ocular surface parameters were recorded on the right eye of each participant in a single session. In order to minimise the impact on tear film and ocular surface physiology for subsequent tests, clinical assessments were performed in ascending order of invasiveness. The Ocular Surface Disease Index (OSDI) questionnaires were administered to grade the level of dry eye symptomatology. The OSDI scores of 13-22, 23-32, and >33 represented mild, moderate, and severe dry eyes, respectively[11]. The subjective evaluation was followed by clinical assessment, which included tear breakup time (TBUT) using fluorescein stain, slit lamp examination for assessing fluorescein staining patterns based on Oxford Scheme grading[12], and Schirmer I tear test using Aurocaine (0.5% proparacaine hydrochloride solution).

To evaluate TBUT, the fluorescein strip was moistened with one drop of sterile saline, the excess fluid was shaken off the strip and applied to the inferior conjunctival cul-de-sac. Subjects were asked to close their eyes for a few seconds and then blink several times. The tear film was then examined using a broad beam of slit lamp with a blue filter, and the appearance of the first black dry spot was recorded as the TBUT in seconds. The three consecutive measurements were taken and averaged. Dry spot/s appearing in less than 10s were considered abnormal[13]. For ocular surface staining, a drop of saline was instilled onto a fluorescein-impregnated strip, which was then applied to the lower tarsal conjunctiva by gently pulling the lower lid on both eyes. After the installation of fluorescein, staining was graded as quickly as possible since the dye then diffuses rapidly into the tissue, and its luminosity blurs the stain margin. After that, the upper eyelid was lifted slightly to grade the corneal surface. The temporal and nasal conjunctiva were assessed by asking patients to look nasally and temporally, respectively. Schirmer I tear test was conducted 10min after other assessments to measure basal tear volume. Individuals with Schirmer test score of ≤10 mm in 5min were indicative of dry eyes (Table 1)[14]. The ocular surface clinical markers (signs and symptoms) were compared based on hours of digital screen use (less than 2, 2-4, 4-6, 6-8h, and more than 8h)[15].

Statistical Analysis The data were recorded on a clinical proforma. Statistical Package for Social Sciences Software (SPSS) Windows Version 25 (New York, USA) and Graph Pad Prism 8.01 (California, USA) were used for statistical analysis. Descriptive statistics, regression analysis and Pearson correlation coefficient were used to assess the significant associations between variables. Non-parametric test *i.e.* Kruskal wallis test to compare the independent variables, for example, TBUT, Schirmer and OSDI scores based on age range, hours and calculate the *P*-value to assess the level of significance. All tests were two-tailed, and $P<0.05$ was considered significant.

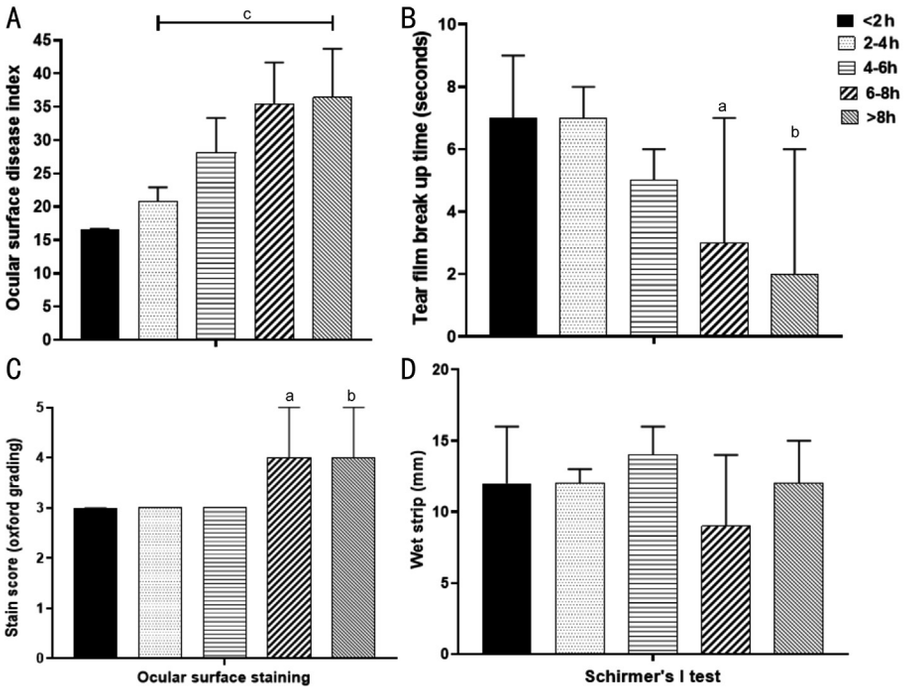

Figure 1 Screen exposure durations stratified on a 2h increment basis was compared with less than 2h exposures across the four clinical outcome measures The OSDI score increased significantly as the number of hours of screen usage increased. The TBUT were significantly lower, and ocular surface staining was significantly higher when screen times were more than 6h per day. The study participants across the five groups of <2, 2-4, 4-6, 6-8, and >8h were 44, 33, 32, 16, and 10, respectively. [a]*P*<0.05; [b]*P*<0.01; [c]*P*<0.0001. TBUT: Tear-film break up time; OSDI: Ocular Surface Disease Index.

Table 1 The diagnostic criteria for clinical symptoms, signs, and overall diagnosis of dry eyes were based on the following criteria

Diagnosis	Criteria
Symptoms of DED	OSDI score ≥13
Signs of DED	TBUT<10s; Schirmer I tear test ≤10 mm in 5min; Ocular surface staining using Oxford Scheme grading[12] to divide corneal staining into six groups according to severity from 0 (absent) to 5 (severe).
Overall diagnosis of DED based on both signs and symptoms	OSDI score ≥13 and TBUT<10s, Schirmer I tear test ≤10 mm in 5min or ocular surface staining of ≥1 grade.

DED: Dry eye disease; OSDI: Ocular Surface Disease Index; TBUT: Tear film breakup time.

RESULTS

The mean±SD age of the 144 enrolled participants (78 females, 66 males) was 34.6±15.2y (10-75y). The OSDI score increased significantly as the number of hours of screen usage increased from 2h. The TBUT were significantly lower, and ocular surface staining was significantly higher when screen times were more than 6h per day (*P*<0.05). There was no change in Schirmer I scores with increasing screen times (*P*>0.05; Figure 1).

The clinical parameters of participants stratified on age are presented in Table 2. The TBUT, Schirmer I scores, and OSDI scores were comparable in age groups above 30 (*P*>0.05). Multiple comparisons between groups revealed statistically significant differences in the TBUT and OSDI scores between subjects ≥20 and 21-30y of age. Younger participants had longer TBUT and smaller OSDI scores (*P*<0.05).

In total, 106 of 144 subjects (73.6%) fulfilled the DEWS II definition of DED. Among the confirmed cases of DED, Spearman correlation analysis showed a significant negative correlation between the duration of computer use with TBUT [*r*=-0.45, 95% confidence interval (CI)=-0.5994 to -0.2752, *P*<0.0001] and a significant positive correlation with OSDI (*r*=0.74, 95%CI=0.6369 to 0.8219, *P*<0.0001). There was no association between the duration of computer use and Schirmer I test values (*r*=-0.10, 95%CI=-0.3016 to 0.09819, *P*=0.29).

When compared with normal subjects, the clinical parameters except Schirmer I test were significantly for the confirmed cases of DED.

Table 2 Clinical characteristics of study participants stratified on presenting age mean±SD

Age (y)	OSDI score	TBUT (s)	Schirmer I test (mm)
≤20 (*n*=41)	18.6±9.1[a]	8.5±4.2[a]	12.6±4.3
21-30 (*n*=43)	25.3±10.2[a]	5.6±3.5[a]	12.7±4.7
31-40 (*n*=26)	26.2±12.2	5.6±4.7	10.5±4.6
41-50 (*n*=14)	19.7±7.5	6.2±4.1	12.9±4.7
>50 (*n*=20)	19.6±10.1	7.7±3.7	12.6±4.7
P	0.004	0.007	0.20

OSDI: Ocular Surface Disease Index; TBUT: Tear-film break up time; SD: Standard deviation. [a]Statistical significant.

Table 3 Clinical findings of the study participants stratified on hours of screen usage median (IQR)

Parameters	Control group (*n*=37)	<2h (*n*=14)	2-4h (*n*=34)	4-6h (*n*=32)	6-8h (*n*=16)	>8h (*n*=10)	*P*
OSDI	10.4 (8.3-11.4)	16.6 (14.5-16.6)[a]	20.8 (18.7-25.5)[a]	28.1 (23.4-34.9)[a]	35.4 (29.6-41.1)[a]	36.4 (33.3-42.1)[a]	<0.0001
TBUT	11.0 (8.5-13.0)	8.5 (7.0-11.25)[a]	7.0 (4.7-9.0)[a]	5.0 (2.0-6.7)[a]	3.0 (0.0-6.7)[a]	2.0 (0.0-5.2)[a]	<0.0001
Schirmer I test	12.0 (9.0-15.5)	12.0 (10.5-14.2)	12.0 (9.0-16.0)	14.0 (11.2-17.0)	9.0 (8.0-13.5)	12.0 (5.5-14.2)	0.09
Ocular surface staining	1.0 (1.0-3.0)	2.0 (2.0-3.0)[a]	3.0 (2.7-4.0)[a]	3.0 (2.0-4.0)[a]	4.0 (2.2-5.0)[a]	4.0 (3.7-4.2)[a]	<0.0001

IQR: Inter quartile range; OSDI: Ocular Surface Disease Index; TBUT: Tear-film break up time. [a]Statistical significant.

In total, 106/144 (73.6%) cases who used screens for various durations from less than 2h to more than 8h per day were confirmed to have DED based on high OSDI scores (≥13) and one or more clinical signs (TBUT, ocular surface staining, or Schirmer I test) outside normal limits (Figure 2).

When compared to the control group (normal OSDI scores), OSDI increased, TBUT decreased, and ocular surface staining increased (P<0.0001) in DED cases across all the exposure durations (Table 3).

DISCUSSION

The present study confirmed DED in 67.4% of total study samples based on DEWS II definition. The results also showed that with increasing hours of screen usage, the abnormal changes in clinical signs of DED were significantly greater than chance.

Dry eyes can result from factors like environmental conditions (low humidity, heating, air conditioning, ventilation fans, airborne contaminants), age, gender, systemic diseases, medications, and prolonged exposure to digital screens leading to increased tear evaporation[16]. Furthermore, many studies have reported that the blink rate is reduced during computer use[17-18]. Tsubota and Nakamori[19] compared the blinking rate in 104 office workers in different states, *i.e.* when relaxed, reading a book, and viewing texts on digital screens. The mean blink rates while relaxed, reading a book and screen were 22/min, 10/min, and 7/min respectively. The disturbance in blink rate, whether a cause or effect, can lead to compromised tear film stability, optical clarity, and visual function, with reduced blink rates commonly observed during computer use[20]. These findings and facts support our findings that there is significant association between digital screen usage and dry eye prevalence.

Although LED light in itself is not inherently harmful to eyes, extended exposure to the blue light (380 to 500 nm) emitted by LED lighting can result in eye fatigue, headache, and other negative effects on vision. Also, blue light exposure is widely reported to be involved in circadian rhythm regulation and sleep cycle, causing sleep deprivation, and affecting mood and task performance[21]. Although, there is no published evidence to support the claim, it has recently been suggested that blue light emitted from digital displays may cause dry eye syndrome (DES)[22].

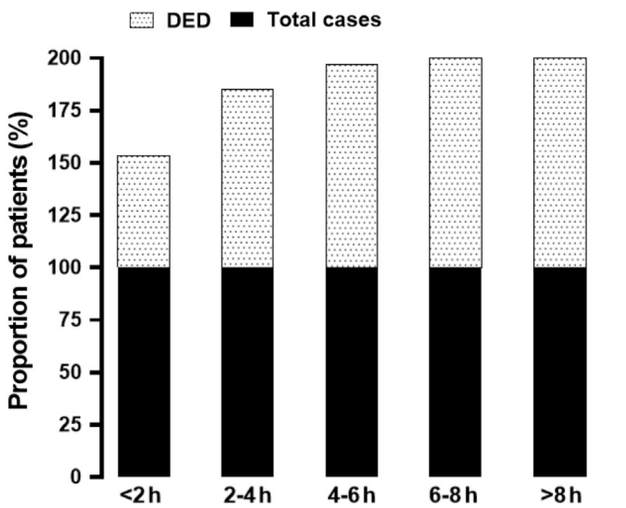

Figure 2 The proportion of DED based on hours of screen usage
DED: Dry eye disease.

Schirmer's test alone does not seem to be a good test for the diagnosis of DES because reflex epiphora might result in the misdiagnosis of dry-eye patients as being normal[23]. The OSDI questionnaire was used in the present study because it is reliable and assesses the frequency of symptoms, environmental triggers, and vision-related quality of life[24]. The OSDI and TBUT tests hold significant prominence in clinical settings as widely utilized assessments. The incorporation of staining patterns further strengthens the study's potential to provide targeted interventions that helped to assess the changes in corneal and conjunctival dryness patterns in various forms of dry eyes. In practice, the Oxford grading scheme has been shown to be subjective and observer dependent, besides being susceptible to poor reproducibility and high inter-observer and intra-observer variability in contrast to computer-assisted, objective digital analysis[25].

TBUT depends on the reduction of surface tension by mucins and other surface-active agents, and therefore, TBUT test is more sensitive for measurement of the stability of the tear film rather than of aqueous tear production[26]. Since the test is invasive, it should be performed by experts which limits its use to a clinical setup. As found by Alves *et al*[27], the best combination of diagnostic tests for DED is OSDI, TBUT, and Schirmer test (sensitivity 100%, specificity 95%, and accuracy 99.3%).

While participants were instructed clearly and specifically to provide precise information regarding their daily usage

of digital screens in hours, the method employed subjective quantification, which may introduce certain limitations. Long-term study needs to be conducted to evaluate the effects of treatment regimens of DED due to digital screen use. Regular screening for DED is suggested to reduce the effects in tear quality and quantity as well as to reduce the risk factors of DED in individuals using digital screens in day-to-day life.

In conclusion, prolonged use of digital screens is strongly associated with the development of Visual Display Terminal (VDT)-related DED, revealing a significant correlation, particularly among frequent screen users.

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Conflicts of Interest: Ghimire R, None; **Kaiti R,** None; **Shyangbo R,** None; **Paudel S,** None; **Neupane Y,** None.

REFERENCES

1 Walsh JJ, Barnes JD, Tremblay MS, *et al*. Associations between duration and type of electronic screen use and cognition in US children. *Comput Hum Behav* 2020;108:106312.

2 Rolland B, Haesebaert F, Zante E, *et al*. Global changes and factors of increase in caloric/salty food intake, screen use, and substance use during the early COVID-19 containment phase in the general population in France: survey study. *JMIR Public Health Surveill* 2020;6(3):e19630.

3 Colley RC, Bushnik T, Langlois K. Exercise and screen time during the COVID-19 pandemic. *Health Rep* 2020;31(6):3-11.

4 Mineshita Y, Kim HK, Chijiki H, *et al*. Screen time duration and timing: effects on obesity, physical activity, dry eyes, and learning ability in elementary school children. *BMC Public Health* 2021;21(1):422.

5 Robinson TN, Banda JA, Hale L, *et al*. Screen media exposure and obesity in children and adolescents. *Pediatrics* 2017;140(suppl 2):S97-S101.

6 Seema R, Varik-Maasik E. Students' digital addiction and learning difficulties: shortcomings of surveys in inclusion. *Front Educ* 2023;8:1191817.

7 LeBlanc AG, Gunnell KE, Prince SA, *et al*. The ubiquity of the screen: an overview of the risks and benefits of screen time in our modern world. *Transl J ACSM* 2017;2(17):104-113.

8 Al-Mohtaseb Z, Schachter S, Lee BS, *et al*. The relationship between dry eye disease and digital screen use. *Clin Ophthalmol* 2021;15:3811-3820.

9 Courtin R, Pereira B, Naughton G, *et al*. Prevalence of dry eye disease in visual display terminal workers: a systematic review and meta-analysis. *BMJ Open* 2016;6(1):e009675.

10 Moon JH, Kim KW, Moon NJ. Smartphone use is a risk factor for pediatric dry eye disease according to region and age: a case control study. *BMC Ophthalmol* 2016;16(1):188.

11 Miller KL, Walt JG, Mink DR, *et al*. Minimal clinically important difference for the ocular surface disease index. *Arch Ophthalmol* 2010;128(1):94-101.

12 Bron AJ, Evans VE, Smith JA. Grading of corneal and conjunctival staining in the context of other dry eye tests. *Cornea* 2003;22(7):640-650.

13 Vidas Pauk S, Petriček I, Jukić T, *et al*. Noninvasive tear film break-up time assessment using handheld lipid layer examination instrument. *Acta Clin Croat* 2019;58(1):63-71.

14 Ghimire R, Kaiti R, Dahal M, *et al*. Central corneal thickness in new cases of dry eyes: a case-control study. *Optom Vis Sci* 2024;101(5):272-275.

15 Agarwal S, Goel D, Sharma A. Evaluation of the factors which contribute to the ocular complaints in computer users. *J Clin Diagn Res* 2013;7(2):331-335.

16 Rosenfield M. Computer vision syndrome: a review of ocular causes and potential treatments. *Ophthalmic Physiol Opt* 2011;31(5):502-515.

17 Schlote T, Kadner G, Freudenthaler N. Marked reduction and distinct patterns of eye blinking in patients with moderately dry eyes during video display terminal use. *Graefes Arch Clin Exp Ophthalmol* 2004;242(4):306-312.

18 Muntz A, Turnbull PR, Kim AD, *et al*. Extended screen time and dry eye in youth. *Cont Lens Anterior Eye* 2022;45(5):101541.

19 Tsubota K, Nakamori K. Dry eyes and video display terminals. *N Engl J Med* 1993;328(8):584.

20 Portello JK, Rosenfield M, Chu CA. Blink rate, incomplete blinks and computer vision syndrome. *Optom Vis Sci* 2013;90(5):482-487.

21 LeGates TA, Fernandez DC, Hattar S. Light as a central modulator of circadian rhythms, sleep and affect. *Nat Rev Neurosci* 2014;15(7):443-454.

22 Rosenfield M. Computer vision syndrome (a.k.a. digital eye strain). *Optom Pract* 2016;17(1):1-10.

23 Ünlü C, Guney E, Sezgin Akçay BI, *et al*. Comparison of ocular-surface disease index questionnaire, tearfilm break-up time, and Schirmer tests for the evaluation of the tearfilm in computer users with and without dry-eye symptomatology. *Clin Ophthalmol* 2012:1303.

24 Wolffsohn JS, Arita R, Chalmers R, *et al*. TFOS DEWS II diagnostic methodology report. *Ocul Surf* 2017;15(3):539-574.

25 Wolffsohn JS, Recchioni A, Hunt OA, *et al*. Optimising subjective grading of corneal staining in Sjögren's syndrome dry eye disease. *Ocul Surf* 2024;32:166-172.

26 Tripathi A, Agarwal R, Kharya P. Dry eye disease related to digital screen exposure in medical students. *Pan Am J Ophthalmol* 2022;4(1):35.

27 Alves M, Reinach PS, Paula JS, *et al*. Comparison of diagnostic tests in distinct well-defined conditions related to dry eye disease. *PLoS One* 2014;9(5):e97921.