RESEARCH PAPER

Association Between Prolonged Digital Screen Exposure and Alterations in Accommodation, Binocular Vision, and Tear Film Stability Among Young Adults: A Cross-Sectional Analytical Study

Javid Ali[1], Abdulrahman Saleh Alhadlag[2], Sarah Sadiq[3], Asif Manzoor[4], Ayesha Chandni[5], Nesr Farooq[6], Muhammad Zia Iqbal[7]

[1]*Medical Officer, Hayat Abad Medical Complex-MTI, Peshawar*
[2]*Consultant & Assistant Professor of Ophthalmology, Oculofacial Plastic and Reconstructive Surgery, Head of Clinical Science Development, College of Medicine, Shaqra University, Shaqra*
[3]*Consultant Ophthalmologist Department of Ophthalmology District headquarter Hospital Okara south city Okara*
[4]*Assistant Professor, Ophthalmology Department, Bakhtawar Amin Medical College, Multan*
[5]*Senior Registrar Department of Ophthalmology Islam Medical College, Sialkot*
[6]*Assistant professor Department of Ophthalmology Shalamar Medical and Dental College Lahore*
[7]*Ophthalmologist & Professor Anatomy Basic Sciences Department Suliman Alrajhi University Al-Bulayriah*

Corresponding Author
Muhammad Zia Iqbal
Ophthalmologist & Professor Anatomy Basic Sciences Department Suliman Alrajhi University Al-Bulayriah
z.iqbal@sr.edu.sa

ABSTRACT

Background: Prolonged digital screen exposure has become increasingly common among young adults and is associated with a spectrum of visual disturbances collectively termed digital eye strain.

Objective: To evaluate the association between duration of digital screen exposure and changes in accommodative function, binocular vision parameters, and tear film stability among young adults.

Methods: This cross-sectional analytical study was conducted at Hayat Abad Medical Complex-MTI, Peshawar from march 2025 to march 2026 included 175 young adults aged 18–30 years. Participants were categorized based on daily screen time into <4 hours, 4–6 hours, and >6 hours groups. Accommodative function was assessed using amplitude of accommodation and accommodative facility, binocular vision was evaluated using near point of convergence and fusional vergence, and tear film stability was measured using tear break-up time (TBUT) and Schirmer's test.

Results: The mean age was 22.8 ± 3.1 years, with a near-equal gender distribution. Increasing screen time was significantly associated with reduced amplitude of accommodation (12.8 ± 2.1 D vs 9.6 ± 1.8 D, $p<0.001$), decreased accommodative facility, increased near point of convergence (6.2 ± 1.4 cm vs 9.1 ± 1.8 cm, $p<0.001$), and reduced fusional vergence ranges. Tear film parameters showed significant deterioration, with TBUT decreasing from 13.5 ± 2.6 seconds to 8.2 ± 2.0 seconds ($p<0.001$). Common symptoms included eye strain (58.3%), dryness (54.3%), headache (46.3%), and blurred vision (43.4%). Significant correlations were observed between screen time and visual parameters.

Conclusion: Prolonged digital screen exposure is significantly associated with impairment of accommodative function, binocular vision, and tear film stability in young adults. Early preventive strategies and awareness are essential to reduce the burden of digital eye strain.

Keywords: Digital screen exposure, accommodation, binocular vision, tear film stability, digital eye strain

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INTRODUCTION

The rapid expansion of digital technology has transformed daily life, with smartphones, tablets, and computers becoming integral to education, work, and social interaction [1]. Young adults represent one of the most heavily exposed groups, often spending several hours per day on digital screens for academic and recreational purposes [2]. While these technologies offer significant advantages, prolonged digital screen exposure has raised growing concerns

*Author for Correspondence: z.iqbal@sr.edu.sa

regarding its impact on visual function and ocular health. Digital screen use is strongly associated with a constellation of visual and ocular symptoms collectively termed digital eye strain or computer vision syndrome [3]. Common complaints include blurred vision, eye fatigue, dryness, headaches, and difficulty focusing. These symptoms are thought to arise from a combination of accommodative stress, binocular vision dysfunction, and tear film instability. However, the underlying mechanisms and their interrelationships remain incompletely understood, particularly in young, otherwise healthy individuals. Accommodation plays a critical role in maintaining clear vision during near work [4]. Prolonged screen exposure requires sustained accommodative effort, which may lead to accommodative fatigue, reduced amplitude of accommodation, and delayed accommodative recovery. This can manifest clinically as difficulty in shifting focus between near and distant objects, a symptom frequently reported by heavy screen users [5]. Repeated accommodative stress may also contribute to transient or sustained changes in visual performance over time, potentially predisposing individuals to functional visual disturbances [6].

In addition to accommodative function, binocular vision is essential for maintaining single, comfortable vision during prolonged near tasks. Continuous digital screen use may disrupt normal vergence mechanisms, potentially leading to convergence insufficiency, reduced fusional reserves, and impaired coordination between the two eyes. These alterations can result in symptoms such as diplopia, eye strain, and reduced reading efficiency, further impacting visual comfort and productivity [7]. Furthermore, prolonged near work may induce changes in vergence adaptation, altering the balance between accommodation and convergence, which is essential for stable binocular vision. Tear film stability is another critical factor affected by digital screen use [8]. Studies have shown that prolonged screen exposure is associated with a reduced blink rate and increased incidence of incomplete blinking, leading to accelerated tear evaporation and ocular surface dryness [9]. This results in tear film instability, which can exacerbate visual symptoms and contribute to the development of dry eye disease. The disruption of the tear film not only affects ocular comfort but also degrades optical quality, leading to fluctuating vision and reduced contrast sensitivity [10]. Over time, these changes may contribute to chronic ocular surface disorders [11]. Environmental and behavioral factors further compound the effects of digital screen exposure. Poor lighting conditions, improper viewing distance, suboptimal screen positioning, and prolonged uninterrupted screen use can all exacerbate visual strain [12]. Additionally, the use of smaller devices such as smartphones often requires closer viewing distances, increasing accommodative and vergence demand. Blue light emission from digital screens has also been implicated in visual discomfort and potential circadian rhythm disturbances, although its direct impact on ocular structures remains a topic of ongoing research [13].

OBJECTIVE

To evaluate the association between duration of digital screen exposure and changes in accommodative function, binocular vision parameters, and tear film stability among young adults.

METHODOLOGY

This was a cross-sectional analytical study conducted at Hayat Abad Medical Complex-MTI, Peshawar from march 2025 to march 2026. A total of 175 young adults aged between 18 and 30 years were included in the study to provide adequate statistical power for evaluating associations between screen exposure and visual parameters. Non-probability consecutive sampling was employed to recruit participants who met the inclusion criteria and consented to participate in the study. Participants included young adults of either gender with regular digital screen use of at least 2 hours per day. Individuals with pre-existing ocular diseases such as glaucoma, cataract, or keratoconus, a history of ocular trauma or surgery, contact lens use, systemic conditions affecting vision such as diabetes mellitus, or use of medications known to affect tear production were excluded to minimize confounding factors.

Data Collection

After obtaining ethical approval and informed consent, participants were assessed using a structured questionnaire to record demographic details, daily duration of digital screen exposure, type of devices used, and associated visual symptoms. Based on screen time, participants were categorized into exposure groups (<4 hours/day, 4–6 hours/day, and >6 hours/day). A comprehensive ophthalmic examination was then performed. Accommodative function was evaluated using amplitude of accommodation measured by the push-up method and accommodative facility testing. Binocular vision assessment included near point of convergence, positive and negative fusional vergence, and evaluation for convergence insufficiency. Tear film stability was assessed using tear film break-up time and Schirmer's test. The primary independent variable was the duration of digital screen exposure measured in hours per day. Dependent variables included amplitude of accommodation, accommodative facility, near point of convergence, fusional vergence parameters, tear film break-up time, and Schirmer's test values. Additional variables such as age, gender, type of device used, and presence of symptoms including eye strain, dryness, headache, and blurred vision were also recorded.

Data Analysis

Data were entered and analyzed using Statistical Package for Social Sciences (SPSS) version 26. Quantitative variables were expressed as mean ± standard deviation, while qualitative variables were presented as frequencies and percentages. Independent t-test and one-way ANOVA were applied to compare means across different exposure groups, while chi-square test was used for categorical variables. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

Data were collected from 175 patients, mean age of participants was 22.8 ± 3.1 years, with a nearly equal gender distribution, comprising 92 (52.6%) males and 83 (47.4%) females. Regarding digital screen exposure, the largest proportion of participants reported 4–6 hours of daily screen time (41.1%), followed by >6 hours (37.1%), while 21.7% had screen exposure of less than 4 hours per day.

Table 1: Baseline Demographic Characteristics (n = 175)

Variable	Category	n (%) / Mean ± SD
Age (years)	—	22.8 ± 3.1
Gender	Male	92 (52.6%)
	Female	83 (47.4%)
Daily Screen Time	<4 hours	38 (21.7%)
	4–6 hours	72 (41.1%)
	>6 hours	65 (37.1%)

Amplitude of accommodation progressively decreased from 12.8 ± 2.1 D in the <4-hour group to 9.6 ± 1.8 D in the >6-hour group ($p<0.001$), along with a similar decline in accommodative facility (11.5 ± 2.4 to 7.9 ± 1.9 cpm, $p<0.001$). Binocular vision parameters showed worsening trends, with near point of convergence increasing from 6.2 ± 1.4 cm to 9.1 ± 1.8 cm ($p<0.001$), and both positive and negative fusional vergence significantly decreasing across groups ($p<0.001$ and $p=0.002$, respectively). Tear film stability also declined significantly, with TBUT reducing from 13.5 ± 2.6 seconds to 8.2 ± 2.0 seconds and Schirmer's test values from 18.2 ± 4.1 mm to 12.9 ± 3.5 mm as screen time increased ($p<0.001$ for both).

Table 2: Association of Digital Screen Exposure with Accommodative Function, Binocular Vision, and Tear Film Stability (n = 175)

Parameter	<4 hrs (n=38)	4–6 hrs (n=72)	>6 hrs (n=65)	p-value
Accommodative Function				
Amplitude of Accommodation (D)	12.8 ± 2.1	11.3 ± 2.0	9.6 ± 1.8	<0.001
Accommodative Facility (cpm)	11.5 ± 2.4	9.8 ± 2.1	7.9 ± 1.9	<0.001
Binocular Vision				
Near Point of Convergence (cm)	6.2 ± 1.4	7.5 ± 1.6	9.1 ± 1.8	<0.001
Positive Fusional Vergence (Δ)	22.5 ± 4.2	19.3 ± 3.8	16.1 ± 3.5	<0.001
Negative Fusional Vergence (Δ)	12.6 ± 2.8	10.9 ± 2.5	9.2 ± 2.3	0.002
Tear Film Stability				
TBUT (seconds)	13.5 ± 2.6	10.9 ± 2.3	8.2 ± 2.0	<0.001
Schirmer's Test (mm)	18.2 ± 4.1	15.6 ± 3.8	12.9 ± 3.5	<0.001

Visual symptoms were commonly reported among participants, with eye strain being the most frequent complaint (58.3%), followed by dryness (54.3%), headache (46.3%), and blurred vision (43.4%), indicating a high prevalence of digital eye strain in the study population.

Table 3: Frequency of Visual Symptoms (n = 175)

Symptom	n (%)
Eye Strain	102 (58.3%)
Dryness	95 (54.3%)
Headache	81 (46.3%)
Blurred Vision	76 (43.4%)

Screen time showed a strong negative correlation with amplitude of accommodation ($r = -0.62$), accommodative facility ($r = -0.60$), and TBUT ($r = -0.65$), while a positive correlation was observed with near point of convergence ($r = +0.58$), all of which were statistically significant ($p<0.001$).

Table 4: Correlation of Screen Time with Visual Parameters

Parameter	Correlation Coefficient (r)	p-value
Amplitude of Accommodation	-0.62	<0.001
Near Point of Convergence	+0.58	<0.001
TBUT	-0.65	<0.001
Accommodative Facility	-0.60	<0.001

DISCUSSION

The present study demonstrates a significant association between prolonged digital screen exposure and alterations in accommodative function, binocular vision, and tear film stability among young adults. With increasing daily screen time, a consistent decline in visual performance was observed across all evaluated parameters, highlighting the multifactorial impact of digital device use on ocular function. Accommodative function showed a clear dose-response relationship with screen exposure. The amplitude of accommodation and accommodative facility were significantly reduced in individuals with higher screen time (>6 hours/day), indicating accommodative fatigue and reduced flexibility of the accommodative system. These findings are consistent with the concept that sustained near work imposes continuous accommodative demand, leading to temporary functional insufficiency. The observed negative correlation between screen time and accommodative parameters further supports the hypothesis that prolonged digital engagement adversely affects the dynamic responsiveness of the accommodative system. Binocular vision parameters were also significantly affected [14]. The near point of convergence increased progressively with screen time, indicating reduced convergence ability, while both positive and negative fusional vergence ranges decreased significantly. These findings suggest that prolonged near work disrupts the delicate balance between accommodation and convergence, potentially leading to convergence insufficiency and reduced binocular stability. The increase in NPC and reduction in fusional reserves are clinically relevant, as they are commonly associated with symptoms such as eye strain, diplopia, and reduced reading efficiency in individuals with digital eye strain [15].

Tear film stability was markedly compromised with increasing screen exposure. A significant reduction in TBUT and Schirmer's test values was observed in participants with higher screen time, reflecting tear film instability and decreased tear production. These findings can be attributed to reduced blink rate and increased incomplete blinking during screen use, which accelerate tear evaporation and disrupt the ocular surface. The strong negative correlation between screen time and TBUT underscores the role of digital devices in the pathogenesis of dry eye symptoms, even in a young population [16]. The frequency of visual symptoms observed in this study further reinforces the clinical significance of these objective findings. More than half of the participants reported eye strain (58.3%) and dryness (54.3%), while a substantial proportion experienced headaches (46.3%) and blurred vision (43.4%). These symptoms closely align with the physiological changes observed in accommodative, binocular, and tear film parameters, suggesting that digital eye strain is a result of combined dysfunction across multiple visual systems rather than a single isolated factor [17].

An important strength of this study is the comprehensive evaluation of multiple interrelated visual parameters within the same population [18]. Unlike previous studies that have focused on individual components such as dry eye or accommodative dysfunction, this study provides a holistic assessment, demonstrating that prolonged screen exposure simultaneously affects accommodation, binocular coordination, and ocular surface integrity. This integrated approach enhances the understanding of digital eye strain as a multifactorial condition. The findings of this study have important clinical implications [19]. Early identification of accommodative and binocular dysfunction, along with tear film instability, can aid in timely intervention through strategies such as visual hygiene education, regular breaks (20-20-20 rule), ergonomic modifications, and the use of lubricating eye drops. Additionally, vision therapy and targeted exercises may be beneficial in individuals with significant binocular vision anomalies [20]. This study has several limitations that should be considered while interpreting the findings. First, the cross-sectional design limits the ability to establish a causal relationship between prolonged digital screen exposure and observed alterations in accommodation, binocular vision, and tear film stability; only associations can be inferred. Second, screen time was based on self-reported data, which may introduce recall bias and affect the accuracy of exposure classification. Third, the study was conducted at a single center with a relatively homogeneous population of young adults, which may limit the generalizability of the results to other age groups or settings. Fourth, environmental and ergonomic factors such as screen brightness, viewing distance, posture, and ambient lighting were not controlled, although they may significantly influence visual performance and ocular surface stability. Fifth, the use of a single-time clinical assessment does not account for diurnal variations or transient fluctuations in accommodative and tear film parameters.

CONCLUSION

Prolonged digital screen exposure is significantly associated with reduced accommodative efficiency, impaired binocular vision, and decreased tear film stability among young adults. A clear dose-response relationship was observed, with higher screen time linked to worsening amplitude of accommodation, increased near point of convergence, reduced fusional vergence, and lower tear film break-up time.

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