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EFFECT OF SCREEN TIME ON VISUAL ACCOMMODATION AND EYE FATIGUE

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ABSTRACT

Background: The increasing dependence on digital devices has led to increased screen time across all age groups. Extended near work on digital screens causes continuous accommodation and convergence in the eyes, and this sustained state can manifest as ocular fatigue and discomfort associated with progressive and disruptive eye strain or digital eye strain/computer vision syndrome. A proper quantitative understanding of accommodation and eye fatigue concerning ever-increasing hours of screen time is needed to understand some of the physiological effects of digital exposure and, hopefully, inspire preventative strategies in work and school settings. **Objectives:** The study focused on examining the impact of daily screen time exposure on visual accommodation and indicators of eye fatigue in young adults. Specifically, the study sought to evaluate near point of accommodation (NPA) and near point of convergence (NPC), and tear film stability in young adult college students categorized by daily screen time exposure, and to examine the relationships among screen time, accommodative fatigue, and symptom scores reported by study participants. **Materials and Methods:** A cross-sectional analytical research study took place at the Department of Ophthalmology of a tertiary care teaching hospital in India from March 2023 to April 2024. A total of 240 individuals between the ages of 18-40 years old who had best-corrected visual acuity of 6/6 or better and were free of ocular pathology were enrolled in the study. Screen time usage was self-reported by participants and verified using logs of smartphone usage, and participants were grouped into three categories: Group A (< 2 hours daily), Group B (2-6 hours daily), and Group C (>6 hours daily). Each participant had refraction and near point of accommodation (NPA) documented using the push-up method, blink rate recorded using a one-minute video, measured tear film break-up time (TBUT) using fluorescein dye and had a subjective symptom scale based on a Computer Vision Syndrome Questionnaire (CVS-Q). Statistical analysis was performed using SPSS version 27.0, using a one-way ANOVA and Pearson correlation test. **Result:** The mean age of participants was 26.4 ± 5.1 years, with an almost equal male-to-female distribution. Mean daily screen exposure was 5.2 ± 2.9 hours. The mean near point of accommodation increased significantly with screen time, measuring 8.1 ± 1.4 cm in Group A, 10.2 ± 2.1 cm in Group B, and 12.8 ± 2.7 cm in Group C ($p < 0.001$). Blink rate decreased progressively from 18.3 ± 3.1/min in Group A to 14.7 ± 3.0/min in Group C ($p < 0.001$), while TBUT declined from 13.1 ± 2.5 seconds to 8.4 ± 2.3 seconds ($p < 0.001$). The mean CVS-Q fatigue score increased from 8.7 ± 3.2 in Group A to 18.6 ± 4.5 in Group C. Pearson's correlation demonstrated a strong positive correlation between screen time and eye-fatigue score ($r = 0.72$, $p < 0.001$) and a negative correlation with tear stability and blink rate. **Conclusion:** Prolonged screen exposure significantly impairs visual accommodation, reduces blink frequency, destabilizes tear film, and increases subjective eye fatigue. The findings highlight the need for incorporating regular visual breaks, maintaining optimal screen ergonomics, and implementing awareness programs to prevent accommodative strain and ocular surface discomfort in frequent digital device users.

INTRODUCTION

The increasing reliance on digital technology has changed how individuals behave visually as a function of age. The use of smart phones, tablets, computers, and other electronic displays has become an important aspect of work, learning and leisure time.[1] The combination of increased screen time, has resulted in a growing incidence of symptoms grouped together as digital eye strain, which may include eye discomfort, blurred vision, headache and fatigue following near work. The visual system, which usually accommodates for dynamic distance viewing, now must accommodate and converge for extended periods of time in near space, placing individuals at risk of accommodative overload and instability of the tear film.[2] Consistent at-screen usage affects the eyes via both optical and physiological bases - the accommodation and vergence systems must coordinate continuously in order to see clearly at near (decreased distances). Prolonged contraction of the ciliary muscle may induce transient myopia, delays in accommodation, or spasm, all potential contributors to visual discomfort.[3] Further, decreased frequency of blinking during extended periods of focused activity with a digital screen can initiate tear evaporation and dryness of the ocular surface. Environmental and ergonomic factors such as glare from the screen, distance created between yourself and the screen, body posture relative to screen position, and modulation of light may further compound the experience. When grouped together, these create a mechanism for digital eye strain, or computer vision syndrome.[4]

Visual accommodation is a crucial mechanism that enables the eye's adjustment through ciliary muscle action to see near objects by modifying the curvature of the lens. If this system is overstressed due to excessive demands of near-vision, the near point of accommodation (NPA) increases, indicating accommodation is less efficiently accommodating near objects. Additionally, prolonged sustained attention on digital screens results in a spontaneous blink rate that is reduced by 40 - 60 percent, resulting in reduction of the tear film stability and ocular dryness.[5] Tear break-up time (TBUT) is a quantitative measure of the stability of the tear film and often times decreasing TBUT values may signify early instability of the ocular surface due to excess of environmental and behavioral demands.[6] It has been reported in a variety of cross-sectional studies, from multiple geographic settings, that there is an association between increased screen time and the symptoms of visual fatigue, more expressly among clossal students and professionals working remotely as the most observed and reported association.[7] The duration of exposure, type of device, background and lighting factors, and habits limit the ability to draw definitive conclusions here. In the context of India, with the use of smartphones becoming prevalent, and with the demand of online education environments increasing after the pandemic, it is valuable as research is to evaluate the extended effects of screen distance on visual outcomes.[8]

Early identification of accommodative dysfunction and tear instability can aid in preventing chronic eye fatigue and refractive complications. Furthermore, understanding these associations is essential for formulating ergonomic guidelines, awareness programs, and screening protocols in workplaces and educational institutions.

Therefore, it is of interest to assess the effect of daily screen exposure duration on visual accommodation and eye fatigue, and to evaluate its association with blink rate, tear film stability, and subjective visual strain among adult digital device users.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional analytical study was conducted in the Department of Ophthalmology at a tertiary care teaching hospital in India from March 2023 to April 2024. The study was approved by the Institutional Ethics Committee and written informed consent was obtained from all participants. The study adhered to the tenets of the Declaration of Helsinki.

Study Population

A total of 240 participants aged 18–40 years were recruited from hospital staff, medical students, and outpatient attendees. All participants had best-corrected visual acuity of 6/6 in both eyes, normal ocular motility, and no systemic illness affecting vision. Subjects were divided into three groups based on self-reported daily screen exposure verified by digital usage logs:

- Group A: Less than 2 hours/day
- Group B: 2–6 hours/day
- Group C: More than 6 hours/day

Inclusion Criteria

1. Adults aged 18–40 years with normal visual acuity (6/6) in both eyes.
2. Routine digital screen users for work, study, or leisure.
3. No history of ocular surgery or active eye disease.

Exclusion Criteria

1. Refractive errors greater than ±3.0 diopters spherical or ±1.0 diopter cylindrical.
2. History of strabismus, amblyopia, or accommodative anomaly.
3. Systemic diseases affecting accommodation (e.g., diabetes mellitus, thyroid disease).
4. Current use of contact lenses, ocular lubricants, or medications affecting tear production.

Ophthalmic Evaluation Protocol

All participants underwent a comprehensive ophthalmic evaluation by a single examiner under standardized lighting and environmental conditions.

1. **Refraction and Visual Acuity:** Objective and subjective refraction were performed using an autorefractor and trial frame. Only individuals

with best-corrected visual acuity of 6/6 were included.
2. **Near Point of Accommodation (NPA):** Measured monocularly using the push-up method with a Royal Air Force ruler. The target was advanced toward the eye until the participant reported sustained blur. The average of three measurements was recorded in centimeters.
3. **Blink Rate:** Blink frequency was determined by continuous one-minute video recording of the participant engaged in reading text on a computer screen positioned 50 cm away. The number of spontaneous blinks per minute was counted manually.
4. **Tear Break-Up Time (TBUT):** Fluorescein dye was instilled into the conjunctival sac, and the interval between the last blink and the first appearance of a dry spot on the cornea was measured using slit-lamp biomicroscopy. The average of three readings per eye was recorded in seconds.
5. **Subjective Eye-Fatigue Assessment:** The validated Computer Vision Syndrome Questionnaire (CVS-Q) was administered to quantify symptom severity. Each symptom was scored on frequency and intensity, generating a composite fatigue score (range 0–40).

Data Collection and Validation

Screen time duration was confirmed using the in-built digital wellbeing or screen time tracker on participants' devices. Participants were also interviewed about their work habits, lighting conditions, screen brightness settings, and use of corrective lenses to ensure consistent exposure assessment.

Outcome Variables

The primary outcome variable was near point of accommodation. Secondary outcomes included blink rate, tear break-up time, and subjective fatigue score. Independent variables were age, gender, and daily screen time duration.

Sample Size Determination

Sample size was calculated using the formula for comparing means between three independent groups, with an expected mean difference in NPA of 2 cm and standard deviation of 3 cm, a power of 80 percent, and a significance level of 0.05. The minimum required sample was 198, which was rounded to 240 to account for potential data loss.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 27.0 (IBM Corp., USA). Continuous variables were expressed as mean ± standard deviation, while categorical variables were represented as frequencies and percentages. Between-group comparisons were performed using one-way ANOVA with post hoc Tukey test for normally distributed data, and the Kruskal–Wallis test for non-parametric variables. Pearson correlation coefficient was applied to evaluate the relationship between screen time and visual parameters. A p-value less than 0.05 was considered statistically significant.

Ethical Considerations

Confidentiality of participants' data was ensured by anonymization and restricted access. Participation was voluntary, and no invasive procedures were performed. Individuals found to have significant visual strain or abnormal tear parameters were counseled and advised appropriate management.

RESULTS

A total of 240 participants completed the study, distributed evenly across the three screen-time exposure groups: Group A (<2 hours/day, n = 80), Group B (2–6 hours/day, n = 80), and Group C (>6 hours/day, n = 80). The mean age of the study population was 26.4 ± 5.1 years, with 126 males and 114 females. The overall mean screen exposure was 5.2 ± 2.9 hours/day. Baseline visual acuity and refractive error did not differ significantly among groups (p > 0.05). Progressive changes in accommodative function, blink rate, tear stability, and subjective fatigue were observed with increasing screen time.

Table 1: Demographic Profile of Study Participants

Parameter	Group A (<2 h)	Group B (2–6 h)	Group C (>6 h)	p-value
Number of participants	80	80	80	—
Mean age (years ± SD)	25.9 ± 4.8	26.3 ± 5.2	26.9 ± 5.3	0.54
Male : Female ratio	41 : 39	43 : 37	42 : 38	0.93
Mean refractive error (D)	−0.45 ± 0.72	−0.48 ± 0.69	−0.50 ± 0.70	0.82

This table presents the demographic characteristics showing uniform age and gender distribution across groups.

Table 2: Mean Daily Screen Time across Groups

Group	Mean screen time (hours/day ± SD)
A (<2 hours/day)	1.6 ± 0.4
B (2–6 hours/day)	4.3 ± 1.1
C (>6 hours/day)	8.7 ± 1.6

This table shows the average daily screen exposure verified from usage logs.

Table 3: Near Point of Accommodation (NPA) in Study Groups

Group	Mean screen time (hours/day ± SD)
A (<2 hours/day)	1.6 ± 0.4
B (2–6 hours/day)	4.3 ± 1.1
C (>6 hours/day)	8.7 ± 1.6

This table presents accommodative distance values showing significant increase with prolonged screen time.

Table 4: Blink Rate among Study Groups

Group	Blink rate (per min ± SD)	p-value
A (<2 h)	18.3 ± 3.1	—
B (2–6 h)	16.5 ± 2.9	<0.001
C (>6 h)	14.7 ± 3.0	<0.001

This table shows the mean spontaneous blink rate recorded during one-minute video observation.

Table 5: Tear Break-Up Time (TBUT) Comparison

Group	TBUT (seconds ± SD)	p-value
A (<2 h)	13.1 ± 2.5	—
B (2–6 h)	10.8 ± 2.4	<0.001
C (>6 h)	8.4 ± 2.3	<0.001

This table displays mean TBUT values, indicating tear film instability with increasing screen exposure.

Table 6: Subjective Eye-Fatigue (CVS-Q) Scores

Group	Mean CVS-Q Score ± SD	Range	p-value
A (<2 h)	8.7 ± 3.2	3–14	—
B (2–6 h)	13.9 ± 4.0	7–22	<0.001
C (>6 h)	18.6 ± 4.5	10–27	<0.001

This table summarizes mean symptom scores representing the severity of visual fatigue.

Table 7: Distribution of Major Reported Symptoms among Participants

Symptom	Group A (%)	Group B (%)	Group C (%)	p-value
Eye fatigue	41.3	68.8	87.5	<0.001
Dryness	30.0	55.0	76.3	<0.001
Headache	28.8	47.5	66.3	<0.001
Blurred vision	18.8	35.0	53.8	<0.001
Burning sensation	22.5	46.3	71.3	<0.001

This table presents the frequency of common eye strain symptoms across exposure groups.

Table 8: Association between Screen Time and Accommodation Parameters

Parameter	Correlation coefficient (r)	p-value	Direction
Screen time vs. NPA	0.71	<0.001	Positive
Screen time vs. Blink rate	−0.64	<0.001	Negative
Screen time vs. TBUT	−0.68	<0.001	Negative

This table shows correlation coefficients for screen exposure with accommodation indices.

Table 9: Gender-based Comparison of Accommodation and Fatigue

Parameter	Male (n = 126)	Female (n = 114)	p-value
Mean NPA (cm)	10.7 ± 2.6	10.9 ± 2.8	0.56
TBUT (s)	10.4 ± 2.8	10.2 ± 2.7	0.63
CVS-Q Score	13.9 ± 4.6	14.7 ± 4.9	0.42

This table compares mean visual parameters by gender.

Table 10: Association between Lighting Condition and Eye Fatigue

Lighting condition	Mean CVS-Q Score ± SD	p-value
Adequate (500–1000 lux)	11.8 ± 4.0	—
Suboptimal (<500 lux)	16.9 ± 4.3	<0.001

This table explores the relationship between ambient lighting and symptom severity.

Table 11: Post Hoc Analysis of NPA Differences between Groups

Group comparison	Mean difference (cm)	p-value
A vs. B	2.1	<0.001
A vs. C	4.7	<0.001
B vs. C	2.6	<0.001

This table presents pairwise comparisons of NPA means using Tukey’s post hoc test.

Table 12: Summary of Key Visual Function Parameters across Screen Exposure Groups

Parameter	Group A (<2 h)	Group B (2–6 h)	Group C (>6 h)
NPA (cm)	8.1	10.2	12.8
Blink rate (/min)	18.3	16.5	14.7
TBUT (s)	13.1	10.8	8.4
CVS-Q score	8.7	13.9	18.6

This table consolidates mean values of major parameters.

Table 1 shows that demographic distribution was uniform, excluding age or gender bias. Table 2 establishes accurate categorization based on verified screen-time duration. Table 3 demonstrates a significant increase in near point of accommodation with prolonged screen exposure, indicating reduced accommodative efficiency. Table 4 confirms a progressive decline in blink rate, while Table 5 documents shorter tear break-up time with longer exposure, reflecting increased ocular dryness. Table 6 and Table 7 show that subjective eye fatigue and symptoms such as dryness, headache, and blurred vision were markedly higher in the high-exposure group. Table 8 illustrates strong correlations between screen time and all physiological parameters, with screen time positively correlating with accommodative distance and negatively with blink rate and tear stability. Table 9 reveals no significant gender differences, suggesting that physiological effects are exposure-dependent rather than sex-related. Table 10 highlights that suboptimal ambient lighting aggravates fatigue symptoms. Table 11 confirms statistically significant differences in accommodation between all exposure groups. Table 12 provides a clear summary of dose–response patterns linking prolonged screen exposure to visual fatigue and reduced accommodation.

Overall, the results demonstrate that prolonged daily screen time is directly associated with accommodative dysfunction, decreased blink frequency, reduced tear film stability, and increased subjective eye fatigue.

DISCUSSION

This study investigated the effects of screen time on visual accommodation and eye strain in healthy adults and found a solid relationship between prolonged use of digital devices and decline in numerous visual factors.[9] Participants who had exposure to more screen time on a daily basis showed more positive near point of accommodation, decreased blink rate, decreased tear break-up time, and higher subjective scores of fatigue. This indicates that prolonged near work and a reduced rate of blink rate combined leads to accommodative stress and instability of the ocular surface.[10] Results supported the conclusion that more time spent on the screen caused an increase in accommodative stress. Participants in the high exposure group had a significantly higher near point of accommodation measured compared to the low exposure group. This indicates there is less flexibility in accommodation and anterior ciliary muscle fatigue developed earlier in the high exposure group. The findings correlate with past experimental measures that indicated more work under a near visual demand changes amplitude of the accommodative response and led to transient myopic shift.[11] Mechanistically, this occurs from a sustained ciliary muscle contraction and delay in relaxation caused from continued near fixation of an object at the same near distance and an increase in accommodative lag. Together contiguously may lead to visual discomfort and intermittent blur, along with headache symptoms which are generally accepted signs and symptoms of digital eye strain.[12] Blink suppression while using screens can also contribute to problems for the eyes. In this study, a significant decline was noted in the frequency of blinks as the length of screen time increased, with blinking rates at approximately 18 blinks per minute for minimal exposure users compared to only 14 blinks per minute in maximal exposure users. This finding corroborates current information on occupational computer users when the cognitive demands are higher, leading to shortened or absent blinks.[13] Less blinking causes the eye surface to undergo more evaporation of the tear film leading to instability of the tear film, dry eye symptoms, and sensations of foreign body. Furthermore, the relationship observed here between blink wasting and tear break-up time indicates that this finding demonstrates the importance of blinking frequency to maintain the tear film.[14]

The tear break-up time was significantly shortened in the high-exposure subjects which indicated compromised ocular surface as a result of a sustained fixation on screens. The tear film consists of three layers: lipid, aqueous, and mucin, and lubricates the cornea as well as preserves optical clarity. Insufficient blinking breaks the even distribution of the lipid layer, resulting in enhanced tear film evaporation, and then leading to exposure of the corneal epithelium. The lower TBUT values found in this study are typical for individuals who utilize digital devices for extended periods of time, especially in air conditioned or low humidity environments, prompting the need for vigilance and management of the environment, including humidity and airflow, to promote ocular surface stability.[15]

Subjective measures of visual fatigue obtained from the CVS-Q demonstrated a distinct dose-response effect of screen time. Participants who utilized screens for at least 6 hours each day reported substantial increases in fatigue, dryness, burning, and headache scores relative to moderate, or low users. The positive correlation between screen time and symptom severity ($r = 0.72$) provides evidence that

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the cumulative fatigue associated with digital work impacts visual function. These findings are consistent with modern workplace studies that report prolonged computer or smartphone use results in a range of discomfort collectively defined as digital-eye strain.[16]

Interestingly, there is no considerable difference in any objective or subjective measure on the basis of sex for gender-based analysis, indicating visible strain is mostly influenced by behavioral rather than physiological factors. However, environmental context such as ambient lighting, as well as sitting posture, had a significant impact on the severity of symptoms. The participants in the low light condition (< 500 lux) reported significantly higher fatigue scores indicating that poor ergonomic conditions can have a compounding effect on the perception of effort of the eyes. Misalignment of brightness of a screen, glare, and poor ambient contrast can cause pupillary fatigue and possible excessive accommodation that can exacerbate visual discomfort.[17]

These findings emphasize and draw upon underlying physiological mechanisms regarding accommodation, blinking, and tear film composition during the use of digital displays. Prolonged ocular effort to sustain accommodation creates parasympathetic overactivity of the ciliary body while cognitive demand reduces spontaneous blinking. Both contribute to the instability of the tear film which will produce additional discomfort and contribute to a cycle of visual discomfort which connects and continues these variables. The connection and interrelatedness might also be of interest when considering intervention approaches that involve interaction with accommodative rest, blink retraining, and environmental modification.[18]

Clinically, these findings support the notion of needing to apply preventive visual hygiene techniques for habitual digital device users. Visual discomfort likely could be reduced by relatively simple visual hygiene methods such as following someone's recommendation of the "20-20-20" rule; that is, at least every 20 minutes looking away from the screen at something approximately 20 feet away, for at least 20 seconds. Ergonomic suggestions in using digital devices focused on the device's distance (40-75 cm) while positioning the bottom of the screen ideally 10-15 degrees below the horizontal eye level, and to remember to blink more often. In addition, regular use of preservative free artificial tears may help support tear film stability with longer amounts of screen time.[19]

Implications of this study extend beyond transient discomforts, as following the COVID-19 pandemic, digital education and digital work for a workforce has become the norm for living life. Prolonged exposure to digital devices for use in adolescents and young adults can create not only transient visual symptoms, but also permanent changes in accommodation function and tear function, if visual hygiene recommendations are not followed. To reduce risk of transient or permanent visual concerns, recommendations for occupational settings, ie: educational institutions, is to encourage regular breaks and prompt ergonomic consciousness, and regular eye exams for heavy screen users.[20]

Strengths in this investigation involved measuring screen exposure quantitatively from digital logbook usage, observing visual task in a standardized environment, and measuring various physiological variables. The fact there was consistency in findings across all measures gives further validity to the report. However, there are limitations to highlight. Because of its cross-sectional, observational design, the trial was not able to sufficiently infer or specify a correlation between cause and effect. The investigators did not perform all measures of dry eye pathology like tear osmolarity and ocular surface staining, though this does not negate the work. Participants self-reported data guiding lighting and posture, raising the potential for recall bias. More specific longitudinal designs and occupational subgroup studies are preferable for delineating time singulars and long-term consequences.

In summary, this trial is a sound contribution to the empirical literature supporting individuals self-reporting prolonged exposure to computer screens are significantly associated with accommodative dysfunction, decreased blink rates, tear film instability, and increased eye fatigue scores in adults, as described in the emerging public health issue of digital eye strain, and requires further consideration toward preventative behavioral modification and ergonomic optimization to support visual efficiency as we move towards the future of work.

CONCLUSION

Prolonged screen time has been shown to demonstrate measurable detriments on visual accommodation and ocular comfort. Increased screen time has been associated with lessened accommodative ability, decreased blink rate, destabilization of the tear film, and increased eye fatigue. Both studies emphasize the importance of visual hygiene, proper ergonomics, a bright enough ambient light, and regular visual breaks to help decrease perceived ocular fatigue due to extensive use of digital technology. Incorporating preventative eye care considerations into workplace and school settings can be an important component in mitigating digital eye strain and enhancing ocular health.

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