RESEARCH PAPER

Impact of Prolonged Digital Screen Time on Binocular Vision among Young Adults: A Cross-Sectional Analytical Study

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ABSTRACT

Purpose: To evaluate the impact of prolonged digital screen exposure on binocular vision among young adults using a comprehensive clinical assessment of accommodative and vergence function.

Methods: In this hospital-based cross-sectional study, 123 participants aged 18-30 years with best-corrected visual acuity of 6/6 and no ocular pathology underwent binocular vision examination. Daily screen exposure was quantified using a seven-day diary and classified as Low (<2 h/day), Moderate (2-6 h/day), or High (>6 h/day). Near point of convergence (NPC), accommodative amplitude and facility, MEM retinoscopy, fusional vergence, and stereoacuity were assessed. Data were analyzed using SPSS v27 with t-tests, ANOVA, correlation, and regression.

Results: Mean age was 23.84±2.71 years; mean screen time was 6.41±2.12 hours/day. High Screen Time users showed significantly receded NPC (8.94±2.15 vs 5.82±1.11 cm), reduced positive fusional vergence (19.14±5.83Δ vs 27.62±4.96Δ), diminished accommodative facility (7.84±2.12 vs 11.94±1.83 cycles/min), increased MEM lag (+0.82±0.28 D vs +0.43±0.17 D), and higher convergence insufficiency prevalence (34.1% vs 8.6%) compared with Low Screen Time users (all $p<0.001$). Screen time correlated positively with NPC ($r=0.69$) and negatively with accommodative facility ($r=-0.63$) and positive fusional vergence ($r=-0.58$). Regression identified screen time as an independent predictor of binocular vision deterioration ($\beta=0.62$, $p<0.001$; adjusted $R^2=0.48$).

Conclusion: Prolonged digital screen exposure is significantly associated with deterioration of binocular vision in young adults, showing a clear dose-response relationship. Comprehensive binocular vision evaluation should be incorporated into routine eye examination of frequent digital device users, with early identification and management potentially reducing visual discomfort and improving quality of life.

Keywords: Digital Screen Time, Binocular Vision, Convergence Insufficiency, Accommodation, Near Point of Convergence, Fusional Vergence, Computer Vision Syndrome, Digital Eye Strain.

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INTRODUCTION

The twenty-first century technological revolution has transformed communication, education, and occupational practice, making smartphones, computers, laptops, and tablets indispensable in daily life. The COVID-19 pandemic further accelerated this shift by moving education and work online, so that individuals, particularly young adults, now spend several hours each day on prolonged near visual tasks. International estimates suggest daily screen exposure among young adults commonly exceeds six to eight hours, with students and IT professionals often reporting more than ten hours daily[1,2,3]. This has produced a marked rise in symptoms collectively termed Digital Eye Strain (DES) or Computer Vision Syndrome (CVS), encompassing eye fatigue, blurred vision, headache, diplopia, dry eye, and reduced work efficiency[4,5,6,7].

Unlike printed material, digital displays impose unique demands on the visual system through variable contrast, glare, refresh rate, and blue-light emission, requiring continuous accommodative and vergence adjustment[4,8].

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Sustained near fixation reduces blink frequency by nearly half, promoting tear film instability[9], while continuous accommodative and convergence effort fatigues the ciliary muscle and extraocular vergence system[6].

Binocular vision depends on precise coordination between accommodation, vergence, sensory fusion, stereopsis, and oculomotor control[10,11]. Even subtle disturbance can cause asthenopia, intermittent diplopia, poor concentration, and reduced performance. Accommodation and vergence are linked through accommodative-convergence and convergence-accommodation mechanisms; repeated activation without relaxation may produce accommodative insufficiency, accommodative infacility, convergence insufficiency, or fusional vergence dysfunction[12,13]. Convergence insufficiency, characterized by an exophoric deviation greater at near, receded near point of convergence, and reduced positive fusional vergence, is among the most frequently reported anomalies in prolonged near workers[14,15,16].

Most previous work on digital screen exposure has emphasized subjective CVS symptoms or ocular surface change rather than comprehensive binocular assessment, and has often been limited by small samples, heterogeneous criteria, and restricted orthoptic evaluation[17,18,19]. This study was therefore designed to comprehensively evaluate accommodative function, vergence parameters, heterophoria, stereopsis, and oculomotor performance in relation to daily screen time among young adults, using standardized clinical assessment, to provide evidence for early diagnosis and preventive strategy[20,21].

METHODS

Study Design and Setting

This hospital-based cross-sectional analytical observational study was conducted from June 2025 to November 2025 in the Department of Optometry of a tertiary eye care center, in accordance with the Declaration of Helsinki. Trained optometrists performed all examinations under standardized conditions to minimize examiner variability.

Participants

A total of 123 apparently healthy young adults aged 18-30 years, recruited by convenience sampling from university students, healthcare professionals, office employees, and the general outpatient population, were enrolled after written informed consent. Inclusion required best-corrected visual acuity of 6/6 in each eye, spherical refractive error within ±5.00 D, cylindrical error <2.00 D, regular digital device use for at least six months, and normal anterior and posterior segments, with no prior binocular vision therapy or ocular surgery within the preceding year. Exclusion criteria included manifest strabismus, amblyopia, nystagmus, corneal or lens pathology, glaucoma, retinal or neuro-ophthalmic disease, systemic disorders affecting motility, medications affecting accommodation, contact lens wear at examination, active infection, severe dry eye, and pregnancy. Ethical approval was obtained from the Institutional Ethics Committee.

Screen-Time Assessment and Grouping

Daily digital screen exposure was quantified using a structured seven-day screen-time diary covering smartphones, laptops, desktops, tablets, and television, and the mean daily duration was calculated. Participants were categorized as Low Screen Time (LST, <2 h/day), Moderate Screen Time (MST, 2-6 h/day), or High Screen Time (HST, >6 h/day).

Clinical Examination

All examinations were performed between 9:00 AM and 12:00 PM under constant room illumination and testing sequence, and included ocular and screen-use history, visual acuity, objective and subjective refraction, slit-lamp biomicroscopy, fundus evaluation, and comprehensive binocular vision assessment. Distance and near heterophoria were measured by the Modified Thorington technique[22]. Near point of convergence (NPC) was recorded as the mean of three break and recovery measurements using an accommodative target[23]. Near point of accommodation was assessed by the push-up method and converted to amplitude using Hofstetter's formula where appropriate[24]. Monocular and binocular accommodative facility were measured using ±2.00 D flippers at 40 cm over one minute[25]. Accommodative response was assessed by monocular estimation method (MEM) retinoscopy[13]. Positive and negative fusional vergence (blur, break, recovery) were measured using prism bars at near[26]. Stereoacuity was assessed with the Titmus Fly test, and ocular motility was evaluated qualitatively[11].

Statistical Analysis

Data were analyzed using IBM SPSS version 27. Continuous variables were expressed as mean ± SD and categorical variables as frequencies and percentages. Normality was assessed with the Shapiro-Wilk test. Independent t-tests, one-way ANOVA with Bonferroni post-hoc correction, Pearson correlation, and multiple linear regression (adjusted for age, gender, and refractive status) were used as appropriate. Odds ratios with 95% confidence intervals were calculated for binocular vision dysfunction. $P<0.05$ was considered significant. Each parameter was measured three times by the same examiner and averaged; instruments were calibrated and data entry was independently verified by two investigators.

RESULTS

All 123 enrolled participants completed the study (100% response rate). Mean age was 23.84 ± 2.71 years (range 18-30), with 66 (53.7%) males and 57 (46.3%) females. Mean daily screen exposure was 6.41 ± 2.12 hours (range 1.4-11.8). Participants were grouped as LST (n=35, 28.5%), MST (n=41, 33.3%), and HST (n=47, 38.2%); the groups were comparable for age, gender, refractive error, and visual acuity ($p>0.05$). Most participants were 21-25 years old (58%), university students (49.6%), smartphone users (100%), and laptop users (82.1%), with 74% using multiple devices concurrently (Table 1).

Table 1. Demographic Characteristics of the Study Population (n = 123)

Variable	Value
Mean age (years)	23.84 ± 2.71
Male / Female	66 (53.7%) / 57 (46.3%)
Mean daily screen time (h)	6.41 ± 2.12
Low screen time (<2 h/day)	35 (28.5%)
Moderate screen time (2-6 h/day)	41 (33.3%)
High screen time (>6 h/day)	47 (38.2%)
Smartphone users	123 (100%)
Laptop users	101 (82.1%)
Multiple-device users	91 (74.0%)

Binocular vision parameters deteriorated progressively with increasing screen exposure (Table 2). NPC receded from 5.82 ± 1.11 cm (LST) to 6.87 ± 1.52 cm (MST) and 8.94 ± 2.15 cm (HST) (ANOVA, $p<0.001$), with significant post-hoc differences between all groups. Accommodative amplitude fell from 12.64 ± 1.38 D to 10.18 ± 1.42 D ($p<0.001$). Monocular accommodative facility declined from 11.94 ± 1.83 to 7.84 ± 2.12 cycles/min, with a similar pattern for binocular facility ($p<0.001$ for both). Positive fusional vergence fell from 27.62 ± 4.96Δ to 19.14 ± 5.83Δ ($p<0.001$), while negative fusional vergence showed a smaller but significant reduction (13.82 ± 2.94Δ to 11.18 ± 2.53Δ, $p=0.003$). MEM-measured accommodative lag increased from +0.43 ± 0.17 D to +0.82 ± 0.28 D ($p<0.001$), and stereoacuity threshold worsened from 34.6 ± 8.2 to 51.8 ± 11.4 seconds of arc ($p<0.001$).

Table 2. Binocular Vision Parameters by Daily Digital Screen Time

Parameter	Low	Moderate	High	p-value
NPC (cm)	5.82±1.11	6.87±1.52	8.94±2.15	<0.001
Accommodation amplitude (D)	12.64±1.38	11.42±1.31	10.18±1.42	<0.001
Monocular AF (cpm)	11.94±1.83	9.86±2.04	7.84±2.12	<0.001
Binocular AF (cpm)	10.82±1.64	8.61±1.83	6.73±1.94	<0.001
PFV (Δ)	27.62±4.96	23.84±5.11	19.14±5.83	<0.001
NFV (Δ)	13.82±2.94	12.71±2.61	11.18±2.53	0.003
MEM lag (D)	+0.43±0.17	+0.61±0.20	+0.82±0.28	<0.001
Stereoacuity (sec arc)	34.6±8.2	42.7±9.4	51.8±11.4	<0.001

Pearson correlation confirmed dose-dependent relationships between screen time and NPC ($r=0.69$), monocular accommodative facility ($r=-0.63$), binocular accommodative facility ($r=-0.61$), positive fusional vergence ($r=-0.58$), accommodative amplitude ($r=-0.55$), MEM lag ($r=0.61$), stereoacuity ($r=0.49$), and negative fusional vergence ($r=-0.34$), all $p<0.01$ (Table 3).

Table 3. Correlation Between Daily Screen Time and Binocular Vision Parameters

Parameter	r	p-value
Near Point of Convergence	0.69	<0.001
Accommodation Amplitude	-0.55	<0.001
Monocular Accommodative Facility	-0.63	<0.001

Parameter	r	p-value
Binocular Accommodative Facility	-0.61	<0.001
Positive Fusional Vergence	-0.58	<0.001
Negative Fusional Vergence	-0.34	0.002
MEM Lag	0.61	<0.001
Stereoacuity	0.49	<0.001

The overall prevalence of non-strabismic binocular vision dysfunction (NSBVD) was 35.8% (44/123), rising from 11.4% in the LST group to 31.7% in MST and 59.6% in HST participants (Table 4). Convergence insufficiency was the most common diagnosis overall (21.1%), followed by accommodative infacility (21.1%), accommodative insufficiency (17.9%), vergence infacility (13.0%), and fusional vergence dysfunction (11.4%); several participants had coexisting anomalies. Convergence insufficiency affected 34.1% of HST participants versus 8.6% of LST participants, and accommodative insufficiency affected 29.8% versus 5.7%, respectively. Participants with NSBVD reported significantly more visual fatigue, intermittent blur, headache, poor concentration, transient diplopia, and reduced reading endurance than those with normal binocular vision ($p<0.001$).

Table 4. Prevalence of Binocular Vision Dysfunctions by Screen-Time Group, n (%)

Dysfunction	Low	Moderate	High	Total
Convergence Insufficiency	3 (8.6)	7 (17.1)	16 (34.1)	26 (21.1)
Accommodative Insufficiency	2 (5.7)	6 (14.6)	14 (29.8)	22 (17.9)
Accommodative Infacility	3 (8.6)	8 (19.5)	15 (31.9)	26 (21.1)
Vergence Infacility	2 (5.7)	4 (9.8)	10 (21.3)	16 (13.0)
Fusional Vergence Dysfunction	1 (2.9)	3 (7.3)	10 (21.3)	14 (11.4)
Any NSBVD	4 (11.4)	13 (31.7)	28 (59.6)	44 (35.8)

Multiple linear regression identified daily screen time as the strongest independent predictor of binocular vision deterioration ($\beta=0.62$, $p<0.001$), with a smaller contribution from age ($\beta=0.16$, $p=0.041$); gender and refractive error were not significant ($p>0.05$). The model explained 48% of the variance (adjusted $R^2=0.48$). Each additional hour of daily screen exposure was associated with an approximate 0.48 cm increase in NPC, a 0.42 cycles/min reduction in accommodative facility, and a 0.93Δ reduction in positive fusional vergence.

DISCUSSION

This cross-sectional study demonstrates a clear, dose-dependent association between prolonged digital screen exposure and deterioration of binocular vision among healthy young adults, affecting accommodative amplitude, accommodative facility, fusional vergence, accommodative accuracy, stereoacuity, and the prevalence of non-strabismic binocular vision dysfunction[6,17].

The progressive recession of NPC with increasing screen time, and its strong correlation with screen duration ($r=0.69$), likely reflects sustained medial rectus contraction combined with continuous accommodative stimulation[4,27]. Unlike printed text, electronic displays demand frequent refocusing due to fluctuating contrast, brightness, refresh rate, and micro-saccadic movement, which may progressively exhaust vergence adaptation and precipitate convergence insufficiency[5,12].

The reduction in accommodative amplitude and, more markedly, in accommodative facility among heavy users suggests transient accommodative fatigue rather than a fixed age-related decline, consistent with continuous ciliary muscle activation and impaired relaxation during prolonged fixation at a constant distance[28]. Because accommodation and vergence are neurologically linked through the AC/A and CA/C relationships, fatigue in one system predictably affects the other, explaining the parallel decline seen across accommodative and vergence measures[13,29].

The marked reduction in positive fusional vergence, exceeding the more modest fall in negative fusional vergence, indicates that prolonged near work predominantly stresses convergence rather than divergence mechanisms, consistent with the increased convergence demand of sustained near viewing[12,15]. Diminished vergence reserve plausibly underlies the higher symptom burden—blur, diplopia, headache, and reduced reading endurance—reported by affected participants[16,30]. Increasing MEM lag with screen time further indicates reduced accommodative accuracy, while modest stereoacuity deterioration suggests subtle impairment of binocular sensory fusion secondary to accommodative-vergence fatigue[27].

The high prevalence of NSBVD among heavy users (59.6% versus 11.4% in low users), and the persistence of screen time as an independent predictor after adjustment for age, gender, and refractive error, together suggest that screen exposure itself—not merely demographic differences—drives this deterioration[20,21]. Convergence insufficiency, accommodative infacility, and accommodative insufficiency were the most common diagnoses, mirroring the combined accommodative-vergence stress expected from sustained near viewing[12,31].

These findings support incorporating comprehensive binocular vision assessment—including NPC, accommodative amplitude and facility, fusional vergence, MEM retinoscopy, and stereoacuity—into routine eye examinations for individuals with prolonged digital screen exposure, even when visual acuity and refraction are normal[10,32]. Early identification could enable timely ergonomic modification, optimized correction, structured visual hygiene (e.g., the 20-20-20 rule)[33,34], and individualized vision therapy[35,36,37], with potential benefit for occupational productivity and quality of life[38], particularly among students and digitally intensive professions[2,3].

LIMITATIONS

This study has several limitations. Its cross-sectional design precludes causal inference, since exposure and outcome were assessed simultaneously; longitudinal studies are needed to clarify progression over time[17]. The sample was limited to young adults at a single tertiary center, limiting generalizability to other age groups. Screen time was self-reported via diary and subject to recall bias; objective monitoring tools could improve accuracy in future work[39]. Device type, viewing distance, ergonomic and environmental factors, and variables such as dry eye status, stress, and sleep quality were not separately analyzed[19,40], and functional real-world outcomes (reading efficiency, productivity, quality of life) were not measured[38]. Intervention strategies were also not tested in this design.

CONCLUSION

Prolonged digital screen exposure is significantly and independently associated with deterioration of binocular vision among healthy young adults, manifesting as receded near point of convergence, reduced accommodative amplitude and facility, diminished fusional vergence reserves, increased accommodative lag, poorer stereoacuity, and a substantially higher prevalence of non-strabismic binocular vision dysfunction—most commonly convergence insufficiency and accommodative infacility/insufficiency—showing a clear dose-response relationship. Comprehensive binocular vision evaluation should be considered a routine component of eye examination in frequent digital device users, and preventive strategies such as ergonomic modification, visual hygiene practices, and individualized vision therapy may help reduce visual discomfort and preserve binocular efficiency in an increasingly digital environment.

DECLARATIONS

Ethical Approval

This study was approved by the Institutional Ethics Committee of Shree Satchandi Jankalyan Samiti and was conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

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None.

Author Contributions

Concept and design: Rajeev Trivedi. Data acquisition: Rajeev Trivedi, Partha Chowdhury. Analysis and interpretation of data: Rajeev Trivedi, Partha Chowdhury, Shyam Asal. Statistical analysis: Partha Chowdhury. Drafting of the manuscript: Rajeev Trivedi. Critical revision of the manuscript for important intellectual content: Partha Chowdhury, Shyam Asal. Administrative, technical, or supervisory support: Shyam Asal. Final approval of the manuscript: Rajeev Trivedi, Partha Chowdhury, Shyam Asal.

Conflicts of Interest

The authors declare no conflicts of interest.

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Patient Consent

Written informed consent was obtained from all study participants.

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