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Original Article

Digital Device Exposure and its Association with Refractive Error Progression and Digital Eye Strain in School-Going Children: A Longitudinal Study

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ABSTRACT

Background: The increasing use of digital devices among children has raised concerns regarding their impact on ocular health, particularly refractive error progression and digital eye strain (DES).
Objectives: To evaluate the association between digital device exposure, refractive error progression, and digital eye strain among school-going children.
Materials and Methods: This prospective longitudinal study was conducted over 8 months at PES Institute of Medical Sciences and Research. A total of 200 school-going children aged 6–16 years were enrolled. Data on digital device usage, including type and daily screen time, were collected using a structured questionnaire. Comprehensive ophthalmic examination and assessment of digital eye strain symptoms were performed at baseline and at the end of the study period. Refractive error progression was defined as a change of ≥0.50 diopters. Statistical analysis was carried out using appropriate tests, with a p-value <0.05 considered significant.
Results: Myopia was the most common refractive error at baseline. Refractive error progression was observed in 36% of participants, with a significantly higher progression rate among children using digital devices for more than 4 hours per day (p <0.001). Digital eye strain symptoms were highly prevalent, particularly eye strain and headache, and showed a strong positive association with increased screen time.
Conclusion: Prolonged digital device exposure is significantly associated with refractive error progression and digital eye strain in school-going children. Regulated screen time, early screening, and promotion of healthy visual practices are essential to reduce the risk of avoidable ocular morbidity.

Keywords*: Digital device exposure; Refractive error progression; Digital eye strain; Myopia; School-going children.*

INTRODUCTION

The rapid advancement of digital technology has led to a significant increase in the use of electronic devices such as smartphones, tablets, computers, and laptops among children and adolescents. While digital devices play an important role in education and recreation, excessive screen exposure has emerged as a growing public health concern, particularly with respect to ocular health in children [1].

Refractive errors are among the leading causes of visual impairment worldwide, with myopia showing a marked increase in prevalence over the past few decades, especially in school-going children [2]. The World Health Organisation estimates that uncorrected refractive errors account for a substantial proportion of avoidable visual disability globally [3]. Recent epidemiological studies have reported a rising trend of myopia in younger age groups, which has been attributed to lifestyle changes including increased near work, reduced outdoor activity, and prolonged digital device use [4,5].

Digital device use requires sustained accommodation, convergence, and exposure to blue light, all of which can contribute to visual discomfort and functional visual disturbances. Prolonged near work has been implicated in the

progression of myopia by inducing accommodative stress and retinal defocus [6]. Several longitudinal studies have suggested that increased screen time may be associated with faster progression of refractive errors in children, though findings remain variable across populations [7,8].

In addition to refractive changes, excessive screen exposure has been linked to Digital Eye Strain (DES), also known as computer vision syndrome. DES is characterised by a constellation of ocular and extra-ocular symptoms, including eye strain, headache, dryness, burning sensation, blurred vision, and difficulty in focusing [9]. Children may be particularly vulnerable to digital eye strain due to prolonged screen use without adequate breaks, improper viewing distance, poor posture, and lack of awareness regarding visual ergonomics [10].

With the increasing integration of digital learning platforms and recreational screen use, especially following the COVID-19 pandemic, children are spending unprecedented amounts of time on digital devices [11]. Despite this growing exposure, longitudinal data assessing the combined impact of digital device usage on refractive error progression and digital eye strain in Indian school-going children remain limited.

Therefore, the present study was undertaken to evaluate the association between digital device exposure, refractive error progression, and digital eye strain among school-going children over 8 months at a tertiary care teaching hospital. Understanding these associations is essential for developing preventive strategies, promoting healthy screen habits, and reducing the burden of avoidable visual morbidity in children.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective, longitudinal, observational study conducted over 8 months at the Department of Ophthalmology, PES Institute of Medical Sciences and Research, India.

Study Population

The study included 200 school-going children aged 6–16 years, recruited from schools affiliated with PES Institute of Medical Sciences and Research and from the ophthalmology outpatient department.

Inclusion Criteria

- School-going children aged 6–16 years
- Children with normal vision or diagnosed refractive errors
- Regular use of digital devices (smartphones, tablets, computers, or laptops)
- Willingness of parents/guardians to provide written informed consent and child assent where applicable

Exclusion Criteria

- Children with ocular pathologies other than refractive errors (e.g., cataract, glaucoma, uveitis)
- History of ocular trauma or surgery
- Presence of systemic illnesses affecting vision
- Children on medications known to influence accommodation or refraction

Sample Size

A total of 200 participants were enrolled using a convenience sampling method, considering feasibility and follow-up compliance over the study duration.

Data Collection Procedure

At baseline, detailed demographic and clinical data were collected using a pre-designed, structured questionnaire. Information recorded included age, gender, class, duration and type of digital device use, daily screen time, viewing distance, posture, breaks during screen use, outdoor activity duration, and lighting conditions.

Assessment of Digital Device Exposure

Digital device exposure was assessed based on:

- Type of device used (smartphone, tablet, computer, television)
- Average daily screen time (hours/day)
- Duration of continuous screen use without breaks
- Total months/years of device usage

Participants were categorised into exposure groups based on daily screen time:

- <2 hours/day
- 2–4 hours/day
- 4 hours/day

Ophthalmic Examination
All participants underwent a comprehensive ophthalmic evaluation at baseline and at the end of 8 months, which included:

- Measurement of visual acuity using Snellen's chart
- Objective and subjective refraction (cycloplegic refraction where indicated)
- Assessment of refractive error progression, defined as a change of ≥0.50 diopters
- Slit-lamp examination of the anterior segment
- Fundus examination using direct or indirect ophthalmoscopy

Assessment of Digital Eye Strain
Digital eye strain symptoms were assessed using a **validated questionnaire** covering symptoms such as:

- Eye strain
- Headache
- Dryness
- Burning sensation
- Blurred vision
- Redness
- Difficulty in focusing

Each symptom was graded based on frequency and severity, and a cumulative Digital Eye Strain Score was calculated.

Follow-Up
Participants were followed for a total duration of 8 months, with reassessment of refractive status and digital eye strain symptoms at the end of the study period.

Ethical Considerations
The study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Approval was obtained from the Institutional Ethics Committee of PES Institute of Medical Sciences and Research. Written informed consent was obtained from parents or guardians beforeenrollment.

Statistical Analysis
Data were entered into Microsoft Excel and analysed using SPSS software (version 26).

- Descriptive statistics were used to summarise demographic data
- Association between digital device exposure and refractive error progression was analysed using the Chi-square test and paired t-test
- Correlation between screen time and digital eye strain scores was assessed using Pearson's correlation coefficient
- A $p\text{-}value<0.05$ was considered statistically significant

RESULTS AND OBSERVATIONS
A total of 200 school-going children were enrolled and completed the 8-month follow-up. The results are presented under demographic profile, digital device exposure, refractive error progression, and digital eye strain (DES).

Table 1: Demographic Characteristics of Study Participants (n = 200)

Variable	Number (%)
Age Group (years)	
6–9	62 (31.0)
10–13	78 (39.0)
14–16	60 (30.0)
Gender	
Male	112 (56.0)
Female	88 (44.0)

The majority of participants belonged to the 10–13 years age group, with a slight male predominance.

Table 2: Pattern of Digital Device Usage Among Participants

Parameter	Number (%)
Type of Digital Device Used	
Smartphone	142 (71.0)
Tablet	24 (12.0)
Computer/Laptop	18 (9.0)
Multiple devices	16 (8.0)

Daily Screen Time	
<2 hours/day	48 (24.0)
2–4 hours/day	86 (43.0)
>4 hours/day	66 (33.0)

Smartphones were the most commonly used devices, and 76% of children had screen exposure of ≥2 hours/day.

Table 3: Baseline Refractive Status of Study Participants

Refractive Status	Number (%)
Emmetropia	78 (39.0)
Myopia	92 (46.0)
Hypermetropia	18 (9.0)
Astigmatism	12 (6.0)

Myopia was the most prevalent refractive error at baseline.

Table 4: Refractive Error Progression Over 8 Months

Refractive Error Progression	Number (%)
No progression	128 (64.0)
Progression ≥0.50 D	72 (36.0)

Refractive error progression was observed in 36% of children during the 8-month follow-up.

Table 5: Association Between Daily Screen Time and Refractive Error Progression

Daily Screen Time	Total (n)	Progression Present n (%)	No Progression n (%)	p-value
<2 hours/day	48	8 (16.7)	40 (83.3)	
2–4 hours/day	86	26 (30.2)	60 (69.8)	
>4 hours/day	66	38 (57.6)	28 (42.4)	**<0.001**

A statistically significant association was found between increased daily screen time and refractive error progression ($p< 0.001$). Children using digital devices for >4 hours/day showed the highest progression rate.

Table 6: Prevalence of Digital Eye Strain Symptoms (n = 200)

Symptom	Number (%)
Eye strain	112 (56.0)
Headache	98 (49.0)
Dry eyes	86 (43.0)
Blurred vision	74 (37.0)
Burning sensation	68 (34.0)
Redness	54 (27.0)

Eye strain and headache were the most commonly reported symptoms of digital eye strain.

Table 7: Association Between Screen Time and Digital Eye Strain

Daily Screen Time	DES Present n (%)	DES Absent n (%)	p-value
<2 hours/day	12 (25.0)	36 (75.0)	
2–4 hours/day	46 (53.5)	40 (46.5)	
>4 hours/day	54 (81.8)	12 (18.2)	**<0.001**

The prevalence of digital eye strain increased significantly with longer screen exposure, with >80% of children using screens for more than 4 hours/day reporting symptoms.

DISCUSSION

The present longitudinal study evaluated the impact of digital device exposure on refractive error progression and digital eye strain (DES) among school-going children over 8 months. The findings demonstrate a significant, dose-dependent association between increased screen time and both refractive error progression and DES, emphasising the growing burden of digital exposure on pediatric ocular health.

In this study, myopia emerged as the predominant refractive error, consistent with global and Indian epidemiological trends reporting a rapid rise in myopia prevalence among school-aged children [1,2]. The observed predominance of myopia supports the hypothesis that environmental factors, particularly increased near work and reduced outdoor exposure, play a crucial role in refractive development during childhood [3].

A key finding of the present study was that 36% of children showed refractive error progression, with significantly higher progression rates observed in those exposed to more than 4 hours of digital screen time per day. This dose-response relationship strengthens the evidence linking prolonged digital device use with refractive changes. Similar associations

have been reported in longitudinal and meta-analytical studies, where extended near-work activities were found to accelerate myopic progression in children [4,5].

The biological plausibility of this association may be explained by sustained accommodative demand, increased accommodative lag, and retinal defocus during prolonged near work, which are known to stimulate axial elongation of the eye [6]. Additionally, digital device use often involves closer viewing distances and continuous visual engagement without adequate breaks, further exacerbating accommodative stress compared to traditional reading tasks [7].

The statistically significant association between screen exposure and refractive progression observed in this study aligns with the findings of Lanca and Saw, who reported increased odds of myopia with longer durations of screen use [8]. Similarly, Lee et al. demonstrated a higher risk of refractive errors in children with excessive digital exposure, supporting the role of screen time as an independent risk factor [9].

Digital eye strain was another major outcome of the present study, with a high prevalence of symptoms such as eye strain, headache, dryness, and blurred vision. Notably, over 80% of children with screen time exceeding 4 hours per day reported DES symptoms, indicating a strong association between prolonged digital exposure and visual discomfort. These findings are consistent with previous studies identifying DES as a common and underrecognized problem in pediatric populations [10,11].

The high prevalence of DES can be attributed to multiple factors, including reduced blink rate, tear film instability, blue light exposure, and improper ergonomics during device usage [12]. Children are often unaware of visual hygiene practices and may use digital devices in suboptimal lighting conditions or improper postures, increasing their susceptibility to ocular fatigue [13].

The post-COVID-19 shift toward online education and increased recreational screen use has further amplified children's exposure to digital devices. Recent studies have reported a significant increase in screen time among children following the pandemic, accompanied by a parallel rise in myopia progression and DES symptoms [14]. These findings highlight the need for structured guidelines on safe digital device use in children.

The strengths of this study include its longitudinal design, adequate sample size, and simultaneous evaluation of refractive progression and DES. However, certain limitations should be acknowledged. Screen time was self-reported and may be subject to recall bias. Additionally, genetic predisposition, outdoor activity duration, and axial length measurements were not objectively assessed, which could further refine the understanding of refractive progression.

Despite these limitations, the study provides clinically relevant evidence that excessive digital device use is significantly associated with adverse ocular outcomes in children. Early screening, parental awareness, and implementation of preventive strategies such as regulated screen time, regular breaks, increased outdoor activities, and ergonomic education are essential to mitigate long-term visual consequences.

CONCLUSION

Excessive digital device use was significantly associated with refractive error progression and digital eye strain among school-going children. Screen time exceeding four hours per day showed a higher risk of myopic progression and visual discomfort. Early screening, regulated screen exposure, and promotion of healthy visual habits are essential to prevent avoidable ocular morbidity in children.

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