Original Article

Convergence Insufficiency and Its Associated Symptoms While Reading Text from Digital Screen and Hard Copy

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ABSTRACT

Purpose: To determine the asthenopic symptoms in patients reading text from digital devices versus hard copy.

Study Design: Cross sectional, observational study.

Pace and Duration of Study: The University of Faisalabad from August 2021 to August 2022.

Methods: Forty subjects of 20-30 years of age were included. After proper history of patient, visual acuity was checked using LogMAR chart. The patients were asked to read from digital screen for 20 minutes and convergence was recorded using RAF ruler, 10 minutes break was given and then patients were asked to read from hard copy for 20 minutes and convergence was checked. Asthenopic symptoms were assessed using self-designed questionnaire. Number of blinks per minute were also recorded for reading from digital screen and hard copy. Data was analyzed by using SPSS version 20.

Results: Mean convergence with reading from hard copy was 11.85 ± 3.690 and from soft copy was 14.33 ± 3.925 (p = 0.005). Readers from digital screen caused greater frequency of asthenopic symptoms such as headache, fatigue, eye ache, tearing, diplopia, eyestrain and red eye. Most participants demonstrated blink rates of 6–10 blinks/minute in both conditions. Low blink rates (1–5 blinks/minute) were more frequent during soft copy reading, whereas intermediate rates (11–15 blinks/minute) were more common during hard copy reading.

Conclusion: Reading from digital devices is associated with higher convergence demand and greater frequency of asthenopic symptoms compared to hard copy. Soft copy reading showed a trend toward lower blink rates, which may contribute to ocular discomfort.

Keywords: Asthenopia, convergence, eye strain.

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INTRODUCTION

Convergence is the disjugate movement of eyes. Convergence allows us to maintain a bifoveal monocular vision. Convergence insufficiency is the binocular problem leading to asthenopic symptoms and causes discomfort. Convergence insufficiency may occur because of several reasons including excessive or prolonged work. Range of convergence is a point where objects start appearing double. The normal range of convergence is 8cm, below which convergence insufficiency starts. Near point of convergence is the nearest point where objects appear as single and clear during bi-foveal fixation. Performing prolonged near work means person uses too much convergence that further imparts asthenopic symptoms because of ocular muscles fatigue.[1] Excessive use of electronic devices or digital devices cause asthenopic symptoms.[2] It also results in computer vision syndrome seen in 90 percent of

computer users and its frequency increases in individuals who spend more than four hours facing digital screen.[3] Factors which affect asthenopic symptoms while reading from hard copy and computer screen are, letter sizes, luminance, correcting refracting error, contrast, gaze angle, convergence and dry eye.[4]

Reading from digital screens or hard copy can alter convergence status over time and under varying conditions. Asthenopia, characterized by eye fatigue, headache, diplopia, blurred vision, and accommodative or visual strain, arises due to the impact of accommodation and vergence on visual function. These symptoms may be transient or persistent and can have significant economic implications, particularly among vocational computer users.[5]

With the increasing use of digital devices for reading and work, visual demands on convergence and accommodation have intensified. Prolonged digital screen exposure is associated with reduced blink rates and higher frequency of asthenopic symptoms, which may impair visual efficiency and productivity. Comparing the effects of digital versus hard copy reading on convergence status, blink rate, and related visual symptoms is essential to better understand the underlying mechanisms and to guide preventive strategies for ocular health, especially in populations with high screen use.

METHODS

This descriptive cross-sectional study was done at University of Faisalabad using non-probability convenient sampling. Forty individuals of 20-30 years of age were included. Ethical review board granted permission (**IRB number TUF/IRB/008/2021).** Duration of study was from August 2021 to August 2022. Patients with any ocular or systemic illness were excluded. Complete history and ocular examination were done. Visual acuity was checked using LogMAR chart at 4m. Patient with best corrected visual acuity of 0.2 log unit were selected. Brightness of screen and font size was adjusted before reading from hard copy and digital screen. Font size was 12, text style was Arial black and paper size was A4.The patients were asked to read from digital screen for 20 minutes and then their convergence was checked by using RAF ruler. Near point of convergence was measured using vertical line with central dot. Similarly, the patients read from hard copy for 20 minutes convergence was checked.

RESULTS

There were 40 individuals including both genders. Mean convergence with digital devices was 14.33 ± 3.925 and with hard copy was 11.85 ± 3.690. Independent sample t test was applied to check statistical significance which was p=0.05.

Convergence insufficiency was most frequent in the 11–15-year age group in both conditions (22 cases with hard copy and 26 with digital copy). In contrast, younger children (6–10 years) showed more cases with hard copy, while older participants (16–20 and 21–25 years) demonstrated higher frequencies with digital copy (Figure 1).

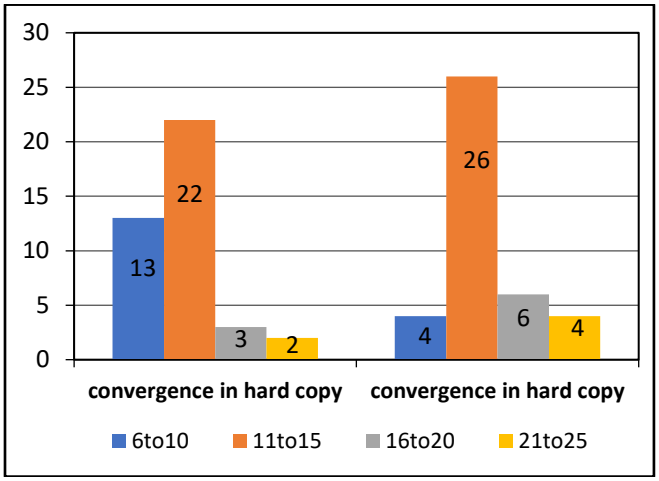

Figure 1: Age groups wise frequency of convergence insufficiency.

Asthenopic symptoms among readers from digital screen and hard copy included headache, fatigue, eye ache, tearing, diplopia, eyestrain and red eye. Out of all the symptoms headache was the most common symptom.

Blinks per minute for both readers of soft copy and hard copy were measured for different age groups. Maximum frequency was found in age group of 6-10years as this age group is school going and have more near work to perform. Most participants demonstrated blink rates of 6–10 blinks/minute in both conditions. Low blink rates (1–5 blinks/minute) were more frequent during soft copy reading, whereas intermediate rates (11–15 blinks/minute) were more common during hard copy reading. Very high blink rates (≥16 blinks/minute) were uncommon in both groups.

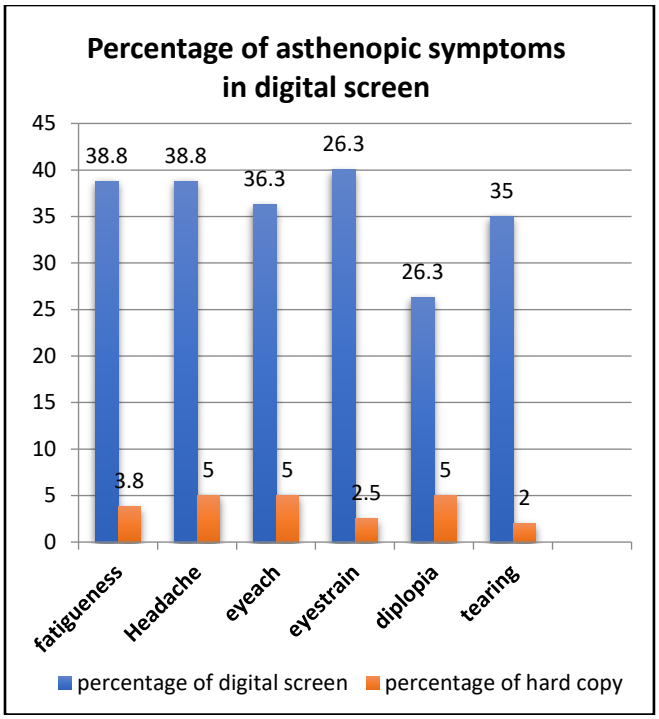

Figure 2: Percentage of asthenopic symptoms after using digital screen and hard copy.

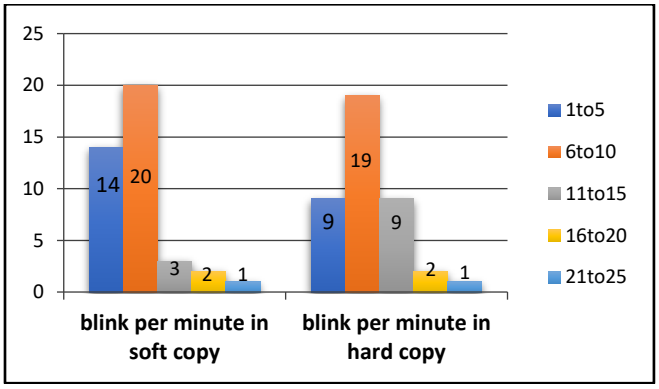

Figure 3: Distribution of blink rates per minute while reading soft copy (on screen) and hard copy (printed text).

DISCUSSION

The results of our study showed that reading from digital screens caused more problems with convergence and asthenopia. Comparable results were reported by another study which showed that there were greater convergence issues while reading from digital screens (t=147.0, p=0.003) compared to hard copy (t=102.5, p=0.04). Symptoms such as blurred vision, tearing, and itching were more frequent with screen use, highlighting computer vision syndrome as a major complication in continuous near work.[6]

This study revealed that percentages of asthenopic symptoms in digital devices were more as compared to hard copy. Another study reported that while paper still holds an advantage for shallow-level comprehension over computers, tablets show comparable performance to paper. Crucially, user familiarity with tablets significantly enhances deep-level reading comprehension, highlighting the importance of training and adaptation to new digital reading devices.[7]Pillay and Munsamy explored the prevalence of convergence insufficiency among younger populations, particularly in the context of increased e-device usage during the digital era.[8] The findings indicate a significant prevalence of CI, ranging from 5.46% to 32.60% in various studies, with a notable increase among school-aged children due to heightened screen time associated with e-learning and other digital activities.[8] The research by Yammouni and Evans investigates the influence of binocular and accommodative anomalies on reading rates in individuals experiencing digital eyestrain (DES).[9] The findings suggest that these anomalies significantly affect visual comfort and performance during digital tasks. Slightly different results were presented by other studies which showed that accommodation and vergence responses to electronic screens seemed comparable to those observed with printed materials, while dry eye symptoms were more common during computer use. This was likely related to reduced blink rate and amplitude, as well as increased corneal exposure due to monitors often being positioned at primary gaze.[10,11]

Up to 90% of individuals using digital devices report symptoms of digital eye strain. Research indicates that several factors contribute to this condition, including uncorrected refractive errors (such as presbyopia), accommodative and vergence disorders, reduced or incomplete blinking, prolonged exposure to bright light, shorter viewing distances, and the use of small font sizes.[12-14]

A lot of research was conducted during the COVID-19 due to excessive use of digital screens by children. Several studies were undertaken in central India under the research project titled *Digital Eye Strain among Kids (DESK)* to evaluate eye strain associated with prolonged online classes. The DESK-3 study specifically aimed to report a series of cases of acute acquired comitant esotropia in children attending online classes during the COVID-19 pandemic.[15-17]

The main factors contributing to its higher

prevalence of convergence insufficiency and asthenopic symptoms include duration of exposure, age, female sex, and occupational setting.[18-20] Its pathophysiology remains poorly understood but is considered multifactorial, involving disruptions in the accommodation-convergence relationship as well as alterations of the ocular surface.

This strengths of study are that it directly compared visual performance and asthenopic symptoms during both digital screen and hard copy reading within the same individuals, reducing inter-subject variability. The standardized reading distance and identical reading material minimized confounding related to task difficulty. Use of objective measures such as convergence with the RAF ruler and blink rate monitoring provided quantitative data in addition to subjective symptom assessment.

The limitations include small sample size (n=40) and limited to young adults (20–30 years), which restricts the generalizability of the findings to other age groups. The cross-sectional design only allowed assessment of short-term effects of reading tasks, without evaluation of long-term ocular consequences. The use of a self-designed questionnaire for asthenopic symptoms, though practical, may not have the same validity and reliability as standardized symptom surveys. Finally, other potential confounders such as ambient lighting, screen resolution, and individual tear film status were not fully controlled, which could have influenced the results.

CONCLUSION

The study concludes that there is more convergence insufficiency while reading text from digital screen than the hard copy. Patients with remote near point of convergence face convergence insufficiency and asthenopic symptoms like eye strain, fatigue, headache, eye ache, tearing and diplopia.

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Patient's Consent: Researchers followed the guidelines set forth in the Declaration of Helsinki.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(TUF/IRB/008/2021)**.

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