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ORIGINAL ARTICLE

Emerging Ophthalmic Complications regarding Digital Eye Strain, Diabetic Retinopathy, and Refractive Errors. A Clinical Study

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ABSTRACT

Objective: To assess the relation of digital device usage, diabetic retinopathy, and refractive error as well as the predictors of severe digital eye strain (DES) in a clinical population.

Methods: Sixty patients (mean age 41.3 ± 10.2 years; 46.7% male, 53.3% female) were subjected to comprehensive ocular examination including visual acuity, refractometry, slit lamp bio-microscopy and fundus photography. A validated questionnaire was used to assess digital device usage, and glycemic control was assessed in the diabetic patients. Independent predictors of severe DES were identified by multivariate logistic regression.

Results: 70% of patients used digital devices for more than 4 hours per day, and 65% had DES symptoms. Diabetes was present in 33.3% of the cohort, and 60% of diabetics had poor glycemic control (HbA1c >8.0%). Of these patients, 75% had refractive errors, including 55% myopia. Multivariate analysis confirmed digital device usage longer than 4 hours a day (OR = 2.9; 95% CI: 1.2–7.0; p = 0.016) and poor glycemic control (OR = 3.2; 95% CI: 1.1–9.3; p = 0.031) as independent significant predictors of severe DES with female gender and myopia marginally significant.

Conclusion: Prolonged digital device exposure and poor glycemic control are strongly associated with severe DES, advanced diabetic retinopathy, and myopic progression. In the digital era, ocular health will depend on integrated strategies of digital hygiene and optimal metabolic management.

Keywords: Digital Eye Strain; Diabetic Retinopathy; Refractive Errors; Myopia; Digital Device Usage; Glycemic Control; Ocular Health; Digital Hygiene

INTRODUCTION

With the advent of the digital age, there has been no turning back, as the way people are working, communicating, and entertaining themselves has changed so drastically that the increase in screen-based activities has become unprecedented. While this digital transformation has facilitated more connectivity and productivity, it has also introduced a spectrum of ocular challenges that need to be investigated at a clinical level [1]. One of these, digital eye strain (DES), has gained traction as a common condition encompassing a panoply of symptoms such as eye discomfort, dryness, blur, and headaches that are due to prolonged screen use. The ubiquity of digital devices in modern life necessitates an in-depth understanding of DES, its underlying mechanisms, and its potential long-term implications on visual function [2].

Diabetic retinopathy is, however, a major public health problem as a leading cause of vision impairment and blindness globally. Lifestyle changes and the aging population have led to an increased burden of diabetic retinopathy due to the rise in the global type 2 diabetes. The retinal microvascular damage associated with diabetic retinopathy is directly related to the duration and severity of hyperglycemia, and poor glycemic control is a major prognostic indicator for the progression of retinal pathology[3]. Studies in recent years have emphasized the significance of early detection and tight metabolic control for the slowing of the progression of diabetic retinopathy; yet the role of digital behavior and retinal health remains a topic of active research[4].

The parallel issues of the growing prevalence of refractive errors, particularly myopia, are also evidenced by a shorter onset and faster progression to myopia in younger populations, the current trends suggest[5]. It has been implicated that prolonged near work, particularly in the form of long digital screen usage, plays a role in the etiopathogenesis of myopic progression. Sustained accommodative stress and decreased outdoor activity are emerging evidence for the global myopia epidemic. Digital eye strain, diabetic retinal complications, and refractive error progression are all convergent issues that exist in the metabolic as well as the environmental domain[6].

These conditions are complex and multifactorial, and their interrelationship is complex. On the one hand, digital eye strain is mainly viewed as a functional disorder associated with ocular surface irritation and accommodative fatigue[7]. Diabetic retinopathy, on the other hand, is a disease of structural retinal damage caused by systemic metabolic dysregulation. Although the etiologies of these two conditions vary, there has been an increasing interest in knowing if digital exposure could further exacerbate the microvascular stress in diabetic patients and, thus, accelerate retinal degeneration. Likewise, such a near focused work in the repetitive manner as found in the use of digital devices may not only result in transient fluctuations of refractive power but may also lead to permanent myopic shifts[8].

Thus, this study aimed to bridge these converging areas by investigating the prevalence and severity of digital eye strain in a diverse patient population, determining the relationship between digital device usage and the progression of refractive errors and the synergistic effect of digital eye exposure on diabetic retinopathy [9, 10]. The study adopts a multidisciplinary approach of clinical ophthalmology, digital ergonomics, and systemic metabolic control to delineate environmental and systemic factors contributing to ocular health in the changing landscape[11].

These conditions have been the subject of the current literature in isolation. Nevertheless, an overview of the total influence of modern digital lifestyles on ocular structures and function is needed. The importance of understanding these interactions becomes ever more critical as these digital devices become further entrenched in daily routines for the development of targeted preventive strategies and clinical guidelines[12]. Therefore, objective of study is to offer an overall evaluation of how digital exposure, in conjunction with systemic conditions such as diabetes, affects the course of ocular health to advise clinical practice and public health policy[13].

MATERIALS AND METHODS

Study Design and Participants: A 12-month cross sectional study was carried out at the Department of Ophthalmology at Ayub Teaching Hospital Abbottabad and Department of Ophthalmology, Ghulam Mohammad Mahar Medical College Sukkur. The study

aimed to determine the relationship between digital eye strain, diabetic retinopathy, and refractive errors in a clinical setting.n=60 consecutive patients aged 18 to 65 years were consecutively recruited during routine ophthalmic evaluations. This sample size was chosen to provide sufficient statistical power to find significant associations while being small enough to permit a focused clinical investigation. The study was approved by the Institutional Review Board and was performed by the Declaration of Helsinki. Before inclusion, all the participants had given their informed consent.

Inclusion and Exclusion Criteria: Patients were included if they were between 18 and 65 years old, used digital devices for at least 2 hours per day, and completed the standardized digital device usage questionnaire. Exclusion criteria were ocular diseases unrelated to the study (e.g., glaucoma, uveitis) with any ocular surgery performed during the past 6 months and incomplete clinical or questionnaire data. Patients with systemic conditions that might complicate the ocular findings, especially those with diabetes, were excluded, except for those with diabetes specifically evaluated for diabetic retinopathy.

Data Collection: A complete ocular examination was performed for each participant. A standardized Snellen chart was used to determine visual acuity, followed by automated refractometry and subjective refinement of refractive errors to achieve an accurate determination. Slit lamp biomicroscopy was used to perform an anterior segment examination. Fundus photography on all patients was performed for the evaluation of the posterior segment, and OCT was done, especially in diabetic patients when retinal pathology was suspected.

The questionnaire that was used to quantify digital device usage documented the average daily screen time, the types of devices used (e.g., smartphones, tablets, computers), and patterns of usage, including how frequent breaks occur and how long there is continuous exposure. In addition, patients diagnosed with diabetes had their systemic data recorded, including the duration of diabetes, the current medication regimen, and recent glycemic control based on HbA1c levels.

Statistical Analysis: The data were analyzed using SPSS version 26.0. Demographic and clinical characteristics of the study population were summarized by descriptive statistics. Independent t-tests were performed on continuous variables, and chi-square tests were performed on categorical variables. We constructed multivariate logistic regression models of independent predictors of digital eye strain severity, progression of diabetic retinopathy, and refractive error changes. Statistically significant results were obtained with a p-value of less than 0.05.

RESULTS

Twenty-eight (46.7%) were male, and 32 (53.3%) were female, and the mean age of all patients enrolled was 41.3 ± 10.2 years. Forty-two of 42 patients (70) utilized digital devices for more than 4 hours per day, and 39 patients (65) had symptoms consistent with digital eye strain (DES). Among the participants, 20 patients (33.3%) had diabetes, and 12 of them (60.0% of diabetics) had poor glycemic control (HbA1c > 8.0%). Thus, in 45 patients (75%), there were refractive errors, of which myopia was the most prevalent (33 patients, 55%). The baseline characteristics for these are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics (n = 60).

Variable	Value
Age (years, mean ± SD)	41.3 ± 10.2
Gender (Male/Female)	28 (46.7%) / 32 (53.3%)
Digital device usage >4 hrs/day	42 (70%)
Digital eye strain symptoms	39 (65%)
Diabetic patients	20 (33.3%)
HbA1c >8.0 (among diabetics)	12 (60% of diabetics)
Refractive errors present	45 (75%)
Myopia	33 (55%)

Stratification of patients was carried out further based on digital device use (≥4 hours per day vs <4 hours per day). Compared to the low exposure group (mean score 2.4 ± 0.8), patients in the high digital exposure group (3.5 ± 1.0; $p < 0.01$) had significantly higher DES severity scores. Furthermore, within the diabetic subgroup, higher digital exposure was associated with more advanced diabetic retinopathy (50% in high exposure group versus 20% in low exposure group, $p = 0.03$), and myopic progression was also more common (52% in high exposure group versus 28% in low exposure group, $p = 0.04$). Table 2 details these associations.

Table 2: Ophthalmic Findings by Digital Device Usage.

Variable	≥4 hrs/day (n = 42)	<4 hrs/day (n = 18)	p-value
DES severity score (mean ± SD)	3.5 ± 1.0	2.4 ± 0.8	<0.01
Advanced diabetic retinopathy (% among diabetics)	50%	20%	0.03
Myopic progression (n, %)	22 (52%)	5 (28%)	0.04

A multivariate logistic regression model was further constructed to investigate the independent predictors of severe digital eye strain (DES Severity Score > median) that included digital device usage (>4 hours/day), diabetes with poor glycemic control (HbA1c >8.0), female versus male gender, and myopia. Overall, a threefold increased risk of severe DES was demonstrated by the model (OR = 2.9, 95% CI: 1.2–7.0; $p = 0.016$) linked to prolonged digital device use. Likewise, diabetes with high HbA1c was significantly predictive (OR = 3.2; 95% CI: 1.1–9.3; $p = 0.031$). Female gender was associated with a higher odds of severe DES (OR = 2.1, 95% CI: 0.9–5.0), but did not meet conventional statistical significance ($p = 0.081$). In addition, myopia was a marginally significant independent predictor (OR = 2.3; 95% CI: 1.0–5.4; $p = 0.049$). Table 3 shows the summary of the regression analysis.

Table 3: Multivariate Logistic Regression for Predictors of Severe Digital Eye Strain.

Predictor	Odds Ratio (95% CI)	p-value
Digital device usage >4 hrs/day	2.9 (1.2–7.0)	0.016
Diabetes (HbA1c >8.0)	3.2 (1.1–9.3)	0.031
Gender (Female)	2.1 (0.9–5.0)	0.081
Myopia	2.3 (1.0–5.4)	0.049

These results suggest that robust independent predictors of severe digital eye strain include prolonged digital device exposure and poor glycemic control in diabetic patients. In addition, the findings also showed that there was no statistical significance associated with the gender (female) and the associated severity of DES in this cohort; however, the myopia was still a marginally significant factor. In general, the integration of these factors in the multivariate model highlights the intricate interplay between lifestyle and systemic factors in shaping ocular health outcomes.

DISCUSSION

Evidence that excessive digital device usage (more than 4 hours per day) is strongly linked to DES severity is provided in this study. Patients with higher screen time also experience more ocular discomfort, visual disturbances, and prevalence of advanced diabetic retinopathy and myopic progression[14]. This finding is consistent with previous literature indicating that digital screen exposure can increase ocular surface stress and lead to accommodative dysfunction. The multivariate logistic regression analysis in our cohort also revealed that poor glycemic control in diabetic patients (HbA1c>8.0) further compounds the risk of severe DES, suggesting that systemic metabolic management plays an important role in preventing ocular complications[15].

Environmental factors, including digital device usage and systemic conditions such as diabetes, are highlighted as factors

that also play a role in ocular health and necessitate a holistic approach. While female gender had a tendency toward higher odds of DES (OR = 2.1) and there may be gender related differences in symptom reporting, the association between gender and the severity of DES did not reach statistical significance, such that while gender differences may exist in symptom reporting, they are not a substantial driver of severity of DES in this sample[16]. In addition, myopia was marginally significant as an independent predictor, suggesting that preexisting refractive errors may predispose people to more severe symptoms under high digital exposure. These observations indicate that despite the lifestyle factors, as well as underlying ocular characteristics, the overall risk of development of severe digital eye strain is determined [17].

Our results suggest that incorporation of such digital hygiene practices as limiting continuous screen time and regularly taking breaks constitutes routine ocular care. Furthermore, for diabetic patients, optimal glycemic control is considered to be a key strategy in preventing exacerbation of ocular complications[18]. This study presents results urging targeted patient education and clinical management protocols aiming to preserve visual function in the setting of modern digital lifestyles that include both digital exposure and metabolic health[19].

CONCLUSION

The study concludes with the multifactorial nature of digital eye strain and its close relation to both digital device usage and systemic health factors. Exposure to the digital environment leading to prolonged time is associated with increased severity of DES and adverse ocular outcomes such as advanced diabetic retinopathy and myopic progression. These effects are further exacerbated by poor glycemic control, emphasizing the importance of rigorous metabolic management in diabetic people. Potential risk factors were female gender and myopia, which were associated either not statistically significant or only marginally so. These insights highlight the necessity of the adoption of combined clinical and public health strategies such as digital hygiene, regular ophthalmic evaluations, and optimal glycemic control to reduce the risks of prolonged digital exposure and to maintain overall ocular health in such a digital world.

Conflict of Interest: The authors affirm that they have no conflict of interests that could have influenced this work.

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