Ophthalmology Research: An International Journal

Volume 19, Issue 6, Page 35-52, 2024; Article no.OR.126714
ISSN: 2321-7227

Assessing Retinal Function Alterations Due to Digital Device Use: A Study of Computer Vision Syndrome in Medical Students

Mohammed Iqbal [a++*], Bishoy Fahim [b], Sandra Emad [b], Shaimaa Fadel [c], Noha SalahEldeen [d], Fathy Gad [e], Somya Zein [f] and Mervat Elgharieb [g,h]

[a] Department of Ophthalmology, Faculty of Medicine, Sohag University, Sohag, Egypt.
[b] Faculty of Medicine, Sohag University, Sohag, Egypt.
[c] Medical Genetics Unit, Faculty of Medicine, Suez Canal University, Ismailia, Egypt.
[d] Faculty of Medicine, Menoufia University, Menoufia, Egypt.
[e] Faculty of Medicine, Cairo University, Cairo, Egypt.
[f] Faculty of Medicine, Minia University, Minia, Egypt.
[g] Department of Ophthalmology, Faculty of Medicine, Suez Canal University, Ismailia, Egypt.
[h] Department of Ophthalmology, King Salman International University, El-Tor, Egypt.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/or/2024/v19i6443

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/126714

Original Research Article

Received: 13/09/2024
Accepted: 15/11/2024
Published: 21/11/2024

[++] Professor of Ophthalmology;
**Corresponding author: E-mail: dr_m_iqbal@yahoo.com, mohamed_ahmed12@med.sohag.edu.eg;*

Cite as: *Iqbal, Mohammed, Bishoy Fahim, Sandra Emad, Shaimaa Fadel, Noha SalahEldeen, Fathy Gad, Somya Zein, and Mervat Elgharieb. 2024. "Assessing Retinal Function Alterations Due to Digital Device Use: A Study of Computer Vision Syndrome in Medical Students". Ophthalmology Research: An International Journal 19 (6):35-52. https://doi.org/10.9734/or/2024/v19i6443.*

ABSTRACT

Digital devices, mainly smartphone with its time-consuming applications and 24/7 internet connection, are accused of the being the main cause of severe distraction and excessive disruptions with fragmentation of everyday life that adversely interrupts the adults and youth lifestyles, health, education and social or family relationships. The medical students underwent objective ophthalmic examination to confirm or exclude CVS diagnosis based on Iqbal's four major criteria for accurate CVS diagnosis. Screen-induced foveal dysfunction (SFD) has been recorded using the multifocal electroretinogram to prove the retinal function alterations due to excessive digital device use. Based on our outcomes, we have defined the term screen-induced foveal dysfunction (SFD) as "the multifocal electroretinogram reduced foveal responses below standard normal ranges that are mostly temporary, reversible and usually associated with reduced visual acuities and performances in computer vision syndrome positive-cases". SFD is characterized by temporary impermanent reduced foveal responses that associates reduced visual acuities and performances in CVS positive-cases. Strict reduction or cessation of exposure to digital screens and/or electronic devices that contains light emitting diodes (LEDs) for 4 weeks results in spontaneous resolution of cone adaptation/saturation thus eventually the retina regains its normal foveal functions and responses with normal visual acuities and performances. Iqbal's instructions are helpful in reducing the medical students' screen-time to reverse the SFD thus improving the foveal responses in CVS positive-cases. It is recommended that the screen-time not exceed 3 hours daily to avoid the visual impacts and sequelae of the digital environment.

Keywords: Blue light; computer vision syndrome; digital eye strain; multifocal electroretinogram; screen-induced foveal dysfunction; digital environment and digital screens.

1. INTRODUCTION

The innovative digital technology has occupied an enormous time of the individuals' daily activities and dramatically affected the modern lifestyle (Wolffsohn et al. 2023, Christian et al. 2023, Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). The digital environment means watching and interacting with several types of digital devices for extended periods through the entire day (Wolffsohn et al. 2023, Christian et al. 2023). The average screen-time in the digital environments reaches up to eight hours daily for the American adult interacting with ≥10 different types of digital screens (Statista 2020, Statista 2022). Within the digital environments, the routine exposure to various digital devices and electronic screens for several daily screen-hours has elicited various visual, ocular surface and extraocular symptoms and complaints known as the computer vision syndrome (CVS) or digital eye strain (DES) (Wolffsohn et al. 2023, Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). The American Optometric Association (AOA) defined the computer vision syndrome (CVS) as follows "Computer vision syndrome, also referred to as digital eye strain, describes a group of eye- and vision-related problems that result from prolonged computer, tablet, e-reader and cell phone use" (American 2023). Meanwhile, the Tear Film & Ocular Surface Society (TFOS) considered DES as a more appropriate and specific tem than CVS and further redefined DES as "the development or exacerbation of recurrent ocular symptoms and/or signs related specifically to digital device screen viewing" (Wolffsohn et al. 2023). CVS is a multifactorial syndrome that affects more than one human system and its sequelae extend beyond the eye (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

The CVS main visual symptoms are visual blur, eye strain/fatigue, seeing unclear objects post-screen use, glare/seeing halos of light around objects, feeling diminution of vision, double vision/diplopia, difficulty in refocusing the eyes, near vision discomfort/difficulty and increased sensitivity to light (Wolffsohn et al. 2023, Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023)., American 2023, Iqbal et al. 2022, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Cougnard-Gregoire et al. 2023, Touitou and Point 2020, Iqbal et al. 2018, Eni and Uahomo 2024, Iqbal et al. 2024). The CVS main ocular surface symptoms are dry eye, eye redness, itching/eye rubbing, watery eye, eye irritation/discomfort, foreign body sensation, burning sensation, heavy eyelids and frequent blinking (American 2023, Iqbal et al. 2022, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Cougnard-Gregoire et al. 2023, Touitou and Point 2020, Iqbal et al. 2018, Eni

and Uahomo 2024, Iqbal et al. 2024). The CVS main extraocular symptoms are headache, neck/shoulder/back pain, joint pain in fingers and wrists, inability to hold objects well, difficulty to write using a pen, sleep disturbances/insomnia and inattention (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023, Iqbal et al. 2022, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Cougnard-Gregoire et al. 2023, Touitou and Point 2020, Iqbal et al. 2018, Eni and Uahomo 2024, Iqbal et al. 2024). Other serious manifestations; mainly behavioral and mental health issues, such as depression, stress, anxiety, tendency to suicide and midnight hunger with weight gain have also been linked to CVS sequelae (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023, Iqbal et al. 2022, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2023, Cougnard-Gregoire et al. 2023, Touitou and Point 2020, Iqbal et al. 2018, Eni and Uahomo 2024, Iqbal et al. 2024, Merhy et al. 2023, Twenge et al. 2018, Park et al. 2019, Petrowski et al. 2021). However, both CVS visual and ocular surface symptoms could be attributed to accommodation disturbances, dry eye disease (DED), binocular vision dysfunction and contact lens wearing (Wolffsohn et al. 2023, (Iqbal et al. 2021, Iqbal et al. 2021).

Digital devices, mainly smartphone with its time-consuming applications and 24/7 internet connection, have been implicated as being the main cause of severe distraction and excessive disruptions with fragmentation of everyday life that adversely interrupts the adults and youth lifestyles, health, education and social or family relationships (Iqbal et al. 2021, Iqbal et al. 2021, Rozgonjuk et al. 2020). Therefore, such subjects may encounter serious troubles in their lives such as low productivity, poor creativity and weak academic performance Iqbal et al. 2021, Rozgonjuk et al. 2020). However, it seems that the problem is not in the digital device or the smartphone itself, but the way people handle it and misuse it. In other words, digital devices are not responsible for exacerbation of CVS but the way and manner it is been used is the actual problem (Christian et al. 2023, Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). The main risk factors and incorrect practices of the individuals' screen-styles are improper or too close eye-screen distance, screen edge at/above horizontal eye level, improper gaze angle (e.g. when lying down or in beds), improper or poor lighting conditions, screen- glare, poor screen- resolution or design, uncomfortable seating postures, watching screen in the dark, small screen-size, excessive screen brightness, small-font size, texting with both thumbs, prolonged screen-hours (average daily screen-hours exceeds five hours) and associated uncorrected refractive errors (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). These risk factors constitute the digital screen or smartphone misuse or abuse practices that are responsible for development, exacerbation and aggravation of CVS (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

2. METHODS

This study obtained the approval of the Institutional Review Board (IRB) in Faculty of Medicine, Sohag University, Egypt. This study was conducted in accordance with the tenets of the Declaration of Helsinki. Our study protocol included subjective information (CVS-F3 questionnaire; Appendix 1) and an objective ophthalmic examination of medical students. Prior to study enrolment, informed consent was obtained from these students after explanation of the nature and possible consequences of the study. Using an alpha level of 0.01 and the survey sample size determination table created by (Bartlett et al. 2021) we determined that the minimum sample size required for this study was 623 participants.

In the three published studies by (Iqbal et al. 2024) all medical students responded to the subjective valid and reliable computer vision syndrome form-3 (CVS-F3; Appendix 1) questionnaire (.742 Cronbach's alpha reliability coefficient, .773 Guttman Split-Half Coefficient and 82% construct validity rate with the Pearson's correlation validity coefficient) that was designed to be ideal for University students (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

Thereafter, the medical students underwent complete objective ophthalmic examination to confirm or exclude CVS diagnosis based on Iqbal's four major criteria for accurate CVS diagnosis (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). The complete ophthalmic examination included both uncorrected and corrected distance visual acuities (UDVA and CDVA; respectively) measurements, testing pupillary reflexes, DED tests, intraocular pressure measurement, subjective and cycloplegic refraction measurements, slit-lamp and dilated fundus examinations (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). The exclusion criteria were amblyopia, strabismus,

accommodation-convergence imbalance, near vision abnormalities, an isometropia greater than 2 diopters (D), myopia >6 D, hyperopia >4 D, astigmatism >4 D, eye or retinal pathology, current eye or systemic diseases and previous eye or systemic surgeries (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

Furthermore, the medical students underwent multifocal electroretinogram (mfERG) examination. We used the mfERG device (RETIscan; Roland Instruments, Wiesbaden, Germany) in accordance with the standard protocol for mfERG of the International Society for Clinical Electrophysiology of Vision (ISCEV). The mfERG stimulus used in our studies was 61 hexagons in dilated subjects with system age-matched norms. The protocol adhered to ISCEV standards and our cut-off values were the normal ranges provided by the ISCEV standard protocol. Eventually, we documented the first foveal peak and amplitude density (P1 AD) in all the mfERG Rings and Quadrants.

2.1 Statistical Analysis

Data was analyzed using STATA version 14.2 (Stata Statistical Software: Release 14.2 College Station, TX: StataCorp LP.). Quantitative data was represented as mean, standard deviation, median and range. As the data was not normally distributed Kruskal Wallis test for comparison of three or more groups and Mann-Whitney test was used to compare two groups. Qualitative data was presented as number and percentage and compared using Chi square test for trend, Chi square test or fisher exact test.

Binary logistic regression analysis was used to find factors affecting occurrence of CVS and linear regression analysis was used to find actors affecting the number of symptoms of CVS. Graphs were produced by using Excel or STATA program. P value was considered significant if it was less than 0.05.

3. RESULTS

3.1 CVS Prevalence

We recorded 55.98% CVS prevalence rate among the medical students (Iqbal et al. 2021). The CVS diagnosis was based on Iqbal's four major criteria for accurate CVS diagnosis (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

Fig. 1 shows comparison between males and females as regards CVS-complaints. Fig. 2 shows the distribution of studied students according to their CVS-complaints. Fig. 3 shows the association between CVS-complaints and type of the commonest screen used. Fig. 4 shows the association between CVS-complaints and how students studied medicine.

3.2 CVS-F3 Logistic Regression Analyses

Tables 1, 2 and 3 summarize the multivariate logistic regression analyses of factors affecting occurrence of CVS, blurred vision and dry eye; respectively.

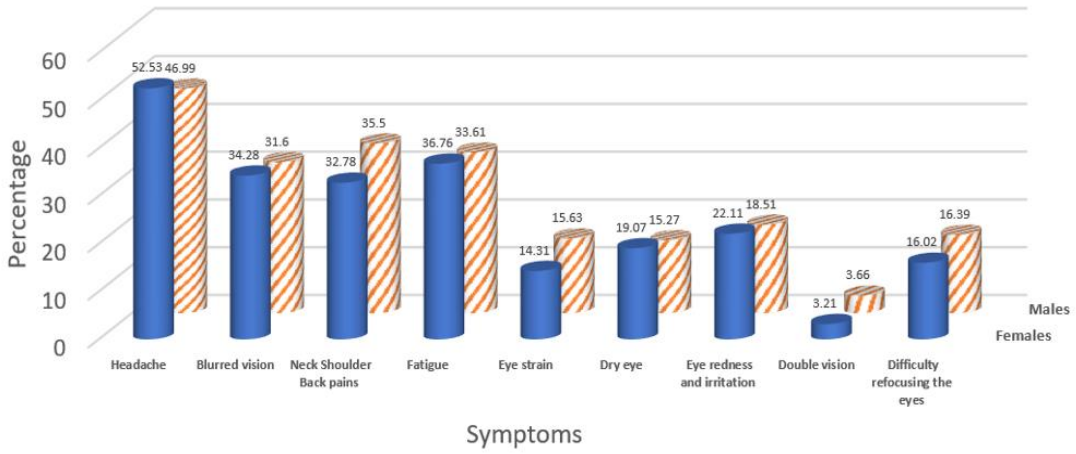

Fig. 1. Comparison between males and females as regards CVS-complaints

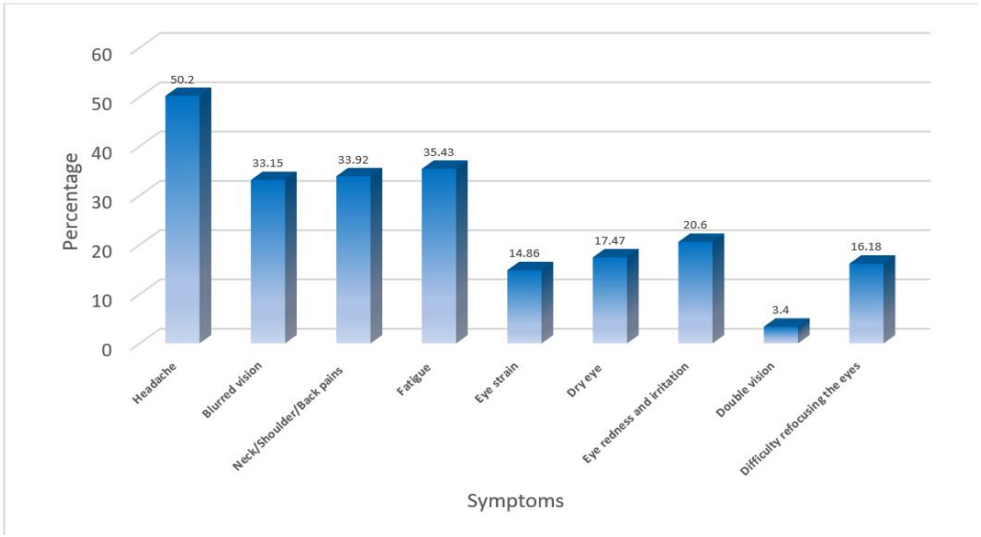

Fig. 2. The distribution of studied students according to their CVS-complaints

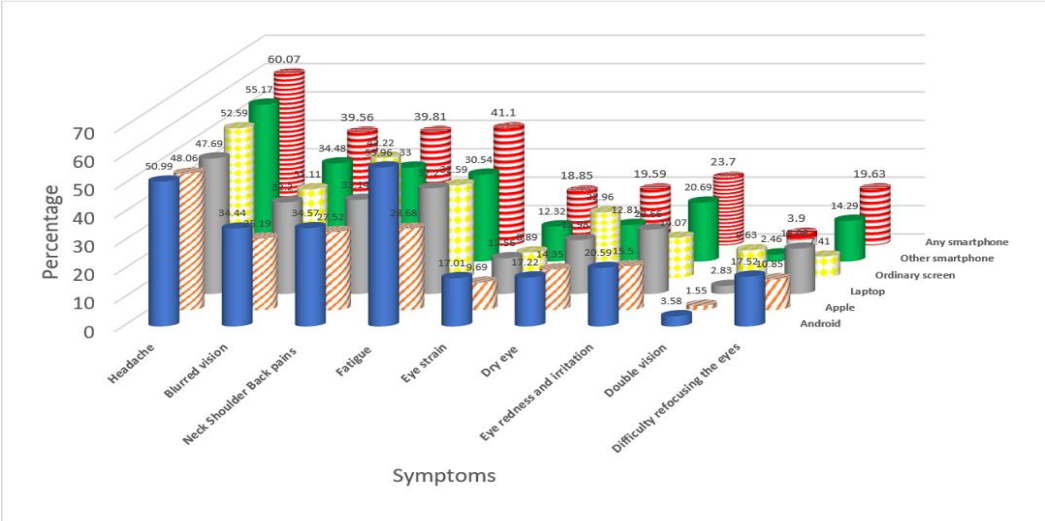

Fig. 3. The association between CVS-complaints and type of the commonest screen used

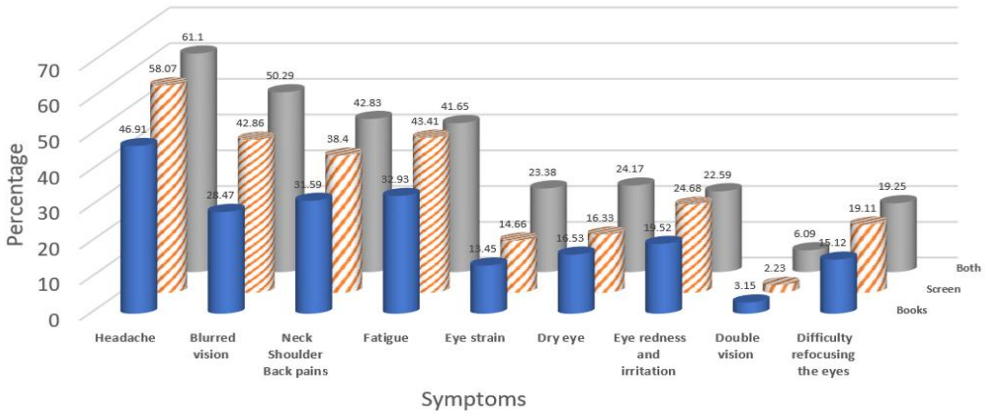

Fig. 4. The association between CVS-complaints and how students studied medicine

Table 1. Multivariate logistic regression analysis of factors affecting occurrence of CVS

Variable	Odds ratio (95% confidence interval)	P value
Gender		
Males	1	
Females	1.25 (1.05:1.51)	0.01
What are the digital screens you commonly use?		
Apple	1	
Android	1.24 (0.87:1.76)	0.23
Laptop	1.07 (0.74:1.56)	0.72
Ordinary	1.59 (0.88:2.88)	0.13
Other smartphone	1.35 (0.79:2.27)	0.27
How many hours do you spend on your digital screen?		
1 hour	1	
2 hours	1.02 (0.69-1.52)	0.91
3 hours	2.57 (1.70-3.87)	<0.0001
4 hours	1.62 (1.09-2.40)	0.02
5 hours	3.42 (2.19-5.35)	<0.0001
≥ 6 hours	2.96 (1.88-4.66)	<0.0001
How many hours you spend watching your screen in the dark?		
1 hour	1	
2 hours	0.97 (0.78-1.21)	0.80
3 hours	1.78 (1.22-2.60)	0.003
4 hours	1.68 (1.01-2.78)	0.04
5 hours	5.20 (1.62-16.72)	0.006
≥ 6 hours	3.80 (0.89-16.11)	0.07
To what level do you illuminate your digital screen (i.e., brightness) in a lit room?		
10%	1	
30%	1.85 (1.41-2.45)	<0.0001
50%	1.90 (1.45-2.47)	<0.0001
80%	1.97 (1.43-2.70)	<0.0001
100%	1.92 (1.35-2.72)	<0.0001
The hours you spend on your digital screen are:		
Interrupted	1	
Continued	1.05 (0.81-1.37)	0.69
How many years have you spent using screens in this manner:		
1 years	1	
2 years	1.33 (0.90-1.96)	0.15
3 years	1.68 (1.16-2.44)	0.006
4 years	3.32 (2.22-4.94)	<0.0001
≥ 5 years	1.79 (1.23-2.62)	0.002
Do you usually study medicine using:		
Book	1	
Screen	3.04 (2.06-4.50)	<0.0001
Both	1.81 (1.34-2.45)	<0.0001

3.3 Ophthalmic Examination and MfERG Outcomes

Table 4 summarizes the outcomes of the CVS versus control groups. Tale 5 shows the mfERG findings before and 4 weeks after reduction of screen-hours in the CVS group while Table 6 shows the correlation between the differences of screen-hours/day and the differences of mfERG parameters.

Table 2. Final multivariate logistic regression analysis of factors affecting occurrence of blurred vision

Variable	Odds ratio (95% confidence interval)	P value
Gender		
Males	1	
Females	1.22 (1.05-1.42)	0.009
What are the digital screens you commonly use? (Please select one or more answers):		
Apple	1	
Android	1.53 (1.11-2.11)	0.009
Laptop	1.32 (0.94-1.87)	0.11
Ordinary	2.04 (1.23-3.41)	0.006
Other smartphone	2.04 (1.31-3.19)	0.002
How many hours do you spend on your digital screen?	1	
1 hour	1.05 (0.68-1.60)	0.83
2 hours	0.86 (0.57-1.30)	0.47
3 hours	1.24 (0.83-1.85)	0.30
4 hours	1.60 (1.06-2.42)	0.03
5 hours	6.64 (4.40-10.04)	<0.0001
≥ 6 hours		
How many hours you spend watching your screen in the dark?		
1 hour	1	
2 hours	1.54 (1.29-1.84)	<0.0001
3 hours	1.76 (1.38-2.25)	<0.0001
4 hours	1.52 (1.11-2.07)	0.009
5 hours	1.92 (1.27-2.91)	0.002
≥ 6 hours	2.15 (1.14-4.06)	0.02
To what level do you illuminate your digital screen (i.e., brightness) in a lit room?		
10%	1	
30%	1.86 (1.44-2.39)	<0.0001
50%	1.51 (1.18-1.93)	0.001
80%	2.40 (1.82-3.16)	<0.0001
100%	2.20 (1.64-2.94)	<0.0001
Do you spend most of your screen time during the day or at night?		
Day	1	
Night	1.22 (1.04-1.45)	0.02
How many years have you spent using screens in this manner:	1	
1 years	4.29 (2.50-7.35)	<0.0001
2 years	4.25 (2.52-7.17)	<0.0001
3 years	4.61 (2.73-7.80)	<0.0001
4 years	3.60 (2.13-6.06)	<0.0001
≥ 5 years		
Do you usually study medicine using:		
Book	1	
Screen	1.92 (1.56-2.39)	<0.0001
Both	1.83 (1.48-2.26)	<0.0001
Do you have any refractive errors?		
No	1	
Yes	1.20 (1.03-1.38)	0.02

Table 3. Multivariate logistic regression analysis of factors affecting occurrence of dry eye

Variable	Odds ratio (95% confidence interval)	P value
Gender		
Males	1	
Females	1.35 (1.14-1.61)	0.001
University		
Ain Shams	1	
Alexandria	1.06 (0.81-1.38)	0.67
Minia	0.63 (0.47-0.85)	0.002
Sohag	1.21 (0.94-1.55)	0.14
Suez Canal	1.03 (0.79-1.35)	0.83
What are the digital screens you commonly use? (Please select one or more answers):		
Apple	1	
Android	1.11 (0.77-1.62)	0.57
Laptop	1.28 (0.87-1.91)	0.21
Ordinary	1.88 (1.08-3.26)	0.03
Other smartphone	0.82 (0.47-1.41)	0.47
How many hours you spend watching your screen in the dark?		
1 hour	1	
2 hours	0.74 (0.61-0.91)	0.004
3 hours	0.79 (0.60-1.04)	0.09
4 hours	1.01 (0.72-1.43)	0.94
5 hours	0.13 (0.05-0.33)	<0.0001
≥ 6 hours	0.90 (0.45-1.80)	0.77
To what level do you illuminate your digital screen (i.e., brightness) in a lit room?		
10%	1	
30%	0.82 (0.63-1.08)	0.15
50%	0.83 (0.64-1.06)	0.14
80%	0.79 (0.59-1.07)	0.13
100%	0.52 (0.37-0.74)	<0.0001
The hours you spend on your digital screen are:		
Interrupted	1	
Continued	1.34 (1.07-1.65)	0.008
Do you spend most of your screen time during the day or at night?		
Day	1	
Night	1.45 (1.20-1.77)	<0.0001
How many years have you spent using screens in this manner:		
1 years	1	
2 years	1.17 (0.70-1.94)	0.55
3 years	1.96 (1.22-3.13)	0.005
4 years	2.03 (1.26-3.25)	0.003
≥ 5 years	1.79 (1.12-2.88)	0.02
Do you usually study medicine using:		
Book	1	
Screen	1.77 (1.39-2.25)	<0.0001
Both	1.01 (0.78-1.30)	0.95
Do you have any refractive errors?		
No	1	
Yes	1.22 (1.03-1.44)	0.02

Table 4. Outcomes of the CVS versus control groups

Parameters	Control Group (Mean ± SD) Median (Range)	CVS Group (Mean ± SD) Median (Range)	P Value
Visual outcomes (logMAR):			
Mean UDVA	0.13±0.16 0.10 (-0.10:1.00)	0.19±0.19 0.15 (0:1.30)	<0.0001
Mean CDVA	0.01±0.03 0 (-0.10:0.20)	0.05±0.07 0 (0:0.40)	<0.0001
Refractive status of students:			
Eyes with Emmetropia	26.99%	33.24%	0.01
Eyes with refractive errors	73.01%	66.76%	
Contact lens-wearers	0.85%	3.88%	0.02
Refractive outcomes (D):			
Mean refractive sphere	-0.71±1.01 -0.25 (-5.5:1.25)	-0.87±0.99 -0.5 (-4.5:1.00)	0.0006
Mean refractive cylinder	-0.28±0.50 0 (-2.50:1.00)	-0.50±0.65 -0.25 (-3.00:0.75)	<0.0001
Mean SE	-0.85±1.09 -0.50 (-5.63:1.25)	-1.10±1.18 -0.75 (-5.38:0.88)	0.001
DED tests:			
Tear film break-up time:			
TBUT in seconds	11.32±2.63 13 (4:17)	8.05±1.40 7 (4:15)	<0.0001
Abnormal TBUT test (< 10 s)	22.16%	74.57%	<0.0001
Schirmer test:			
Schirmer test in mm	17.76±5.28 19 (6:33)	10.76±4.79 8 (5:26)	<0.0001
Abnormal Schirmer test (< 10 mm)	10.22%	58.95%	<0.0001
Slit-Lamp examination (positive findings):			
Conjunctival hyperemia	12.93%	64.49%	<0.0001
Watery/Mucous eye discharge	1.56%	11.79%	<0.0001
Fundus examination:	Normal	Normal	
Students/Eyes documented with:			
CVS	0	100%	<0.0001
Diminished UDVA	68.89%	81.11%	<0.0001
Unexplained reduced CDVA	12.36%	36.51%	<0.0001
DED	22.16%	74.57%	<0.0001
Eye redness	12.93%	64.49%	<0.0001

UDVA: uncorrected distance visual acuity; CDVA: corrected distance visual acuity; TBUT: tear film break-up time test; CVS: computer vision syndrome; DED: dry eye disease; SE: spherical equivalent

Table 5. CVS group mfERG findings before and 4 weeks after reduction of screen-hours

Parameters	Before reduction of screen-hours (Mean ± SD) Median (Range)	After reduction of screen-hours (Mean ± SD) Median (Range)	Mean difference 95% Confidence of Interval	P value
Visual outcomes (logMAR):				
UDVA	0.46±0.23 0.45 (0.1:0.9)	0.16±0.18 0.15 (-0.1:0.5)	-0.30±0.08 (-0.36:-0.24)	0.008
CDVA	0.11±0.08 0.2 (0.1:0.3)	-0.01±0.06 0 (-0.1:0.1)	-0.13±0.05 (-0.26:-0.10)	0.04
I- Amplitudes P1(nV/deg^2):				
Ring 1 (normal 66.6-130.8)	57.67±14.75 53.24 (44.36:89.14)	74.74±18.30 76.82 (45.43:100.1)	14.06 (5.13:28.99)	0.01
Ring 2 (normal 30.9-77.8)	31.28±4.27 31.25 (25.59:38.2)	37.36±8.92 35.75 (27.36:52.96)	6.09 (-0.28:12.46)	0.03
Ring 3 (normal 21.7-59)	21.18±1.77 21.32 (18.41:23.62)	22.61±5.24 21.21 (17.11:33.4)	1.43 (-2.67:5.53)	0.04
Ring 4 (normal 12.9-37.1)	13.14±2.35 13.09 (9.81:17.83)	12.22±3.27 11.63 (8.35:19.03)	-0.93 (-2.26:0.51)	0.17
Ring 5 (normal 10-28.2)	9.26±1.76 8.97 (7.55:12.62)	9.41±2.81 8.73 (6.7:14.95)	0.14 (-1.08:1.36)	0.79
II- Amplitudes P1 (nV/deg^2):				
Quadrant 1 (normal 15.8-42.74)	10.18±1.77 10.06 (7.69:13.68)	12.93±4.00 12.11 (8.47:21.79)	2.76 (0.51:5.00)	0.02
Quadrant 2 (normal 15.98-42.75)	14.82±2.49 14.27 (12.01:20.18)	15.94±3.33 13.58 (8.97:19.41)	1.12 (3.00:0.76)	0.02
Quadrant 3 (normal 15.18-42.05)	15.80±2.31 16.39 (12.87:18.4)	15.21±4.11 13.71 (10.81:22.19)	-0.59 (-3.40:2.21)	0.63
Quadrant 4 (normal 13.87-39.61)	10.06±2.41 10.44 (7.3:13.45)	9.92±3.03 9.19 (6.36:14.62)	-0.14 (-1.14:0.87)	0.76

UDVA, uncorrected visual acuity; CDVA, , uncorrected visual acuity; logMAR, logarithm of minimal angle of resolution; Amplitudes P1, amplitude density of the first foveal peak; deg, degree; nV, nanovolts; R1 to R5, Ring 1 to Ring 5; Q1 to Q4, Quadrant 1 to Quadrant 4; SD, standard deviation.

Fig. 5 shows the mfERG outcomes with reduced foveal responses of a medical student in the CVS group. Fig. 6 shows the mfERG outcomes of another student before and 4 weeks after reduction of screen-hours in the CVS group with improvements in the foveal responses. During these 4 weeks of strict screen-time reduction, all CVS positive cases followed Iqbal's instructions (Iqbal's anti-CVS protective measures) (Iqbal et al. 2023, Iqbal et al. 2023, Iqbal et al. 2024).

4. DISCUSSION

We have exhibited that the digital environment including the digital devices and electronic screens that LEDs that emits blue light, affects the macular integrity as we have already documented the existence of the screen-induced foveal dysfunction (SFD) in our three published studies (Iqbal et al. 2021), Iqbal et al. 2021, Iqbal et al. 2023). We are the first ophthalmic team that investigated the mfERG foveal changes elicited by the exposure to blue light emitting-screens (Iqbal et al. 2021). These mfERG changes exhibited the reduction in foveal responses representing the foveal dysfunction that was associated with corresponding reduction in visual performances and acuities. The SFD was recorded in the university students diagnosed as positive CVS-cases who watching digital devices for prolonged screen-hours (>5 average screen-hours) with extensive exposure to various types of blue light emitting-screens such as laptops, smartphone, pads/tabs and/or desktop devices (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). Interestingly, most of these positive CVS-cases were medical students who were involved in the University mandated computer system use program.

Our studies included two groups; the control and the CVS groups. The control groups involved medical students that had no-CVS diagnosis, spending less than three daily screen-hours on average, exhibited normal mfERG findings that revealed within normal preserved foveal peak and mfERG Quadrants and Rings were within ISCEV standard protocol normal ranges. On the other hand, CVS groups included medical students that had positive CVS diagnosis that was based on Iqbal's four major criteria for accurate CVS diagnosis (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). spending more than five daily screen-hours on average, exhibited abnormal mfERG findings with statistically significant foveal amplitude reduction in P1 AD in most of the mfERG Quadrants and Rings below ISCEV standard protocol normal ranges (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). In comparison with the control groups, the CVS groups exhibited a statistically significant foveal amplitude reduction in the uncorrected and the corrected distance visual acuities (UDVA and CDVA; respectively) (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023).

Furthermore, we discovered that the SFD is a potential reversible phenomenon (Iqbal et al. 2023). We recorded both the mfERG changes and associated visual acuities before and 4 weeks following strict reduction of the screen-time to ≤1 screen-hour daily in both the control and the CVS groups (Iqbal et al. 2023). Thereafter, the medical students in the CVS group exhibited remarkable statistically significant improvements in mfERG foveal responses near to normal ranges with correlated improvements in both UDVA and CDVA (Iqbal et al. 2023). We also documented a positive correlation between the differences of average daily screen-hours reduction and the differences in mfERG Quadrants and Rings P1 AD (Iqbal et al. 2023, Iqbal et al. 2023). Therefore, the lower the daily screen-hours with less exposure to the blue light emitted from digital screens, the more the improvements in the foveal responses (Iqbal et al. 2023).

Table 6. Correlation between the differences of screen-hours/day and mfERG parameters

Study parameters	r (correlation co-efficient)	P value
CDVA	-0.24	0.08
UDVA	-0.61	<0.0001
mfERG Q 1	0.38	0.006
mfERG Q 2	-0.12	0.38
mfERG Q 3	0.19	0.20
mfERG Q 4	-0.06	0.74
mfERG R 1	0.53	0.0001
mfERG R 2	0.51	0.0002
mfERG R 3	0.27	0.07
mfERG R 4	0.04	0.81
mfERG R 5	0.16	0.39

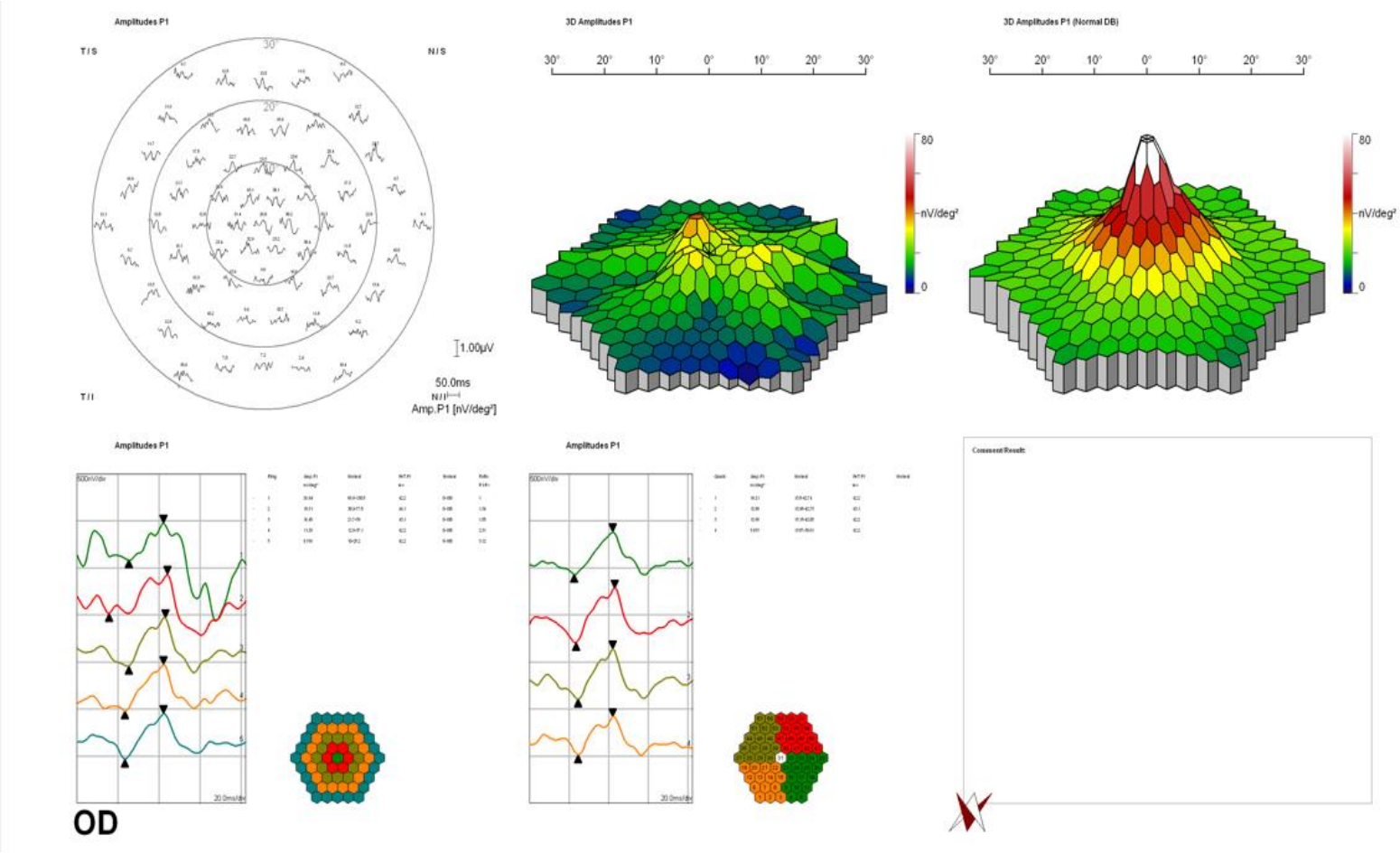

Fig. 5. The mfERG outcomes with reduced foveal responses of a medical student in the CVS group

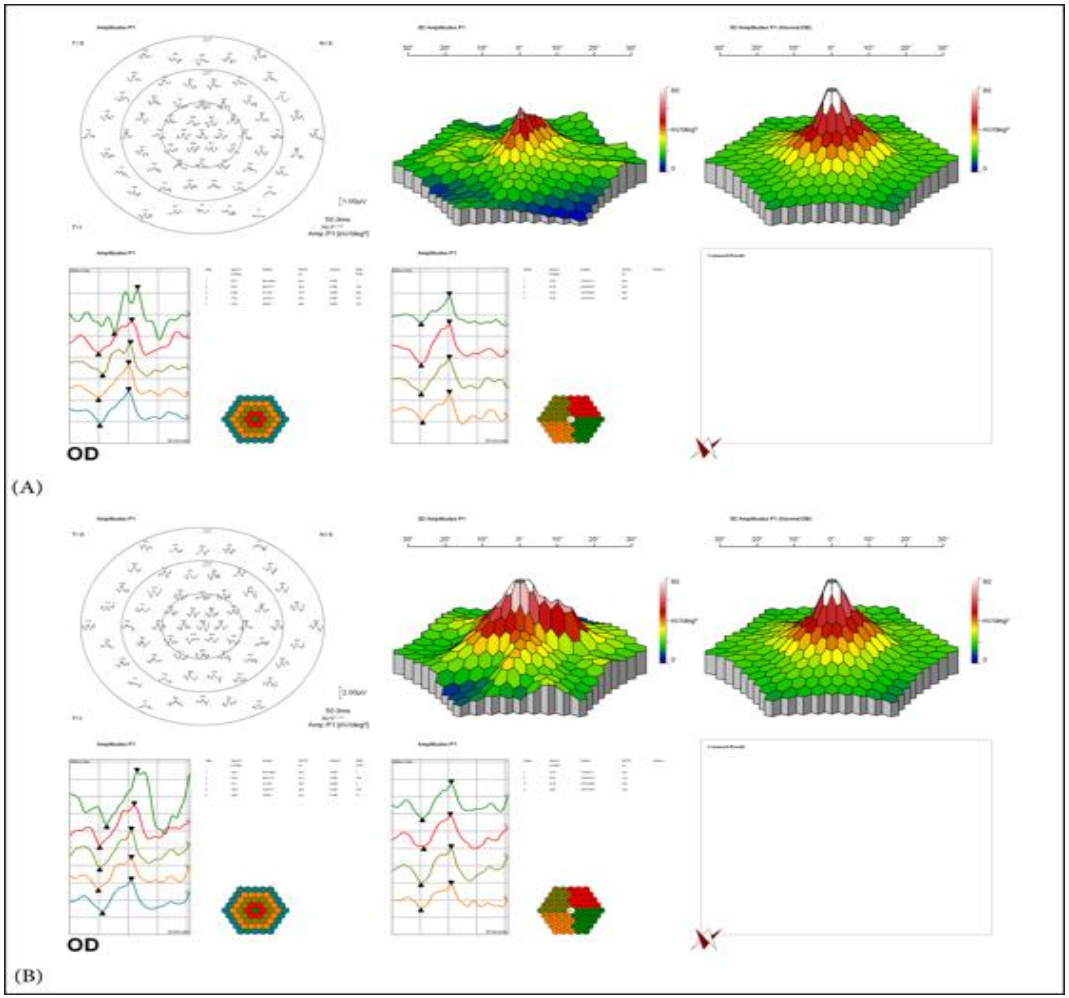

Fig. 6. The mfERG outcomes of another student before and 4 weeks after reduction of screen-hours in the CVS group with improvements in the foveal responses

Meanwhile, SFD in positive CVS-cases and is usually associated with blurring of vision, feelings of diminution of vision, halos around objects with reduced visual performances. In addition, we think that the SFD is a potential type of retinal phototoxicity that could be attributed to excessive exposure to blue light emitting LEDs, encountered in the manufacture of modern digital screens and electronic devices, with subsequent photochemical injury (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023, (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). Furthermore, we have discovered that SFD is a temporary retinal phototoxicity phenomenon that has short-term adverse impacts on normal foveal functions and intact macular integrity. Moreover, SFD might be reversed by restrict reduction of the screen-time thus minimizing the retinal exposure to blue light emitting screens (Iqbal et al. 2021, Iqbal et al. 2021, Iqbal et al. 2023). Meanwhile, we unfortunately don't know underlying pathophysiological mechanisms of SFD; however, it might be could be caused by the macular cone/bipolar cell dysfunction due to the cone adaptation and/or saturation resulting from the excessive levels of blue light with a potential level of retinal phototoxicity resulting in a photochemical injury inducing SFD.

Similar to our outcomes, (Cougnard-Gregoire et al. 2023) concluded that the potential toxicity of long-term cumulative exposure to blue light emitting LEDs and the dose-response effect are currently unknown. In agreement with our results, (Li et al. 2021) reported the mfERG outcomes that ≥8 daily hours viewing of the screens reduced the retinal photoreceptor cells amplitude in the parafoveal region of the macula with delayed peak time. They also stated that the long-term exposure to blue light is a cause of structural and functional damage of the retinal tissue (Li et al. 2021).

Moreover, (Eni CG and Uahomo PO 2024) documented a significant association between increased screen time and reduced normal visual acuity that concedes with our outcomes as we exhibited a negative correlation between the differences of the daily screen-hours and UDVA, i.e. the lower the daily screen-hours the better the UDVA (Iqbal et al. 2023, Iqbal et al. 2023, Bartlett et al. 2001).

5. CONCLUSIONS

Based on our outcomes, we have defined the term screen-induced foveal dysfunction (SFD) as "the multifocal electroretinogram reduced foveal responses below standard normal ranges that are mostly temporary, reversible and usually associated with reduced visual acuities and performances in computer vision syndrome positive-cases". Therefore, SFD could be discovered in positive CVS-cases and is mostly associated with blurring of vision, feelings of diminution of vision, unclear visualization of objects especially post-screen use, complaining of annoying halos of light around objects with subsequent reduction in visual performances. Furthermore, SFD is a potential type of retinal phototoxicity that could be reversed by strict reduction or cessation of exposure to digital devices and electronic screens for 4 weeks that results in spontaneous resolution of cone adaptation/saturation thus eventually the retina regains its normal foveal functions and responses with normal visual acuities and performances.

Finally, our studies recommended that the higher educational authorities should re-plan the mandated computer system use program and consider other alternatives. We also recommend that further future studies including mfERG investigations regarding this topic.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

CONSENT AND ETHICAL APPROVAL

The three studies by Iqbal et al. gained the approval of the Medical Research Ethics Committee (MREC) in Faculty of Medicine, Sohag University, Egypt. All three studies were registered as clinical trials at the ClinicalTrial.gov (ID: NCT04398212 and NCT04405648) and the Pan African Clinical Trial Registry (PACTR201811618954630). All studies were conducted in accordance with the tenets of the Declaration of Helsinki. All participants signed an informed consent prior to enrolment in the studies.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. Fouad Metry Yosef, the expert statistician who performed all statistical analyses, and Prof. Youssef Waheeb, professor of community medicine at Suez Canal University, for his advice

and guidance. The authors are also grateful for the great help and support of Dr. Mona Abo-Ali, Mr. Hamza Mohammed, Seif Mohammed, and Lina Mohammed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

American Optometric Association. (2023, June 24). Computer vision syndrome. *American Optometric Association*. Retrieved from https://www.aoa.org/patients-and-public/caring-for-your-vision/protecting-your-vision/computer-vision-syndrome

Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal, 19*, 43–50.

Cougnard-Gregoire, A., Merle, B. M. J., Aslam, T., Seddon, J. M., Aknin, I., Klaver, C. C. W., Garhöfer, G., Layana, A. G., Minnella, A. M., Silva, R., & Delcourt, C. (2023, April). Blue light exposure: Ocular hazards and prevention—a narrative review. *Ophthalmology and Therapy, 12*(2), 755–788. https://doi.org/10.1007/s40123-023-00675-3

Eni, C. G., & Uahomo, P. O. (2024). The effects of excessive use of computer screens on visual acuity among non-academic university staff. *Ophthalmology Research: An International Journal, 19*(5), 63–76. https://doi.org/10.9734/or/2024/v19i5439

Iqbal, M., & Gad, A. (2023). Analysis of the outcomes of screen-time reduction in computer vision syndrome: A cohort comparative study [Response to letter]. *Clinical Ophthalmology, 17*, 361-363. https://doi.org/10.2147/OPTH.S419372

Iqbal, M., & Said, O. (2023). Letter to the editor regarding “A study on correlation of computer vision syndrome and dry eye disease and knowledge regarding its associated factors among health professionals.” *Indian Journal of Ophthalmology*. Epub ahead of print. https://doi.org/10.4103/ijo.ijo_1755_22

Iqbal, M., Elmassry, A., & Said, O. (2023, July 10). Letter to the editor regarding "Blue light exposure: Ocular hazards and prevention—a narrative review." *Ophthalmology and Therapy*. https://doi.org/10.1007/s40123-023-00759-0

Iqbal, M., El-Massry, A., Elagouz, M., & Elzembely, H. (2018). Computer vision syndrome survey among the medical students in Sohag University Hospital, Egypt. *Ophthalmology Research: An International Journal, 8*(1), 1–8. https://doi.org/10.9734/OR/2018/38436

Iqbal, M., Elmassry, A., Elgharieb, M., Elzembely, H., & Said, O. (2023, June 13). Letter to the editor regarding "TFOS Lifestyle: Impact of the digital environment on the ocular surface." *Ocular Surface, 29*, 416–421. https://doi.org/10.1016/j.jtos.2023.06.006

Iqbal, M., Elmassry, A., Elgharieb, M., Said, O., Saeed, A., Ibrahim, T., Kotb, A., Abdelhalim, M., Shoughy, S., Elgazzar, A., Shamselden, H., Hammour, A., Eid, M., Elzembely, H., Abdelaziz, K. (2024, July 1). Visual, ocular surface, and extraocular diagnostic criteria for determining the prevalence of computer vision syndrome: A cross-sectional smart-survey-based study. *Medical Hypotheses, Discoveries & Innovations in Ophthalmology, 13*(1), 1–15. https://doi.org/10.51329/mehdiophthal1489

Iqbal, M., Elzembely, H., & Said, O. M. (2022). Letter to the editor: “Self-reported student awareness and prevalence of computer vision syndrome during COVID-19 pandemic at Al-Baha University.” *Clinical Optometry, 14*, 193–194. https://doi.org/10.2147/OPTO.S370435

Iqbal, M., Elzembely, H., El-Massry, A., et al. (2021). Computer vision syndrome prevalence and ocular sequelae among medical students: A university-wide study on a marginalized visual security issue. *Open Ophthalmology Journal, 15*, 156-170. https://doi.org/10.2174/1874364102115010156

Iqbal, M., Said, O., Ibrahim, O., & Soliman, A. (2021). Visual sequelae of computer vision syndrome: A cross-sectional case-control study. *Journal of Ophthalmology, 2021*, 6630286. https://doi.org/10.1155/2021/6630286

Iqbal, M., Soliman, A., Ibrahim, O., & Gad, A. (2023). Analysis of the outcomes of screen-time reduction in computer vision syndrome: A cohort comparative study. *Clinical Ophthalmology, 17*, 123-134. https://doi.org/10.2147/OPTH.S419372

Li, H., Zhang, M., Wang, D., Dong, G., Chen, Z., Li, S., Sun, X., Zeng, M., Liao, H., Chen, H., Xiao, S., & Li, X. (2021, May 16). Blue light from cell phones can cause chronic retinal light injury: The evidence from a clinical observational study and a SD rat model. *Biomedicine Research International, 2021*, 3236892. https://doi.org/10.1155/2021/3236892

Merhy, G., Akel, M., Kheir, N., Hallit, S., & Obeid, S. (2023, January 19). Computer vision syndrome in Lebanese male adolescents: Correlates with mental health and mediating effect of stress. *Primary Care Companion for CNS Disorders, 25*(1), 21m03180. https://doi.org/10.4088/PCC.21m03180

Montag, C., & Elhai, J. D. (2023). Do we need a digital school uniform? Arguments for and against a smartphone ban in schools. *Societal Impacts, 100002*. https://doi.org/10.1016/j.socimp.2023.100002

Park, Y. M., White, A. J., Jackson, C. L., Weinberg, C. R., & Sandler, D. P. (2019, August 1). Association of exposure to artificial light at night while sleeping with risk of obesity in women. *JAMA Internal Medicine, 179*(8), 1061–1071. https://doi.org/10.1001/jamainternmed.2019.0571

Petrowski, K., Bührer, S., Albus, C., & Schmalbach, B. (2021, May). Increase in cortisol concentration due to standardized bright and blue light exposure on saliva cortisol in the morning following sleep laboratory. *Stress, 24*(3), 331–337. https://doi.org/10.1080/10253890.2020.1803265

Rozgonjuk, D., Sindermann, C., Elhai, J. D., & Montag, C. (2020). Fear of missing out (FoMO) and social media's impact on daily-life and productivity at work: Do WhatsApp, Facebook, Instagram, and Snapchat use disorders mediate that association? *Addictive Behaviors, 110*, 106487. https://doi.org/10.1016/j.addbeh.2020.106487

Statista. (2020). Average number of devices residents have access to in households worldwide in 2020, by country. *Statista*. Retrieved from https://www.statista.com/statistics/1107307/average-number-connected-devices-households-worldwide/2020

Statista. (2022). Average time spent per day with digital media in the United States from 2011 to 2022 [Electronic Resource]. *Statista*. Retrieved from https://www.statista.com/statistics/262340/daily-time-spent-with-digital-media-according-to-us-consumers/#:~:text=In%202020%2C%20adults%20spent%20an,five%20and%20a%20half%20hours.2022

Touitou, Y., & Point, S. (2020). Effects and mechanisms of action of light-emitting diodes on the human retina and internal clock. *Environmental Research, 190*, 109942. https://doi.org/10.1016/j.envres.2020.109942

Twenge, J. M., Joiner, T. E., Rogers, M. L., & Martin, G. N. (2018). Increases in depressive symptoms, suicide-related outcomes, and suicide rates among U.S. adolescents after 2010 and links to increased new media screen time. *Clinical Psychological Science, 6*(1), 3–17. https://doi.org/10.1177/2167702617723376

Wolffsohn, J. S., Lingham, G., Downie, L. E., Huntjens, B., Inomata, T., Jivraj, S., Kobia-Acquah, E., Muntz, A., Mohamed-Noriega, K., Plainis, S., Read, M., Sayegh, R. R., Singh, S., Utheim, T. P., & Craig, J. P. (2023). TFOS Lifestyle: Impact of the digital environment on the ocular surface. *Ocular Surface, 28*, 213-252. https://doi.org/10.1016/j.jtos.2023.04.004

APPENDIX: 1

Computer Vision Syndrome Form-3 (CVS-F3) Questionnaire

Please mark your answers (√): (University) **Date:** **Name:**

- Age: 16 17 18 19 20 21 22 23 24 25 26
- Gender: Male Female
- How many hours do you spend on your digital screen every 24 hours (total screen-hours)?
- 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
- How many of your total screen-hours do you spend on your digital screen during the daytime?
- 0 1 2 3 4 5 6 7 8 9 10 11 12
- How many of your total screen-hours do you spend on your digital screen at night?
- 0 1 2 3 4 5 6 7 8 9 10 11 12
- How many years have you spent using screens in this manner?
- 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
- Do you spend most of your screen-hours during the day or at night? Day Night
- The hours you spend on your digital screen are? Continuous Interrupted
- What are the digital screens you commonly use? (Please select one or more answers):
- Desktop computer Laptop iPad/Tab Apple smartphone Android smartphone others
- What is the most common primary/single screen you use? (Please select one answer only):
- Desktop computer Laptop iPad/Tab Apple smartphone Android smartphone others
- What is the screen-size of the most common individual/single screen you use?
- Small-sized screen Medium-sized screen Large-sized screen
- What is the screen-version of the most common individual/single screen you use?
- New-version screen (within last 2 years) Old-version screen
- To what average level do you illuminate your primary screen (i.e., screen-brightness) in the dark?
- 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
- Do you have any of the following symptoms frequently with screen use over last 12 months?

(Please select all answers that apply; if none apply, leave blank):

Ocular symptoms:

Blurred vision		Eye strain and fatigue		Difficulty in refocusing the eyes	
Dry eyes		Eye redness and irritation		Near vision discomfort/difficulty	
		Double vision/diplopia		Unclear objects post-screen use	

Extraocular symptoms:

Headache		Insomnia		Neck/shoulder/back pain		Inability to hold objects well	
		Depression		Joint pain in fingers and wrists		Difficulty to write using a pen	

- How many symptoms-attacks on average, if any, you suffer from every month over last 12 months?
- 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 6
- How many years, on average, do you suffer from these symptoms-attacks, if any?
- 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 1516
- Are your symptoms-attacks associated with screen use? N/A Yes No
- Do you have previous diagnosis of dry eye disease or use eye drops to treat it? Yes No
- Do you have any refractive error or wearing glasses? Yes No
- Do you wear contact lenses or have contact lenses related diseases? Yes No

- Do you have previous eye or systemic disease or surgery? Yes No
- Do you feel that digital screens affect your lifestyle and eye health? Yes No
- Are you willing to decrease your screen hours to guard against CVS? Yes No
- Is your medical school involved in mandated computer system use program? Yes No
- How do you usually study medicine? Screens alone Books alone Both
- What is the main screen you usually use to study medicine?
- Desktop computer Laptop iPad/Tab Apple smartphone Android smartphone Others one
- What is your main purpose that consumes most of your screen-time? (Select one answer only):
- Medicine/Science Social communication/Entertainment others
- Do you have any of the following practices frequently with screen use? (Please select all answers that apply; if none apply, leave blank):

Poor screen- resolution or design		Screen- glare		Poor lighting conditions	
Screen edge at/above horizontal eye level		Close eye-screen distance		Watch screen in the dark	
Uncomfortable seating postures		Small-font size		Texting with both thumbs	

Consent: By completing this survey, I agree that the data or outcomes of CVS-F3 and/or ophthalmic examination will be used as a part of CVS research project for publication worldwide. Yes No

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/126714