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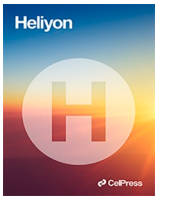

Research article

Impact of online learning during COVID-19 pandemic on digital device related ocular health

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ABSTRACT

Objective: The aim of this study was to evaluate the impact of the COVID-19 pandemic on ocular health related to digital device usage among university students in Lebanon.
Design: A cross-sectional design was utilized to examine the association between the pandemic and ocular health.
Participants: A total of 255 university students in Lebanon participated in the study, selected based on their enrollment during the pandemic.
Methods: An online survey assessed participants' digital device usage, awareness of digital eye strain, and experienced symptoms. The study addressed the relationship between symptom frequency and screen time, especially in their connection to the pandemic and online learning.
Results: Prior to the pandemic, the majority of participants (73.0 %) were unaware of digital eye strain. Following the transition to online learning, nearly half of the participants (47.0 %) reported using digital devices for 12 or more hours. The majority (92.0 %) experienced a substantial increase in daily digital device usage for learning, with an average increase of 3–5 h. Symptoms of digital eye strain, including headache, burning of eyes, blurry vision, sensitivity to light, worsening of vision and dryness of the eyes intensified in both frequency and severity during the pandemic and online learning period.
Conclusions: The study emphasizes the importance of promoting healthy habits and implementing preventive measures to reduce the prevalence of digital eye strain symptoms among university students. Healthcare professionals and public health authorities should educate individuals on strategies to alleviate digital eye strain, considering the persistent reliance on digital devices beyond the pandemic.

1. Introduction

The global impact of the novel coronavirus disease 2019 (COVID-19) has affected many aspects of our lives, especially our mental and physical health. While conjunctivitis has emerged as one of the most common symptoms of the virus [1], a far more common manifestation of the COVID-19 pandemic is dry eye disease primarily attributed to the surge in digital screen usage [2]. The lockdown

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has led to a global shift toward e-communication and e-learning, which has drastically impacted ocular health across all age groups, whether for social, educational or professional purposes [3].

Computer vision syndrome (CVS), also known as digital eye strain (DES), describes the wide range of symptoms experienced during and after digital device usage (phones, laptops, desktops, tablets and television). Symptoms include but are not restricted to blurry vision, headache, tearing sensation, burning of eyes, dryness of eyes and sleep disturbances [1]. At the start of COVID-19, the recurrent lockdown periods, along with quarantining, led schools and universities to adapt a form of remote learning. Some opted for a hybrid learning experience, whereby some students go to school/university while others stay at home, while others offered an exclusive online curriculum.

Moreover, the digital revolution triggered by the COVID-19 pandemic has not only elevated the prevalence of DES among university students but has also underscored the critical need for proactive measures in safeguarding ocular health. As virtual platforms become integral to education, work, and social interactions, the implications extend beyond immediate symptomatic relief. During the lockdown, individuals with pre-existing eye conditions and heightened device usage experienced a threefold increase in the occurrence of new eye complaints compared to the period before the lockdown [4].

Our study aimed not only to determine the prevalence of DES/CVS among university students in Lebanon during the pandemic lockdown but also to assess their awareness of this condition. Additionally, this study examined the relationship between screen time, symptom frequency, and their connection to the pandemic and online learning. The targeted focus on university students allows for a more nuanced understanding of the impact of online learning and increased digital device on this population. The results of the study could help identify the risk factors for developing DES and the interventions that might prevent or reduce the symptoms of this condition among university students for the future.

2. Methods

This was a cross-sectional survey-based study conducted between April and June 2021 in a single center at the American University

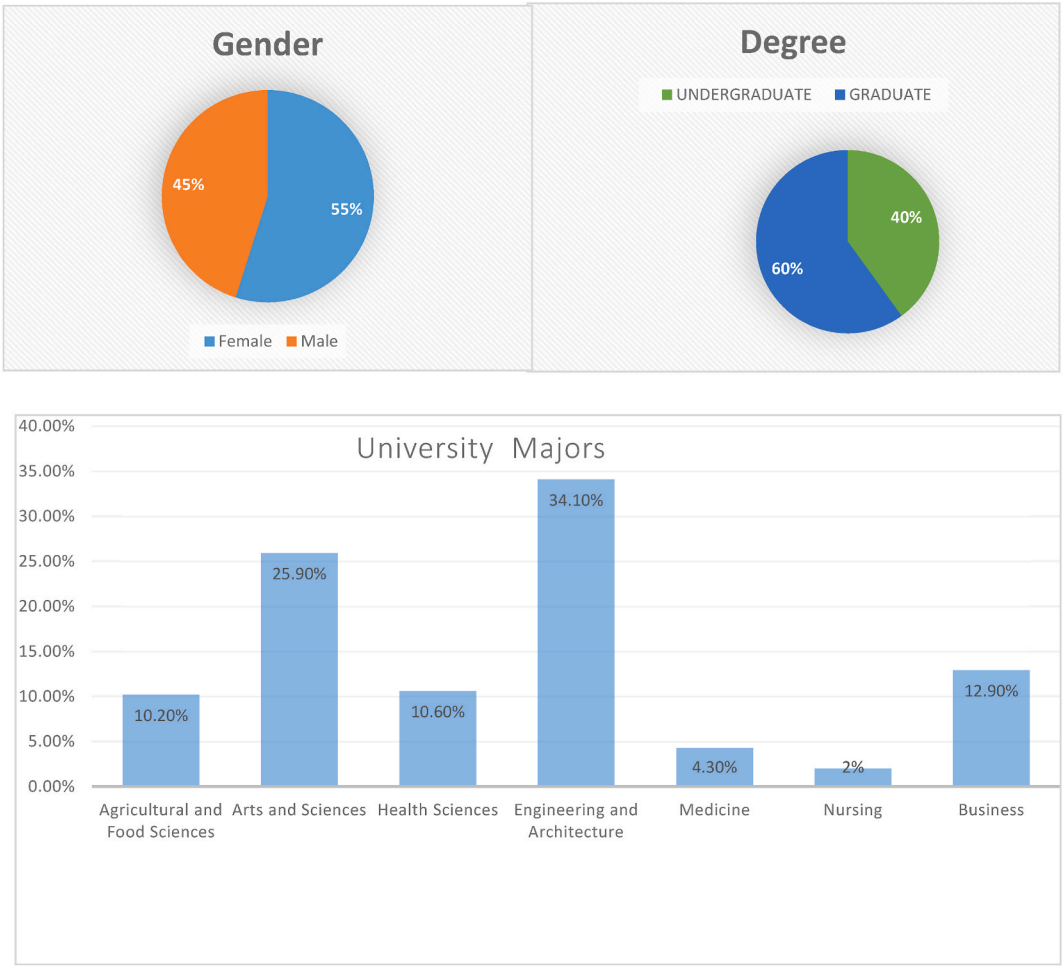

Fig. 1. General Characteristics of respondents (N = 255).

of Beirut (AUB), Lebanon. The study population included AUB undergraduates and graduates above the age of 18. Institutional Review Board at the AUB approved the study ensuring adherence to the principles of the Declaration of Helsinki.

An automated list of randomly selected undergraduate and graduate students was generated by the Institutional Review Board (IRB) in collaboration with the IT desk. This list was utilized to send an online questionnaire to students' university emails through the Lime survey portal. Students who agreed to participate in the study provided an informed consent before filling out an anonymous English language questionnaire consisting of 20 questions. The questionnaire included questions about demographics and history of ocular conditions. The other main section included questions about the amount of time spent on digital devices, the purpose of use, changes in the time spent and eye symptoms experienced, as well as their frequency and severity. Exclusion criteria were used to ensure that the study focused on the effects of digital devices on eye health. Participants who wore contact lens, used glaucoma drops, or had undergone a previous refractive surgery were excluded from the study.

2.1. Statistics

The data was analyzed using Microsoft Excel and IBM SPSS v.28, and the study reported descriptive statistics. For categorical variables, the study reported frequencies and proportions and utilized the chi-square test (or Fisher's exact test if expected counts were less than 5) to determine associations. Associations were considered significant at p-value <0.05.

Table 1
Questionnaire results of the 255 participants.

Question	Number (%)
Heard of Digital Eye Strain(DES)	
Yes	73 (28.6)
No	182 (71.4)
Purpose of digital device usage	
Education	174 (68.2)
Entertainment	53 (20.8)
Work from home	28 (11.0)
Since online learning device usage prevents sleep	
Yes	152 (59.6)
No	103 (40.4)
Need to take a break from screen	
Every 1 h	78 (30.6)
Every 40 min	26 (10.2)
Every 30 min	64 (25.1)
Every 20 min	34 (13.3)
Every 10 min	10 (3.9)
No break needed	43 (16.9)
Frequency and intensity of DES[a] symptoms increased since online learning	
Yes	215 (84.3)
No	40 (65.7)
DES[a] Symptoms relieved after discontinuing digital device use	
Yes	201 (78.8)
No	54 (21.2)
Have tried closing eyes while using digital devices	
Yes	156 (61.2)
No	99 (38.8)
Have tried artificial tears while using digital devices	
Yes	76 (29.8)
No	179 (70.2)
Total number of hours on digital devices before online learning	
0–5 h	106 (41.6)
6–11 h	134 (52.6)
12 and more	15 (5.9)
Total number of hours on digital devices after online learning	
0–5 h	14 (5.5)
6–11 h	122 (47.8
12 and more	119 (46.7)
Increase in digital device time for learning	
1–2 h	20 (7.8)
3–5 h	112 (43.9)
6–8 h	86 (33.7)
9 and more	37 (14.5)
Increase in digital device time for entertainment	
1–2 h	139 (54.5)
3–5 h	85 (33.3)
6–8 h	23 (9.0)
9 and more	8 (3.1)

[a] Digital Eye Strain (DES).

3. Results

The questionnaire was designed to assess the impact of online learning during the COVID-19 pandemic on ocular health related to digital device usage. It included demographic information, digital device usage habits, awareness of eye health conditions, and experiences of symptoms related to prolonged digital device use.A total of 317 people responded to the questionnaire. Of all the respondents, 32 (10.1 %) wore contact lenses, 26 (8.2 %) had undergone refractive surgery, and 12 (3.8 %) used eye drops for glaucoma. Contact lens wearers, glaucoma drops users and those who have undergone refractive surgery were excluded from the analysis, resulting in a total of 255 participants. The general characteristics of the 255 participants are summarized in Fig. 1. 140 respondents (54.9 %) were females, and 115 (45.1 %) were males, with a homogenous sample of participants ($p > 0.05$). The age group of 18–26 years included the largest number of participants (210, 82.3 %). Other age groups included 36 (14.1 %) participants between 27 and 34 years, 7 (2.7 %) participants between 35 and 42 years, and 2 (0.8 %) participants between 43 and 64 years.

3.1. Digital device usage patterns and dry eye syndrome symptoms

Digital devices were primarily used for educational purposes (n = 174, 68.2 %), followed by entertainment (n = 53, 20.8 %), and work (n = 28, 11.0 %), as shown in Table 1. Most participants had not heard about DES or CVS (n = 182, 71.4 %). The analysis showed that the use of digital devices for education was associated with a higher number of DES symptoms,compared to entertainment and work from home, as shown in Table 2. Most participants spent more than 6 h using digital devices per day for educational purposes, as shown in Fig. 2. A direct association was observed between the longer time spent on digital devices, that is, 6 h and more, and the severity of reported DES symptoms. Participants of younger age group (18–26 years) tended to report more symptoms of DES (moderate to severe) compared to other age groups. However, those who had heard about DES were more likely to report moderate symptoms rather than severe.

3.2. Impact of online learning on dry eye syndrome symptoms

The data supported an increase in the frequency and intensity of DES symptoms overall since the beginning of online learning, as reported by 215 participants. Moreover, 78.8 % of students reported that their DES symptoms were relieved after discontinuing the use of digital devices (Table 1). Before online learning, only 6.0 % of participants spent 12 h or more on digital devices, compared to 47.0 % after the online learning era. There was an increase in the frequency and intensity of DES symptoms after the COVID-19 online era, which is related to the increase in the number of hours spent on digital devices after the pandemic (Fig. 3). The vast majority (92.0 %) reported an increase in digital device time for learning purposes by at least 3–5 h per day. However, more than 50.0 % reported an increase by 1–2 h only for entertainment purposes (Table 1).

3.3. DES symptoms

Long hours spent on digital devices (6+ hours) were associated with symptoms of blurry vision, sensitivity to light, dryness, double vision, and seeing colored rings around bright objects. Notably, the most reported symptom of DES was a headache (87.8 %) followed by burning of eyes (72.9 %), then blurry vision (72.1 %), sensitivity to light (66.3 %), worsening of vision (65.1 %), and dryness of the eyes (62.7 %) as shown in Fig. 4. Therefore, a multivariable analysis was done for each DES symptom and the three-time categories spent on digital devices (i.e., 0–5 h, 6–11 h, and 12 h or more).

Table 2
Associations of between the number of hours of digital device use since online learning and questionnaire results of the 255 participants.

Questionnaire	Hours spent per day on digital devices since online learning started N (%)			p-value
	0 to 5	6 to 11	12 and more	
Purpose of digital device usage				0.027
Education	5 (31.3)	73 (61.3)	76 (63.3)	
Entertainment	8 (50.0)	30 (25.2)	28 (23.3)	
Work from home	3 (18.9)	16 (13.4)	16 (13.3)	
Since online learning device usage prevents sleep				0.006
Yes	10 (62.5)	59 (49.6)	72 (60.0)	
No	6 (37.5)	60 (50.4)	48 (40.0)	
Frequency and intensity of Digital Eye Strain (DES) symptoms increased since online learning				0.020
Yes	11 (68.8)	92 (77.3)	106 (88.3)	
No	5 (31.3)	27 (22.6)	14 (11.7)	
Total	16 (6.3)	119 (46.7)	120 (47.0)	

For categorical variables, the study reported frequencies and proportions and utilized the chi-square test (or Fisher's exact test if expected counts were less than 5) to determine associations. Associations were considered significant at p-value <0.05.

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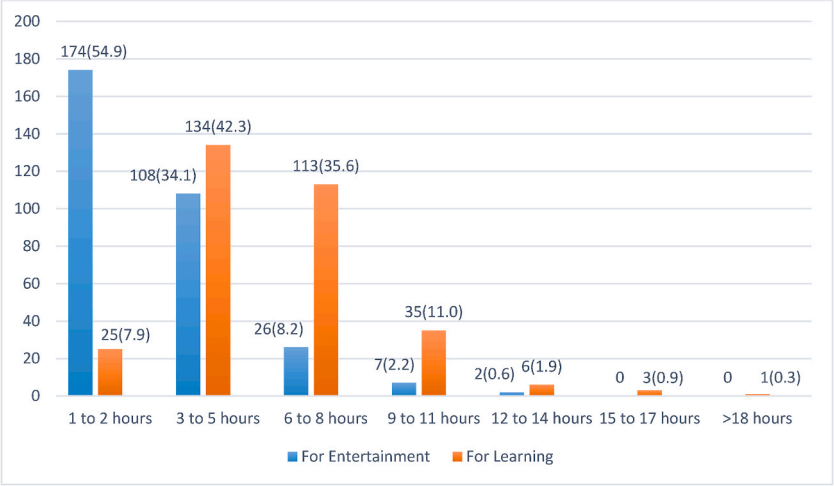

Fig. 2. Digital device usage increase per day in hours for entertainment vs. learning purposes **N(%).**

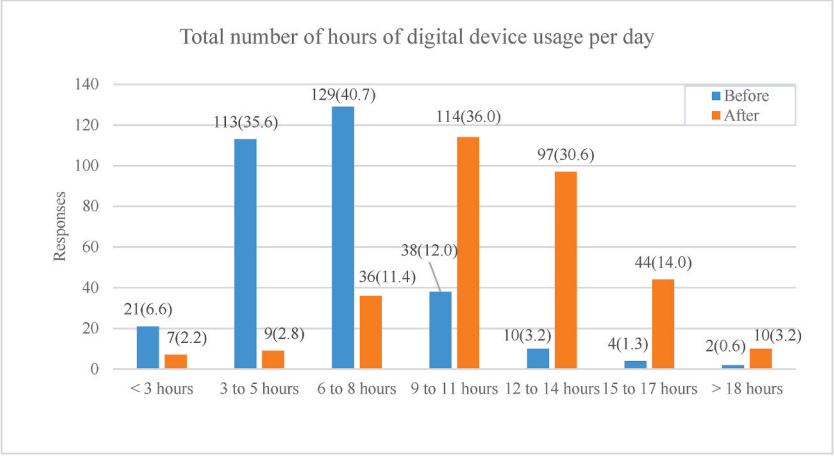

Fig. 3. Total number of hours of digital device usage per day before and after the onset of the COVID-19 pandemic.

3.4. Break/sleep

Most of the participants at some point tried closing their eyes while using the digital device (61.2 %). Only 76 students (29.8 %) used artificial tears while working on a digital device as compared to the majority that did not. Applying artificial tears or closing the eyes while using a digital device were associated with moderate symptoms of DES (Table 3). Sleep was reported to be affected by the increased use of digital devices (59.6 %). The longer the hours spend on digital devices the more the reported disruption of sleep (Table 2). Different break times were needed to rest the eyes in between digital device usage; Most respondents reported a break after 1hr of usage (30.6 %), while 25.0 % took a break every 30 min. The more frequent breaks taken from the screen, the fewer the symptoms of DES reported, as indicated in Table 3.

4. Discussion

The transmission of Covid-19 was more likely to occur in university settings because it was difficult to enforce social distancing among students. Consequently, higher education moved from in-person classes to online instruction, leading to a notable increase in symptoms related to digital eye strain (DES) and dry eye disease (DED) among university students during the COVID-19 pandemic [5].

This study surveyed 317 participants to investigate the prevalence and severity of DES symptoms associated with increased use of digital devices for educational purposes. Results showed that the longer the time spent on digital devices, the more severe the reported symptoms of DES, with a higher frequency and intensity of symptoms reported after the COVID-19 online learning era. A study conducted by Tesfaye et al. in Northwest Ethiopia similarly found a high prevalence of CVS (78.8 %) during the pandemic [6].

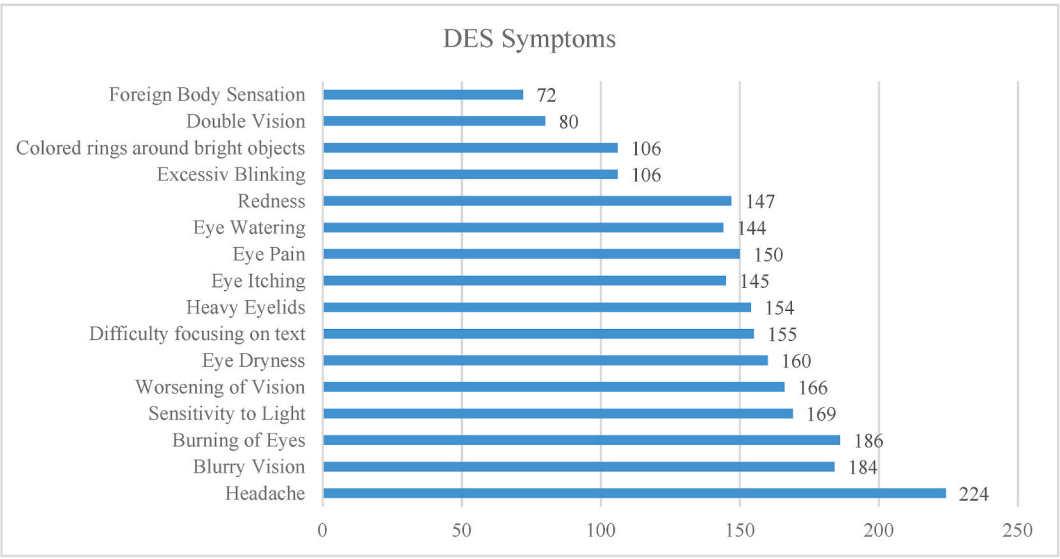

Fig. 4. Reported Digital Eye Strain (DES) symptoms by the 255 participants.
DES symptoms collected as yes/no indicating the presence of each symptom.

Symptoms of DES included blurry vision, sensitivity to light, dryness, double vision, and seeing colored rings around bright objects, with the most common symptom being a headache. A study by Sezen Akkaya et al. examined the impact of long-term computer use on eye dryness. The findings suggest that prolonged computer use may lead to decreased tear production and contribute to eye dryness [7]. Our study found that applying artificial tears or closing the eyes while using a digital device were associated with milder symptoms of DES, and different break times were needed to rest the eyes in between digital device usage.

Recent literature has shown a positive association between the prevalence of DES and the time spent on digital devices during the COVID-19 pandemic. Two studies from India showed evidence of increased prevalence of DES among children using online learning [2,3]. DES scores were directly proportional to the number of hours spent using digital gadgets and hours of screen time during the pandemic compared to the pre-pandemic period [8,9]. Another study on the impact of COVID-19 lockdown on digital-related ocular health in India targeted 4 subsets of the population including students, medical and paramedical staff, nonmedical working professionals, and others. Results showed a sharp increase in digital devices usage along with a gradual decline in the ocular health across all age groups [10].Additionally, another study involving undergraduate students revealed a significant increase in screen time (106.61 % increase, p-value$<$0.05) following the implementation of online classes [11]. Prior to the widespread use of online education, individuals spent an average of 3.32 $\pm$ 2.08 h on screens [11]. With the introduction of online classes, this time surged to 6.86 $\pm$ 2.23 h, marking a notable rise of 106.61 % (equivalent to 3.54 $\pm$ 0.15 h). The majority of participants [88.02 % (n = 485)] experienced at least one symptom of digital eye strain, most commonly feeling heaviness or tiredness in the eyes [11]. In a study by García-Ayuso et al., the occurrence of symptomatic Dry Eye Disease (DED) was significantly (p-value$<$0.001) more common among students who engaged in online classes for seven or more hours (81.2 %) compared to those with 1–3 h (44.1 %) and 4–6 h (53.1 %) [12].

Haddam et al. aimed to investigate the prevalence of Digital Eye Strain (DES) and Mask-Associated Dry Eyes (MADE) during the COVID-19 pandemic in Lebanon [13]. The results showed that the prevalence of DES and MADE was high among 100 participants, with 78.8 % of participants reporting DES symptoms and 68.8 % of participants reporting MADE symptoms. The study also found a significant positive correlation between the duration of digital screen use and the severity of DES symptoms [13].

Our data has shown a correlation between the use of digital devices for various purposes and its effect on the eye health. The frequency and intensity of DES symptoms had increased considerably with the increased dependence on e-learning and e-communication worldwide [14]. The COVID-19 pandemic forced a global lockdown that, in turn, led to reliance on online communication. Digital devices have been used massively in different domains for assignments, meetings, conferences, online classes, and for social media and entertainment affecting ocular health, mainly leading to increased headaches, blurry vision, and dryness, as indicated by our study. The association between the time spent on electronic devices and the worsening of DES symptoms could be explained by the increased corneal exposure and larger gaze angle, which increase the rate of tear evaporation [14]. This may also explain why most participants tried closing their eyes at some point while using an electronic device and why DES symptoms improved and lessened when using artificial tears.

In addition, we found that the increase in the use of digital devices subjectively affected students' sleep. The use of electronic devices at night has been associated with shorter sleep duration, sleep deprivation, and difficulty falling asleep [15]. With many individuals using digital devices more frequently throughout the day, the cumulative effect of blue light exposure may be significant. Some studies suggest that exposure to blue light may disrupt the sleep cycle and the circadian rhythm [16].

Table 3
Association of the severity (by number) of DES symptoms with questionnaire results of 255 participants.

Questionnaire Results	Number of DES Symptoms N (%)			p-value
	0 to 5 (No to mild DES)	6 to 11 (moderate DES)	12 to 16 (severe DES)	
Purpose of digital device usage				0.028
Education	26 (10.2)	85 (33.4)	63 (24.7)	
Entertainment	15 (5.9)	28 (11.0)	10 (3.9)	
Work from home	9 (3.5)	11 (4.3)	8 (3.1)	
Since online learning device usage prevents sleep				0.001
Yes	18 (7.1)	78 (30.6)	56 (22.0)	
No	32 (12.5)	46 (18.0)	25 (9.8)	
Need to take a break from screen				0.686
Every 1 h	13 (5.1)	37 (14.5)	28 (11.0)	
Every 40 min	5(2.0)	15 (5.9)	6 (2.4)	
Every 30 min	14 (5.4)	30 (11.8)	20 (7.8)	
Every 20 min	5 (2.0)	15 (5.9)	14 (5.4)	
Every 10 min	1 (0.4)	5 (2.0)	4 (1.6)	
No break needed	12 (4.7)	22 (8.6)	9 (3.5)	
Frequency and intensity of DES[a] symptoms increased since online learning				<0.001
Yes	31 (12.2)	107 (42.0)	77 (30.2)	
No	19(4.5)	17 (6.7)	4 (1.6)	
DES[a] Symptoms relieved after discontinuing digital device use				0.040
Yes	33 (12.9)	100 (39.2)	68 (26.7)	
No	17 (6.7)	24 (9.4)	13 (5.1)	
Have tried closing eyes while using digital devices				<0.001
Yes	17 (6.7)	80 (31.3)	59(23.1)	
No	33 (12.9)	44 (17.3)	22(8.6)	
Have tried artificial tears while using digital devices				0.001
Yes	6(2.4)	36 (14.1)	34 (13.3)	
No	44(17.3)	88 (34.5)	47 (18.4)	
Increase in digital device time for learning				0.005
1–2 h	6 (2.4)	12 (4.7)	2 (0.8)	
3–5 h	29 (11.4)	57 (22.4)	26 (10.2)	
6–8 h	11 (4.3)	39 (15.3)	36 (14.1)	
9 and more	4 (1.6)	16 (6.3)	17 (6.7)	
Increase in digital device time for entertainment				0.159
1–2 h	27 (10.6)	71 (27.8)	41 (16.1)	
3–5 h	16 (6.3)	44 (17.3)	25 (9.8)	
6–8 h	4 (1.6)	6 (2.4)	13 (5.1)	
9 and more	3 (1.2)	3 (1.2)	2 (0.8)	
Total	50 (19.6)	124 (48.6)	81 (31.8)	

For categorical variables, the study reported frequencies and proportions and utilized the chi-square test (or Fisher's exact test if expected counts were less than 5) to determine associations. Associations were considered significant at p-value <0.05.
[a] Digital Eye Strain(DES).

This study found that students who were aware of the digital eye strain (DES) syndrome were more likely to report experiencing worse symptoms. This could be due to their better understanding and familiarity with the condition. However, a limitation of this finding arises from the potential influence of recall bias, where subjects are more likely to recall exposure if they are previously aware of the outcome. The study had several limitations, including a small sample size which may impact the generalizability of the findings to a broader population. The inherent characteristics of the study population, predominantly composed of university students in Lebanon, may limit the extrapolation of results to different demographics or age groups. Additionally, the retrospective design introduces the possibility of recall bias not only in terms of awareness but also in the accurate recollection of digital device usage and symptoms. To better understand the impact of DES, larger studies with more diverse populations and a wider age range are needed.

However, this study holds several strengths that fortify its contributions to the understanding of digital eye health among university students during the COVID-19 pandemic. Its focused examination of a university student population provides unique insights into the challenges posed by increased digital device usage during online learning. The comprehensive 20-question survey, encompassing demographic details, digital device usage patterns, and reported eye symptoms, ensured a multifaceted exploration of the factors influencing digital eye strain in this specific demographic.

Based on our findings, we find it crucial to educate individuals about DES symptoms, their pattern of occurrence and ways to prevent them. It is important to address these issues by taking regular breaks from digital device use and practicing good eye care habits, such as blinking regularly and adjusting the brightness and contrast of screens. Individuals can also consider using blue light filters or glasses to reduce the impact of blue light on their circadian rhythm. The 20-20-20 rule can be a useful technique as well to reduce symptoms of eye strain during work or remote learning [17]. Phone applications are available to remind users to take breaks from digital device use. Further research is necessary to objectively measure the effects of screen time on the eye surface. It is also

important to evaluate the impact of digital device use on other parameters, such as intraocular pressure, muscle strain, and the long-term effects on the posterior chamber of the eye. Overall, the COVID-19 pandemic has highlighted the importance of taking care of our eyes and using digital devices responsibly to prevent or reduce the incidence of DES and related symptoms.

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Ethical approval

This is study was approved by the Institutional Review Board (IRB), IRB ID: SBS-2021-0046.

Data availability

All Data is available upon reasonable request from the authors.

CRediT authorship contribution statement

Alaa Bou Ghannam: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Hanadi Ibrahim:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Hana Mansour:** Writing – original draft, Methodology, Conceptualization. **Wajiha Jurdi Kheir:** Writing – review & editing, Writing – original draft, Supervision, Investigation. **Sally Al Hassan:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Joanna S. Saade:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors involved in this research declare that they have no competing conflicts of interest related to the subject matter. Their participation in this study was driven by the objective of providing unbiased and impartial information, analysis, and interpretation of the data. They affirm that they have acted with complete transparency, ensuring that no conflicting interests could compromise the integrity or objectivity of their contributions.

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