ORIGINAL RESEARCH

Prevalence of Digital Eye Strain Among University Students and Its Association with Virtual Learning During the COVID-19 Pandemic

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Introduction: The prolonged use of digital devices is a major risk factor for digital eye strain (DES) syndrome.

Aim: To estimate the prevalence of DES symptoms among students at Imam Abdulrahman University who use digital devices for virtual learning and leisure activities.

Methods: This was a retrospective cross-sectional study conducted by asking medical students of Imam Abdulrahman bin Faisal University to complete a self-administered online questionnaire. The questionnaire was used to determine the effect of the hours spent on digital devices and other factors, such as screen distance and not using artificial tears, on the development of DES. The severity (moderate or severe) and frequency (occasionally, always, or never) of 16 eye strain-related symptoms, including eye pain, headache, and itching, were evaluated by using the Computer Vision Syndrome Questionnaire.

Results: The overall prevalence of DES in the sample was found to be 68.53%. The largest proportion of students were found to have mild DES (43.20%), and only 11% had severe DES. The most common symptoms reported in our sample were headache, dryness, and burning. Female gender, using smartphones for online classes, and not using eye lubricants were significantly associated with increased severity of DES.

Conclusion: In the wake of the COVID-19 pandemic, virtual learning has become an integral part of education, leading to increased use of digital technology. The aim of this study was to investigate the impact of virtual learning on eye strain and to determine the prevalence and effects of DES. A questionnaire was administered to participants, and the findings revealed a DES prevalence of 68.53%. The use of eye drops for lubrication and smartphones for classes was significantly associated with DES. Furthermore, females were found to be more susceptible to severe DES symptoms than males. The development of a tool such as the Computer Vision Syndrome Questionnaire to predict DES prevalence could reduce clinic time and resources by minimizing unnecessary follow-up and ophthalmology referrals.

Keywords: digital eye strain, digital devices, computer vision syndrome, virtual learning

Introduction

The use of electronic devices has markedly increased in the last few years among all age groups. Prolonged screen time results in a noticeable impact on vision. During the COVID-19 pandemic period, the time spent on digital screens increased with the shift to virtual learning. Hence, students tend to suffer from a condition known as digital eye strain (DES). The American Optometric Association defines DES as "a complex of eye and vision problems related to activities, which stress the near vision and which are experienced in relation or during the use of computer."[1] The prevalence of DES has been estimated to be above 50% among prolonged screen users in most of the literature, with a high incidence of DES in the lockdown period accordingly.[2–18]

DES symptoms include blurred vision, eye dryness, burning eyes, lacrimation, eye redness, and headache[1]. The sustained state of focusing and refocusing creates ophthalmic muscle fatigue and causes accommodative symptoms related to DES. Reduced blink rate and horizontal gaze both increase the surface area of the cornea and result in evaporative dry eye.[2] The extent of digital learning's impact on vision depends on the screen time, the body posture adopted, the type of device, the brightness and distance of the screen, and the lighting conditions in the room.[1] Having uncorrected refractive errors, wearing contact lenses (which are associated with an increased risk of dry eye and cause friction on the eye surface area), having a history of eye disease, being a female (due to the use of cosmetic products that cause eye irritation and, as mentioned in Bahkir et al study, the fact that females have a higher incidence of dry eye), and having diabetes or autoimmune diseases increase the risk of developing more severe symptoms of DES.[2,12,19]

The extensive use of digital devices in teaching and learning during the pandemic necessitated an evaluation of the disorder's effect on the students. Although symptoms are usually transient, the condition can be severe and interferes with concentration and academic performance.[3] Recent studies are reviewed in our research to present data and information on the use of digital devices, the prevalence of DES, risk factors, and protective measures.

Aim
The aim of this study was to estimate the prevalence of DES among medical field students at Imam Abdulrahman bin Faisal University who participated in virtual learning during the COVID-19 pandemic.

Method
Study Setting and Participants
Our inclusion criteria were medical students 18 years of age or older who were taking online classes. The exclusion criteria were a) students suffering from amblyopia, conjunctivitis, eye infection, strabismus, glaucoma, or cataract and b) students suffering from preexisting medical conditions, such as arthritis or hypertension.

Procedure and Ethical Considerations
Approval from the Imam Abdulrahman bin Faisal ethical committee was obtained. In addition, all participants chose to complete the survey of their own free will and were fully informed about the essential elements of the research project.

Prior to completing the survey, participants were given an informed consent form that included details about the research study, such as the research statement and purpose. Furthermore, the confidentiality of the subjects was protected.

The study was performed following the standards of the 1964 Helsinki Declaration and its later amendments.

Measures
The symptoms and severity of DES were measured by using the Computer Vision Syndrome Questionnaire (CVS-Q) developed by Segui et al.[2] The severity (moderate or severe) and frequency (occasionally, always, or never) of 16 eye strain-related symptoms (eye pain, headache, itching, burning, foreign body sensation, watering, excessive blinking, double vision, vision worsening, eyelid heaviness, dryness, blurred vision, colored halos, near vision difficulty, light intolerance, and redness) were evaluated by using the CVS-Q.[5,6]

Statistical Analysis
The data were entered initially into Excel. After counterchecking and data cleaning, STATA software version 17 was used to analyze the data. Frequencies with proportions were used to describe the categorical variables, and the continuous variable was presented as standard deviation and mean. The chi-square test was used to investigate the association between participants with and without DES in relation to several risk factors. Moreover, to create a model of the relationship between the three DES groups and predictor variables, ordinal logistic regression was used. The strength of the association was displayed as the odds ratio. Furthermore, multivariate analysis was chosen as a method to adjust for suspected confounding factors. P-value < 0.05 was considered statistically significant.

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Results

A total of 750 participants were included in the analysis. The study subjects were aged between 18 and 27, with a mean age of 21.6. Most students were females (60%) versus males (40%), and the majority of them were in their third academic year (27.6%), followed by fourth-year students (20%). Students in their second year were the least observed in the sample, constituting only 13.20%. With regard to preexisting eye conditions, nearly half of the participants reported having myopia at baseline (47.60%). In contrast, amblyopia and strabismus were the least detected among students, each recording below 3% (2.93% and 1.87%, respectively). The overall prevalence of DES in the sample was found to be 68.53%. The largest proportion of students were found to have mild DES (43.20%), and only 11% had severe DES (Table 1).

With respect to eye risk factors and their relationship with DES, only the use of eye drops for lubrication was significantly associated with DES (P = 0.004; Table 2). Furthermore, using a smartphone for classes was found to be significantly associated with DES (P = 0.002; Table 3).

The most common reported symptoms in the current study included headache (n = 423), dryness (n = 408), and burning (n = 405), whereas the least reported symptoms were having double vision (n = 89) and observing halos around

Table 1 Participants' Demographic Characteristics and Prevalence of DES

Variable	Value	N (%)
Age	Mean ± SD	21.567 ± 1.473 (range 18–27)
Gender	Male	300 (40)
	Female	450 (60)
Current academic year	2nd	99 (13.20)
	3rd	207 (27.60)
	4th	150 (20)
	5th	149 (19.87)
	6th	145 (19.33)
Myopia	No	393 (52.40)
	Yes	357 (47.60)
Hyperopia	No	704 (93.87)
	Yes	46 (6.13)
Astigmatism	No	532 (70.93)
	Yes	218 (29.07)
Amblyopia	No	728 (97.07)
	Yes	22 (2.93)
Strabismus	No	736 (98.13)
	Yes	14 (1.87)
DES	No	236 (31.47)
	Yes	514 (68.53)
DES Score	Mild	324 (43.20)
	Moderate	105 (14)
	Severe	85 (11.33)

Table 2 Distributions of Eye Risk Factors in Relation to DES Symptom Severity

Variables		Mild DES		Moderate DES		Severe DES		X^2	P value
		N	%*	N	%	N	%		
Using eye lubricants	No	229	67.35	67	19.71	44	12.94	11.0799	0.004
	Yes	95	54.60	38	21.84	41	23.56		
Screen protector	No	262	63.29	84	20.29	68	16.43	0.0571	0.972
	Yes	62	62	21	21.00	17	17		
Blue filter	No	239	62.08	83	21.56	63	16.36	1.2104	0.546
	Yes	85	65.89	22	17.05	22	17.05		
Regular screen break	No	259	62.56	86	20.77	69	16.67	0.2216	0.895
	Yes	65	65	19	19	16	16		
Eyeglasses	No	150	63.56	45	19.07	41	17.37	0.5986	0.741
	Yes	174	62.59	60	21.58	44	15.83		
Last eye exam	2 years or fewer	216	62.61	71	20.58	58	16.81	0.1468	0.929
	>2 years	107	64.07	34	20.36	26	15.57		

Notes: *Percentages are presented within rows (exposure group).

Table 3 The Distribution of Online Learning Risk Factors in Relation to Digital Eye Strain Symptom Severity

Variables		Mild DES		Moderate DES		Severe DES		X^2	P value
		N	%*	N	%	N	%		
Currently taking online classes	No	95	65.07	23	15.75	28	19.18	3.1753	0.204
	Yes	229	62.23	82	22.28	57	15.49		
Using desktop for classes	No	167	66.01	47	18.58	39	15.42	1.9134	0.384
	Yes	157	60.15	58	22.22	46	17.62		
Using laptop for classes	No	91	65.47	23	16.55	15	17.99	1.8256	0.401
	Yes	233	62.13	82	21.87	60	16.00		
Using tablet device for classes	No	66	72.53	12	13.19	13	14.29	4.7579	0.093
	Yes	258	60.99	93	21.99	72	17.02		
Using smartphone for classes	No	180	70.59	41	16.08	34	13.33	12.4077	0.002
	Yes	144	55.60	64	24.71	51	19.69		
Distance using digital devices	<20 inches	276	62.02	96	21.57	73	16.40	2.7019	0.259
	≥21 inches	48	69.57	9	13.04	12	17.39		
Total hours using digital devices	<4 hours	7	41.18	6	35.29	4	23.53	9.6255	0.141
	4–6 hours	77	71.96	13	12.15	17	15.89		
	6–10 hours	178	62.24	63	22.03	45	15.73		
	>10 hours	62	59.62	23	22.12	19	18.27		

(*Continued*)

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Table 3 (Continued).

Variables		Mild DES		Moderate DES		Severe DES		X^2	P value
		N	%*	N	%	N	%		
Total hours watching any screen	<1 hour	222	66.07	61	18.15	53	15.77	4.2490	0.373
	1–2 hours	80	57.14	35	25.00	25	17.86		
	>2 hours	22	57.89	9	23.68	7	18.42		
Hours using smartphone for reasons other than studying	<1 hour	13	44.83	6	20.69	10	34.48	8.1662	0.086
	1–2 hours	98	62.03	33	20.89	27	17.09		
	>2 hours	213	65.14	66	20.18	48	14.68		

Notes: *Percentages are presented within rows (exposure group).

objects (n = 149). Figures 1–17 shows the frequency of students reporting different CVS-Q symptoms in terms of their frequency and severity.

The enter method was applied in ordinal logistic regression, and Table 4 shows the significant association of some covariates with the main outcome variable. In the univariate model, gender, using eye lubricants, and using a smartphone
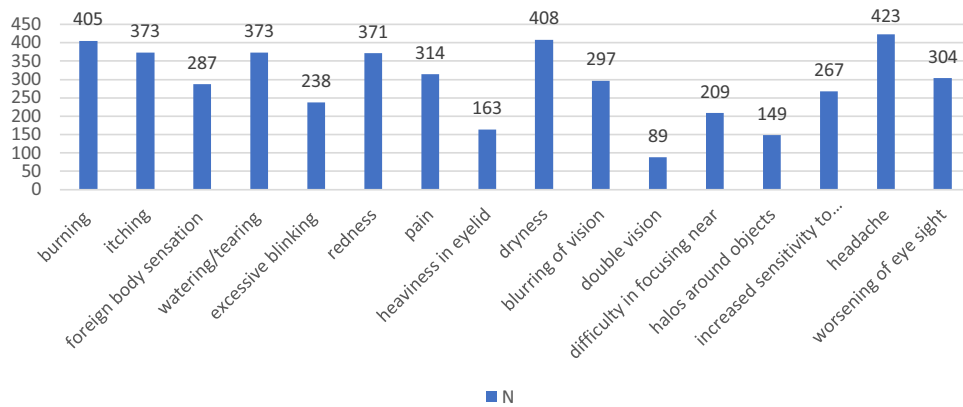
Figure 1 Frequency of symptoms in relation to DES.
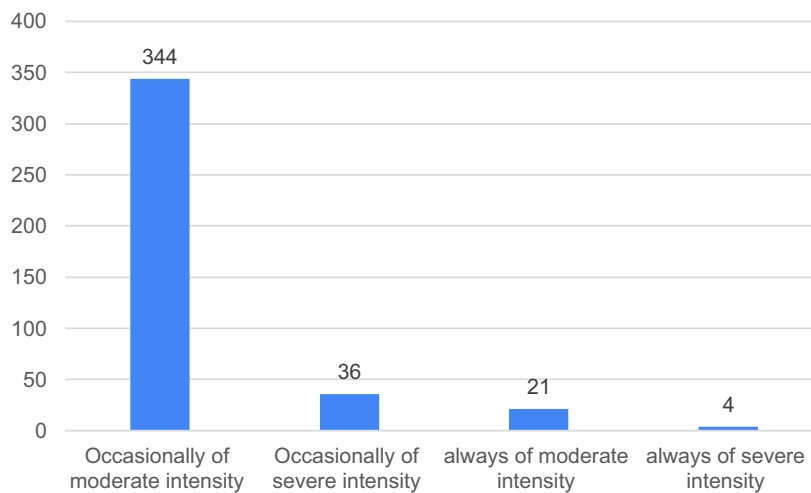
Figure 2 Frequency and intensity of burning as a symptom of DES.
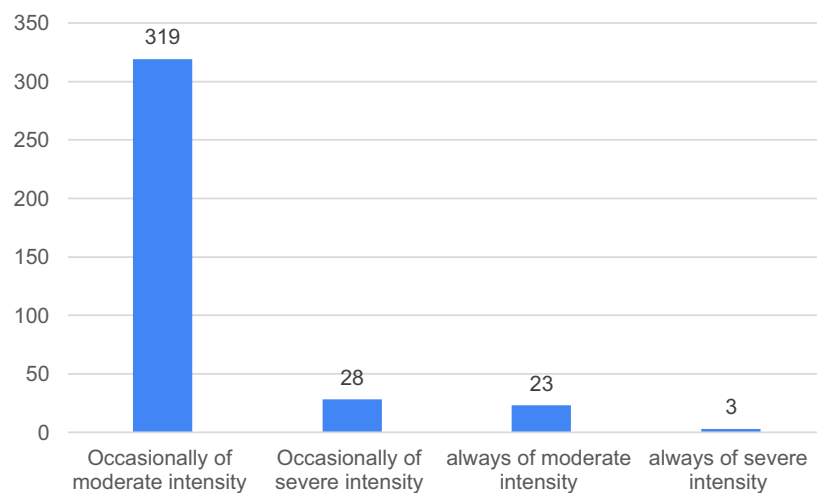
Figure 3 Frequency and intensity of itching as a symptom of DES.
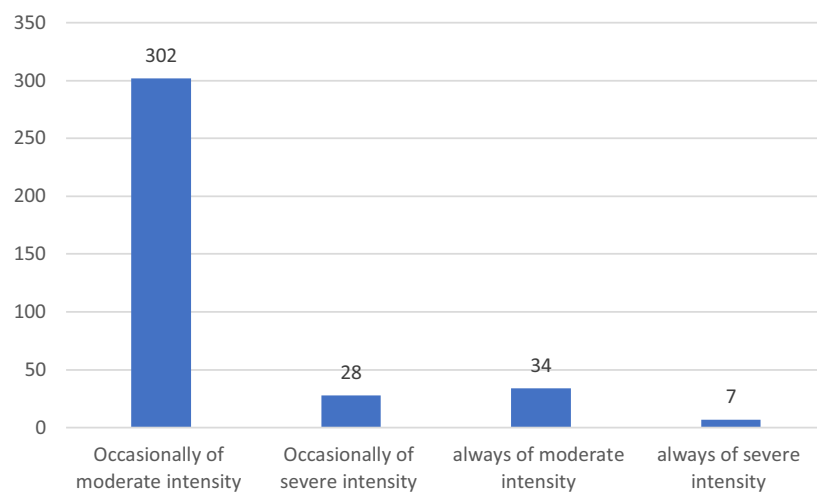
Figure 4 Frequency and intensity of redness as a symptom of DES.
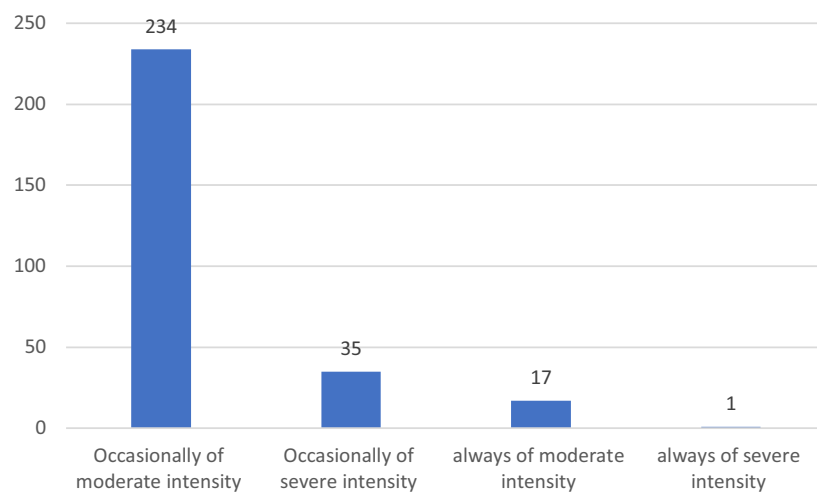
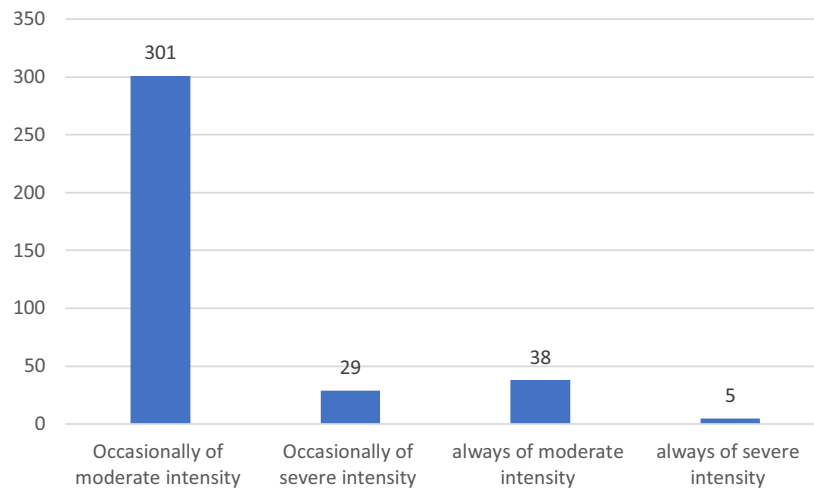**Figure 5** Frequency and intensity of foreign body sensation as a symptom of DES.

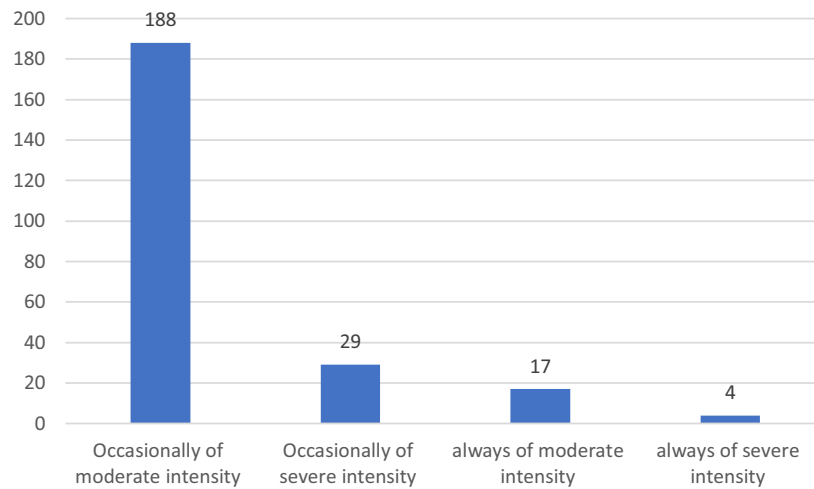**Figure 6** Frequency and intensity of watering/tearing as a symptom of DES.

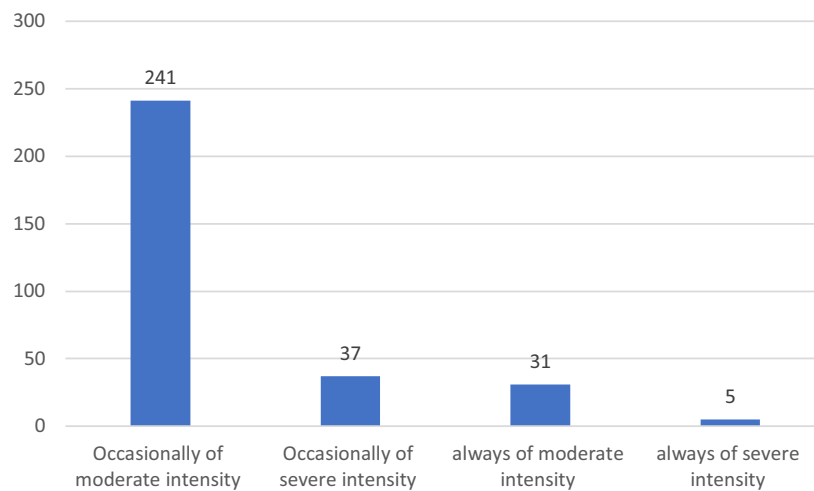**Figure 7** Frequency and intensity of excessive blinking as a symptom of DES.

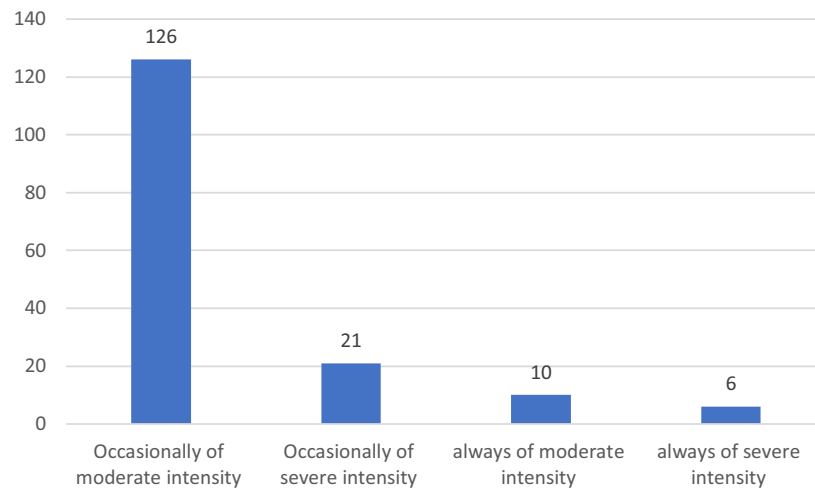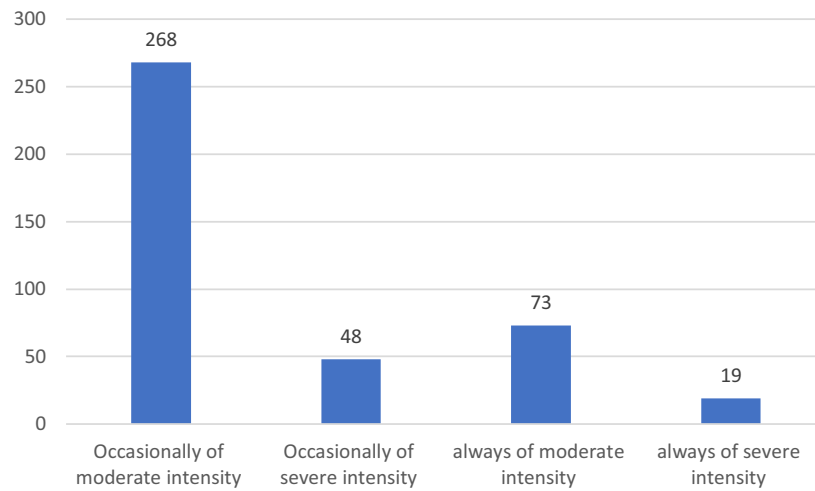

Figure 8 Frequency and intensity of pain as a symptom of DES.

Figure 9 Frequency and intensity of heaviness in the eyelids as a symptom of DES.

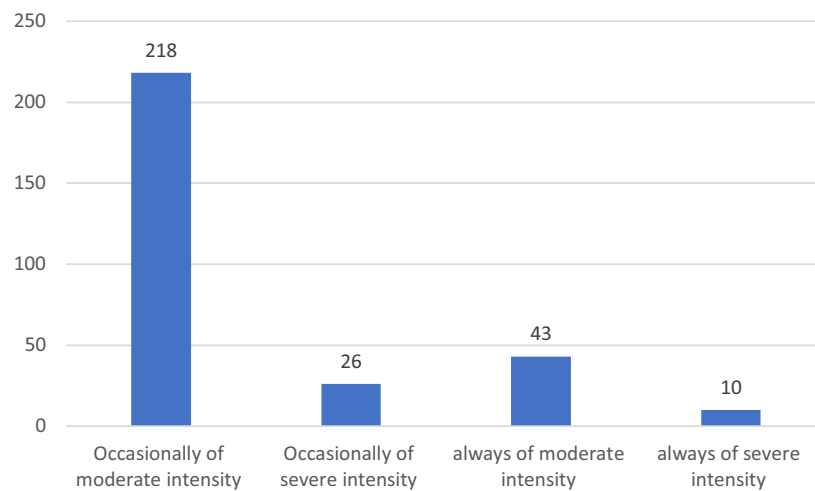**Figure 10** Frequency and intensity of dryness as a symptom of DES.

Figure 11 Frequency and intensity of blurred vision as a symptom of DES.
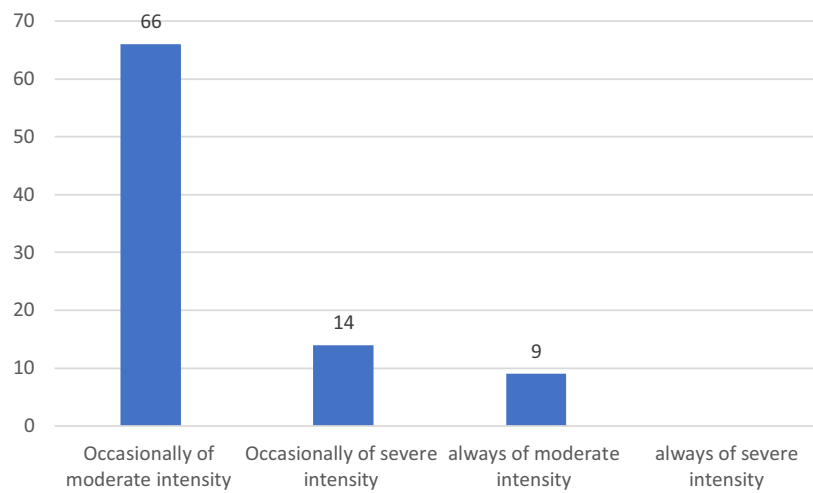
Figure 12 Frequency and intensity of double vision as a symptom of DES.
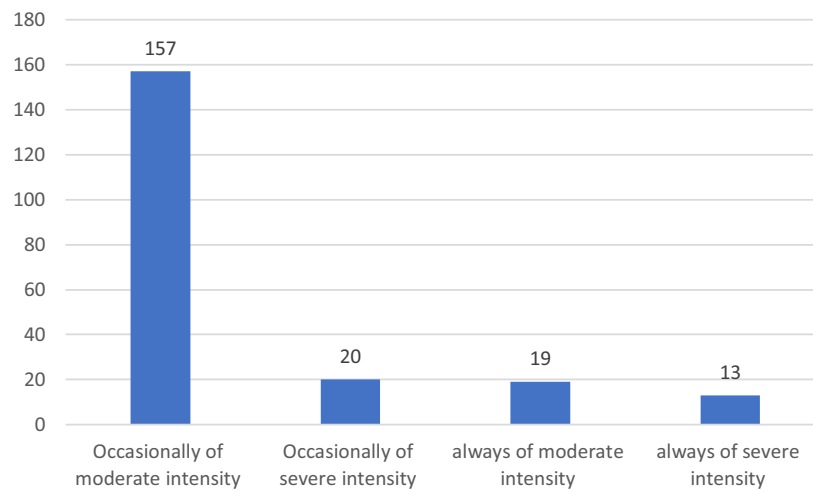
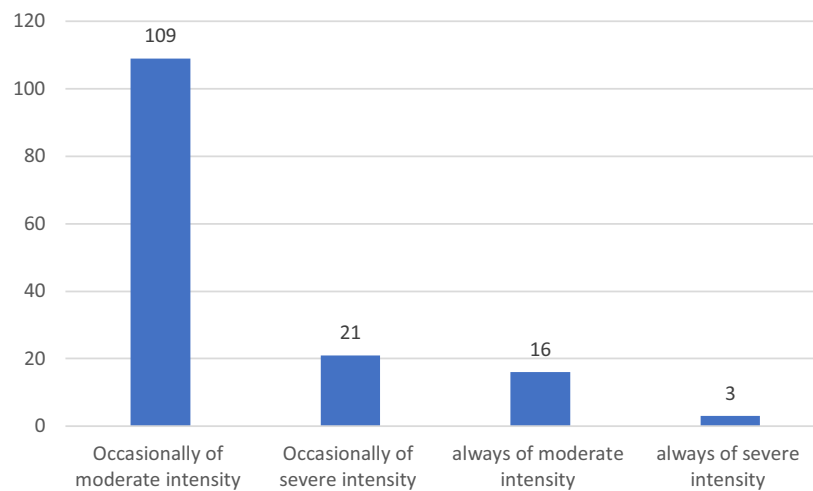**Figure 13** Frequency and intensity of difficulty in focusing near as a symptom of DES.

Figure 14 Frequency and intensity of halos around objects as a symptom of DES.
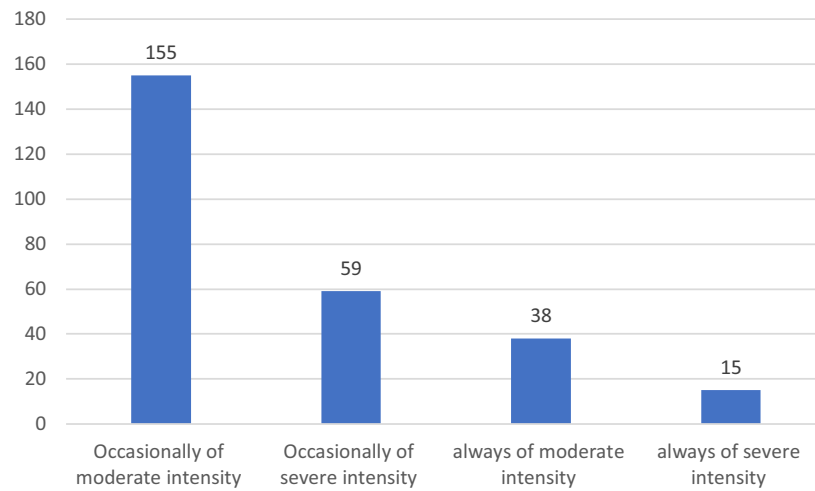
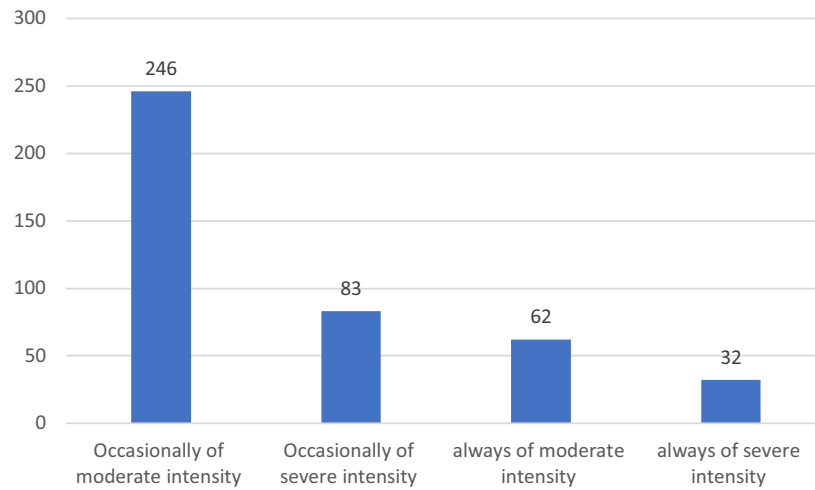**Figure 15** Frequency and intensity of increased sensitivity to light as a symptom of DES.

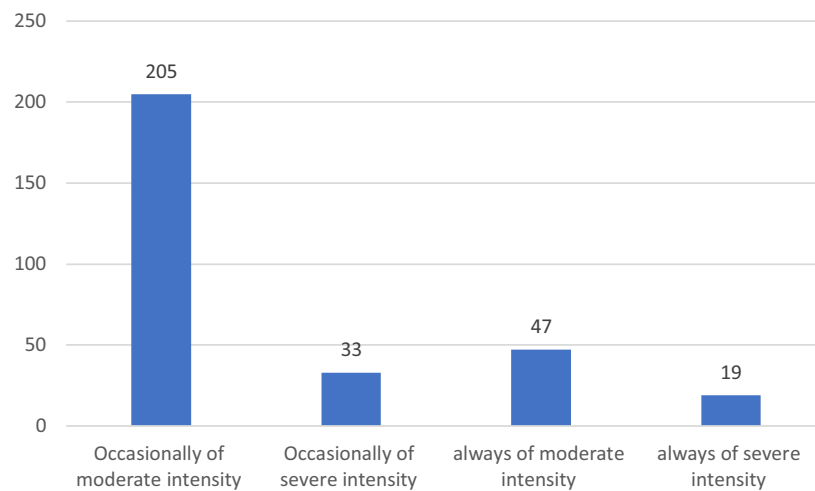**Figure 16** Frequency and intensity of headache as a symptom of DES.

Figure 17 Frequency and intensity of worsening of eyesight as a symptom of DES.

Table 4 Ordinal Regression Model of Risk Factors Associated with DES

Variable	Category	Univariate			Multivariate		
		OR	95% CI	P value	OR	95% CI	P value
Age		0.9344664	0.8296136–1.052571	0.264			
Gender	Male	1	–	–	1	–	–
	Female	1.498699	1.02141–2.199019	0.039	1.319303	0.8790874–1.979963	–
Using eye lubricants	No	1.795872	1.248542–2.58314	0.002	1.623434	1.113208-2.367517	0.012
	Yes	1	–	–			
Using iPad for classes	No	1	–	–			
	Yes	1.603906	0.9779673–2.630472	0.061			
Using smartphone for classes	No	1	–	–			
	Yes	1.847154	1.294928–2.634877	0.001	1.751413	1.223589–2.506927	0.002
Usual distance from device	<21 in	1	–	–			
	≥21 in	0.7708328	–	0.346			
Total hours watching any screen	≤2	1	–	–			
	>2 hours	1.493426	0.893417–2.496394	0.126			
Hours attending online classes in a day				0.758			
	<1 hour	1	–	–			
	1–2 hours	1.940376	1.047375–3.594757	0.035			
	>2 hours	1.387133	0.7935156–2.424825	0.251			

were significant predeterminants of DES. Females had a 1.5-times greater risk than males of scoring severe in DES versus mild and moderate (OR= 1.498; 95% CI 1.021–2.199, P = 0.001). Additionally, not using eye lubricants and using smartphones for classes were significantly associated with increased severity of DES (P < 0.05). When the significant covariates were adjusted in the multivariate model, gender was no longer significant (P = 0.181). After adjustment for potential confounders, students who reported not using eye lubricants had a 1.6-times increased risk of having severe DES compared with mild and moderate (OR = 1.623; 95% CI 1.1132–2.3675; P = 0.012). In addition, those who used their smartphone for online classes had a nearly twofold higher risk of experiencing severe versus mild or moderate DES (OR = 1.8; 95% CI 1.2235–2.5069; P = 0.002).

Discussion

Since the revolution of digital devices in the 1980s, the use of these devices has been increasing and will continue to rise over time. The coronavirus pandemic further contributed to increased use of electronics through the shift toward online teaching and working. The increased use of electronics predisposes users to a syndrome known as digital eye strain. According to the American Optometric Association, DES involves an array of eye- and vision-related symptoms that result from prolonged usage of digital devices that increase stress in the near vision.[6] Blehm defined computer vision syndrome, or DES, as a group of visual and nonvisual symptoms experience by digital device users. Among the two groups, visual symptoms are more common.[13]

The prevalence of DES in our sample was found to be 68.53%. This is a lower prevalence in comparison with the prevalence reported in other studies (90.42% and 78%).[2,3] This could be explained by the timing of these studies, which correlated with the COVID-19 lockdown and increased use of digital devices during that period. The most common

symptoms reported in our sample were headache (56%), dryness (54%), and burning (54%), whereas the least present symptoms were having double vision (11.8%) and observing halos around objects (19.8%). The most frequently reported symptoms in other studies were headache, dryness, and burning sensation.[4,7] Other symptoms, such as difficulty focusing near and worsening of eyesight, were experienced more by students using digital devices for attending online classes for more than 2 hours. This could be attributed to the continuous and frequent accommodation changes that overwhelm the accommodative muscle capability.[8]

With respect to risk factors associated with the severity of DES symptoms, the univariate analysis of this study showed that only gender, using eye lubricants, and using a smartphone for classes were significantly associated with increased symptom severity. In the current study, not using eye lubricants was found to increase the risk of experiencing severe DES symptoms by 1.6 times. The American Optometric Association also reported that using lubricating eye drops was found to be significantly associated with DES, in addition to other factors including gender, age, and screen time.[1] The association between not using lubricating eye drops and the severity of symptoms could be explained by the reduction in blinking rate when using digital devices for a long time, which would lead to eye dryness and exacerbation of symptoms.[9–12] Moreover, several studies suggested that using lubricating eye drops can help alleviate the severity of dryness and DES symptoms.[12–17] Regarding the gender risk factor, the results of the current study showed that females were at a 1.5-times greater risk than males of scoring severe in DES versus mild and moderate. This could be attributed to high somatic symptoms amplification in females compared with males, as was found in different studies.[18,20,21]

In the current study, the use of smartphones for online classes was found to be a statistically significant predeterminant of DES. In a similar cross-sectional study done by Mohan et al, a statistically significant association of DES with the use of smartphones was reported.[4] Moreover, other similar studies reported that the use of smartphones over other devices was significantly associated with DES and considered an independent risk factor.[4,22–25] This could be attributed to the fact that using smartphones requires viewing screens from a shorter distance compared with larger devices, thus leading to more stress on ocular muscles and development of DES.[4,25] The total hours spent using digital devices per day was not found to be significantly associated with the severity of DES symptoms in the current study (P = 0.141). However, several studies showed that the duration of digital device use was considered a significant risk factor for DES.[4,26,27] In a cross-sectional study involving secondary school students, Mohan et al reported that using devices for 5 hours or more was significantly associated with increasing the risk of DES (P = 0.0007).[4] Several studies reported that DES prevalence was found to be higher in participants who use digital devices for 4 hours or more per day.[27–30] In other studies, using digital devices for more than 2 hours daily was associated with a higher prevalence of DES among adolescents.[4,30] A different study conducted on college students showed that there was a relationship between symptoms of DES and the duration of digital device use per day and reported that 93.9% of students who spent 6 hours or more using digital devices suffered from DES.[31] Hence, the researchers suggested that using digital devices for more than 6 hours was one of the risk factors for developing DES.[31–34] This difference in results could be attributed to the difficulty of determining the accuracy of self-reported answers to the exact number of hours spent using digital devices each day.[31] Furthermore, the majority of the previous studies examined the prevalence of DES in relation to the duration spent using electronic devices in hours, but none mentioned the effect of total hours spent per day on the severity of symptoms.

The main purpose of the survey in the current study was to gather more data about DES and determine students' habits in using digital devices in order to help them avoid DES. The symptoms of DES can be effectively managed and relieved by taking frequent breaks.[12] Many experts recommend implementing the 20-20-20 rule during screen time. This rule consists of taking a break for 20 seconds every 20 minutes by gazing at a distance of 20 feet. Regular use of lubricating eye drops is another way to manage DES symptoms.[35] Regarding vision screening, the American Optometric Association recommends vision screening at least every 2 years in asymptomatic low-risk adults from age 18 through 64.[36]

There are some limitations to our study. Data obtained from self-reported questionnaires are inherently biased. Subjects may overestimate or underestimate their symptoms. Additionally, the impact of refractive errors was not examined, despite the fact that DES symptoms may be impacted by the type of refractive errors and their correction. Another limitation is that our study did not include eye examinations.

Conclusion

In the wake of the COVID-19 pandemic, virtual learning has become an integral part of education, leading to increased use of digital technology. The aim of this study was to investigate the impact of virtual learning on eye strain and to determine the prevalence and effects of DES. A questionnaire was administered to participants, and the findings revealed a prevalence of 68.53%. The use of eye drops for lubrication and smartphones for classes was significantly associated with DES. Furthermore, females were found to be more susceptible to severe DES symptoms than males. The development of a tool such as the CVS-Q to predict DES prevalence could reduce clinic time and resources by minimizing unnecessary follow-up and ophthalmology referrals.

Disclosure

The authors report no conflicts of interest in this work.

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