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Digital eye strain and its associated factors in children during the COVID-19 pandemic

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Purpose: This study was undertaken to identify the prevalence of symptoms related to the use of display devices and contributing factors in children engaged in distance learning during the COVID-19 pandemic. **Methods:** An online electronic survey form was prepared using Google Forms (Alphabet Co., Mountain View, CA) and sent to parents of children under the age of 18 years engaged in distance learning during the COVID-19 pandemic. The types of display devices children use, how often such devices are used, the symptoms of digital eye strain, and the severity and frequency of the symptoms were recorded, and the associations between the factors were analyzed. **Results:** A total of 692 participants were included. The mean age of the children was 9.72 ± 3.02 years. The most common display devices used were personal computers (n = 435, 61.7%) for online classes and smartphones (n = 400, 57.8%) for nonacademic purposes. The mean duration of display device use was 71.1 ± 36.02 min without a break and 7.02 ± 4.55 h per day. The most common reported symptom was headache (n = 361, 52.2%). Of the participants, 48.2% (n = 332) reported experiencing 3 or more symptoms. The multivariate analysis detected that being male (P = 0.005) and older age (P = 0.001) were independent risk factors for experiencing 3 or more symptoms. **Conclusion:** The increasing use of digital devices by children is exacerbating the problem of digital eye strain in children as a side effect of online learning. Public awareness should be improved.

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Since the World Health Organization declared the SARS-Cov-2 virus an epidemic, state and local governments have enacted numerous restrictions on social and commercial activities to stop it spreading.[1] In Turkey, schools at all levels were closed in March 2020 and have not reopened yet. Students have been taught online for a year and restrictions preventing children from going outside have been imposed in an effort to prevent the spread of COVID-19. Unfortunately, increasing the time children are required to spend at home means that they have spent more time using display devices. Computer vision syndrome (CVS) is characterized by a range of eye- and vision-related symptoms and has been a recognized health problem for over 20 years.[2-4] The condition is also called digital eye strain (DES), reflecting the variety of display devices linked to potential eye problems. The ocular complaints experienced by computer users typically include eye strain, eye fatigue, burning sensations, irritation, eye redness, blurred vision, and dry eyes, among other problems.

Some authors have reported that the prevalence of myopia has increased since the beginning of the pandemic due to increased screen time, near work, and reductions in children's outdoor activity. This phenomenon is now sometimes referred to as "quarantine myopia".[5] A study from India showed that the prevalence of DES among children has increased in the COVID-19 era.[6] The present study aims to identify the frequency of symptoms related to the use of display devices and their associated factors in children who have been engaged in distance learning for the past year during the COVID-19 pandemic.

Methods

An open online survey created using Google Forms (Alphabet Co., Mountain View, CA) and it was available between 1st and 10th May 2021. The questionnaire was developed by authors and had three parts: demography-digital device usage, DES symptoms, and eye health background. DES symptoms, frequencies, and intensity were evaluated by simplifying the Computer Vision Syndrome Questionnaire (CVS-Q) developed by Seguí Mdel *et al*.[7] A pretest was conducted to see how the questionnaire worked, its ease of understanding, and whether it could be completed in an acceptable time. It is applied to 10 people and they are not included in the study. The survey form is presented in Table 1. The survey was aimed at parents whose children are under 18 years of age and who have been

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attending school online during the COVID-19 pandemic. The schools in the neighborhood of researcher's hospitals were selected. The administrators of the schools assisted to share the link of the survey on WhatsApp (Facebook Corp., USA) groups that the parents belonged to. The parents were asked to complete the survey by discussing each question with their children. Multiple responses could not be submitted from the same IP address. For parents who have more than one child, we informed they should respond from different devices if they would to respond for more than one child. Informed consent was obtained before the parents began to answer the questions. Only completed forms were considered for the study. Exclusion criteria included the children having history of any ocular surgery or wearing contact lenses.

Kocaeli University Ethical Board approved the study (XX 2021/66). The sample size was calculated with studies reporting 60% symptom prevalence at the 0.05 level of significance and 95% power while assuming a 10% difference. Using the two-proportion formula, a sample size of 687 was obtained.

All statistical analyses were performed using SPSS for Windows v. 20.0 (IBM, Armonk, NY, United States) and Med Calc for Windows, version 19.2.0 (Med Calc Software, Ostend, Belgium). The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess the assumption of normality. Numeric variables were presented as mean ± standard deviation. Categorical variables were summarized as counts (percentages). As the normality assumption did not hold, comparisons of numeric variables between groups were conducted using the Mann–Whitney U test and the Kruskal–Wallis test. The Dunn test was used to conduct pairwise multiple comparisons. Associations between two categorical variables were examined using the χ^2. Binary logistic regression analysis was used to determine the factors affecting the outcome variable. A receiver operator characteristic analysis was used to determine the area under the curve, sensitivity, specificity, and cut-off values. All statistical analyses were carried out with 5% significance, and a two-sided P value < 0.05 was considered statistically significant.

Results

A total of 712 parents responded to the questionnaire. We included 692 participants who provided complete responses to the survey. The mean age of the children was 9.72 ± 3.02 years, and 360 (52%) were girls. All of them were attending online classes. Of the respondents, 62.57% were students in primary school (n = 433). Demographic data of children are summarized in Table 2.

The mean number of display devices used for online classes was 1.3. All of the participants reported continuing to use their display devices after online classes and the mean number of display devices used for recreational purposes was 2. The most common display device used for online classes was a personal computer (PC; n = 435, 61.7%), while smartphones were most commonly used for recreation (n = 400, 57.8%). The mean duration of display device use was 71.1 ± 36.02 min without a break and 7.02 ± 4.55 h per day. Five hundred and fifty-seven participants (80.5%) reported using a device for over 30 min without a break and 430 (62.1%) had more than 4 h of screen time a day.

Table 1: Study questionnaire

How old is your child?
What is his/her gender?
□ Male □ Female
Which grade does he/she study in?
□ Primary □ Elementary □ High School
Which electronic devices does he/she use for online learning?
□ PC □ Tablet □ smartphone □ TV □ other
Which electronic devices does he/she use apart from online learning?
□ PC □ Tablet □ smartphone □ TV □ other
How many minutes does he/she spend time in front of screen without break?
How many hours does he/she spend time in front of screen in a day totally?
The distance between his/her eyes and screen
□ under 40 cm (your arm length) □ over 40 cm
The brightness level of his/her preferred
□ high □ intermediate □ low
When he/she close the digital screen?
□ before 20^{00} o'clock □ 20^{00}-22^{00} o'clock □ after 22^{00} o'clock
How is his/her room illumination when he/she uses digital screen?
□ by artificial lamp mostly □ by sunlight mostly
Does he/she use the digital device in dark ambience?
□ no □ yes, sometimes □ yes, often
How often does he/she spend time in open air in a week?
□ No time □ under 3 days □ 3-6 days □ everyday
How often does he/she spend time in open air in a day?
□ under 2 h □ 2-4 h □ more than 4 h
Does he/she experience any of these symptoms in the last year? (Please rank the frequency and the severity for each symptom, or choose no symptom if not present)
(Mild- moderate: transient symptoms that persist for few minutes to few hours, Severe: more than half of the day.)

Symptoms	No symptom	Sometimes	Often	Mild-moderate	Severe
Eye pain					
Headache					
Fatigue in eyes					
Redness					
For. body sens.					
Watering					
Blurred vision					
Double vision					

Does he/she experience any of these symptoms in the last year? (one or more)
□ neck pain □ back pain □ shoulder pain
Does he/she wear glasses?
□ yes □ no
If yes, does he/she start to wear in the last year?
□ yes □ no
If you say 'yes' for 16th question, is there increasing in prescription of glasses 1 diopter or more ?
□ yes □ no
Does he/she have an eye examination in the last year?
□ yes □ no
Does he/she have any ocular diseases?

Three hundred and thirty-two of the participants (48.2%) reported experiencing 3 or more symptoms. The most common symptoms reported were headaches (n = 361, 52.2%), eye fatigue (n = 341, 49.3%), and eye redness (n = 341, 49.3%). The least common symptom was double vision (n = 61, 8.8%).

Table 2: Demographical data and digital device usage characteristics

Demography	Number (%)
Mean age (years) ± SD	9.72±3.02 (range: 7-18)
Male: Female	332:360
Class	
Primary school	433 (62.5%)
Elementary school	180 (26.0%)
High school	79 (11.4%)
Devices for online class	
Personal computer	435 (62.9%)
Tablet	261 (37.7%)
Smartphone	193 (27.9%)
Television	18 (2.6%)
Devices-out of online class	
Smartphone	400 (57.8%)
Television	396 (57.2%)
Tablet	312 (45.1%)
Personal computer	220 (31.8%)
Eye-screen distance	
Under 40 cm	312 (45%)
Over 40 cm	380 (54%)
Ending time for digital devices	
Before 20.00 o'clock	260 (37.6%)
Before 22.00 o'clock	253 (36.6%)
After 22.00 o'clock	179 (25.9%)
Luminance	
Low	53 (7.7%)
Medium	600 (86.7%)
High	39 (5.6%)
Ambient lightning	
Day light	394 (56.9%)
Artificial light	298 (43.1%)
Usage at dark ambient	
No	345 (49.9%)
Sometimes	313 (45.2%)
Often	34 (4.9%)
Spending time in open air (in a week)	
None	91 (13.2%)
1-3 days	403 (58.2%)
4-5 days	104 (15.0%)
Everyday	94 (13.6%)
Spending time in open air (in a day)	
0-2 h	519 (75%)
2-4 h	143 (20.6%)
More than 4 h	30 (4.3%)

Table 3 lists the reported ocular symptoms and Table 4 lists the reported nonocular symptoms.

A receiver operator characteristic analysis was conducted to investigate the cut-off value [Table 5]. Using a display device for more than 3 h a day was found to be a significant risk factor for headaches ($P < 0.001$). Eye pain, foreign body sensation, and watering were significantly associated with spending more than 4 h a day using a display device ($P = 0.027$, 0.003, and 0.030, respectively). Spending more than 5 h a day using a display device was found to be a significant risk factor for eye fatigue and eye redness ($P =< 0.001$ and < 0.001, respectively). Thirty-five minutes of screen time without a break was found to be a significant risk factor for headaches ($P = 0.001$), and there was a significant association between spending over 80 min without a break and eye pain ($P = 0.045$).

Chi-square test was used to investigate the association between DES-related symptoms and digital device usage characteristics. Statistically significant findings are shown in Table 6. Preferring to use a smartphone for online learning was found to be significantly associated with eye pain and blurred vision. Recreational use of smartphones, tablets, and PCs and use of digital devices in a dark environment were found to be significantly associated with eye pain, headache, eye fatigue, eye redness, and blurred vision. Usage of display devices after 8:00 p.m. showed a significant correlation with headache, eye fatigue, and eye redness. Reliance on artificial light also showed a significant correlation with eye pain, eye fatigue, eye redness, and watering. A high degree of screen light showed a significant correlation with eye pain and foreign body sensation, while a screen distance under 40 cm was found to be significantly associated with eye fatigue.

A multivariate analysis revealed that being male ($P = 0.005$) and older age ($P = 0.001$) were independent risk factors for having 3 or more symptoms [Table 7].

Of the participants, 27.5% ($n = 190$) used glasses to correct refractive errors and 38.4% ($n = 266$) had undergone an eye exam in the preceding year. Of the children who had glasses, 20.5% ($n = 39$) had started to use glasses in the last year, and 36.8% ($n = 70$) had a degree increase over 1 diopter. Strabismus had been detected in a total of 5.3% ($n = 37$) of the participants in the preceding year.

Discussion

In the literature, there are many studies about CVS and DES in young adults, but only a few studies have assessed DES

Table 3: Frequencies and degrees of ocular symptoms

Symptoms	Frequency		Degree		None
	Sometimes	Often	Mild-moderate	Severe	
Headache	272 (39.3%)	89 (12.8%)	279 (40.3%)	82 (11.8%)	331 (47.8%)
Fatigue in eyes	254 (36.7%)	87 (12.6%)	292 (42.1%)	49 (7.0%)	351 (50.7%)
Redness	254 (36.7%)	87 (12.6%)	306 (44.2%)	35 (5.0%)	351 (50.7%)
Eye pain	206 (29.8%)	37 (5.3%)	195 (28.1%)	48 (6.9%)	449 (64%)
Watering	171 (24.7%)	37 (5.3%)	188 (27.1%)	20 (2.8%)	484 (69.9%)
Foreign bodies	139 (20.1%)	36 (5.2%)	144 (20.8%)	31 (4.4%)	517 (74.7%)
Blurring	119 (17.2%)	41 (5.9%)	123 (17.7%)	37 (5.3%)	532 (76.9%)
Double vision	56 (8.1%)	5 (0.7%)	56 (8.0%)	5 (0.7%)	631 (91.2%)

Table 4: Frequencies of nonocular symptoms

Nonocular symptoms	Positive
Back pain	198 (28.5%)
Neck pain	197 (28.6%)
Shoulder pain	110 (15.9%)

Table 5: Area under the curve and cut-off values for parameters

Symptoms	Cut-off value	AUC	*P**
Screen time without break			
Headache	35 min	0.569	0.001
Eye pain	80 min	0.545	0.045
Screen time per day			
Headache	3 h	0.585	<0.001
Foreign body sensation	4 h	0.571	0.003
Watering	4 h	0.549	0.030
Eye pain	4 h	0.550	0.027
Eye fatigue	5 h	0.607	<0.001
Eye redness	5 h	0.607	<0.001

*A ROC analysis ; AUC: area under the curve

Table 6: Association between DES-related symptoms and digital device usage characteristics

Symptoms	Digital device use	*P**
Eye pain	Smartphone for online learning	0.014
	Smartphone for recreational	0.049
	Tablet for recreational	0.001
	Dark environment	0.002
	High screen luminance	0.038
	Artificial light	0.005
Headache	Tablet for recreational	0.020
	Smartphone for recreational	0.040
	Dark environment	0.002
	After 8. 00 p.m	0.016
Eye fatigue	Tablet for recreational	0.006
	Smartphone for recreational	0.009
	Dark environment	0.000
	After 8. 00 p.m	0.047
	Screen distance under 40 cm	0.049
	Artificial light	0.013
Redness	Tablet for recreational	0.006
	Smartphone for recreational	0.009
	Dark environment	0.001
	After 8. 00 p.m	0.046
	Artificial light	0.013
Blurred vision	Smartphone for online learning	
	Tablet for recreational	0.002
	Smartphone for recreational	0.007
	Dark environment	0.001
Foreign body sensation	High screen luminance	0.018
Watering	Artificial light	0.014

*Chi-squared test, only statistically significant findings were shown

in children.[8,9] Ocular symptoms and side effects related to children's increasing use of display devices during the COVID-19 pandemic have been frequently discussed in the media but to date only one such report from India has been published.[6]

This study included 692 subjects. The mean age of the subjects was 9.7 years and most were students in primary school. All of the participants had engaged in online learning during the COVID-19 pandemic. These characteristics meant that the data in our study were gathered from younger children and a larger sample population than the previous study from India.[6] The average screen time per day was found to be 7.02 h (range: 1–12 h) in our study, which is higher than that found by Mohan *et al*.,[6] who reported an average screen time of 3.9 h. This figure was also higher than those reported by UK studies, which found that participants spent approximately 4 h using display devices, and by Badri *et al*.,[10] who reported that students spent an average of 5.2 h per day on social media. These two reports were published before online learning was made mandatory during the COVID-19 pandemic, which may be why they report students spending less time using display devices. Ganne *et al*.[11] reported that sevenfold increase of average daily screen time were found in their study included students older than 18 ages.

In this study, spending more than 3 h a day using a display device was found to be a significant risk factor for headaches. Eye pain, foreign body sensation, and watering were significantly associated with over 4 h screen time, while spending over 5 h a day using a display device was found to be a significant risk factor for eye fatigue and eye redness. Portello *et al*.[12] divided DES symptoms into two groups: 1) accommodation-related symptoms (headache, eye pain, and blurred vision for near objects); and 2) dryness-related symptoms (foreign body sensation, watering, burning, itching, and eye redness). Our results indicate that dryness-related symptoms are more common than those related to accommodation when screen time is increased.

The most common symptom reported in our study was headache, which affected 52.2% of the respondents; this was also the most commonly reported "severe" symptom. Continuous near work required the eye to always be in a state of accommodation, which, when maintained for extended periods, causes the visual-motor system to become fatigued and leads to headaches.[13] In a meta-analysis reported in 2015, the prevalence of DES was 19.7% in children.[8] A prevalence of 43.5% for headaches was reported in young adults during the COVID-19 lockdown. This difference may be due to the increased use of display devices by children during the COVID-19 pandemic.

For girls, the mean screen time was 64.3 ± 45.3 min without a break and 6.9 ± 3.2 h per day, while for boys the mean screen time was 80.5 ± 45 min without a break and 7.15 ± 3.6 h per day. Of the boys, 53.1% were reported to experience 3 or more symptoms; of the girls, 42.9% experienced 3 or more symptoms. A multivariate analysis also found that being male was an independent risk factor for experiencing 3 or more symptoms. Most of the studies that assessed young adults reported a higher incidence of symptoms in women, which is thought to be the reason for their higher incidence of dry eyes.[14,15] One study reported that no gender difference was found about DES.[8] Mohan *et al*.[6] found that DES symptoms were more common in boys similar to our study.

Table 7: Multivariate logistic regression analysis of risk factors associated 3 or more symptoms

Risk Factor	OR	95% CI	*P*
Age	1.25	1.09-1.43	0.001*
Male gender	0.63	0.46-0.87	0.005*
Primary school	1.76	0.65-4.80	0.265
Elementary school	1.43	0.38-5.30	0.586
High school	1.10	0.18-6.56	0.910
Screen time	0.99	0.98-1.0	0.433

OR: odd's ratio, CI: confidential interval. P<0.05 is significant

A multivariate analysis revealed that older age was an independent risk factor for experiencing 3 or more symptoms. Moon *et al*. reported that symptoms of dry eye diseases were more common in older children, which may be associated with dry eye disorders.[16] In another study conducted with adults about DES, the younger age was reported as a risk factor for DES.[17]

Smartphone, tablet, and PC use were found to be significantly associated with eye pain, headaches, eye fatigue, eye redness, and blurred vision. Because of their small screens, smartphones are held closer to the face, and so the use of such devices is related to higher asthenopia symptoms. The screen luminance of such devices is usually stronger, and when combined with a decreased blink rate can cause dry-eye-related symptoms. Moon *et al*. found that smartphone use was more commonly related to dry eye disease in children than other display devices.[16]

Of the participants, 27.5% (n = 190) had used glasses to correct refractive errors, 20.5% (n = 39) had started to use glasses in the preceding year, and 36.8% (n = 70) had an degree increase of over 1 diopter. Outdoor activity is a well-known factor in preventing the progression of myopia, but it has been restricted in Turkey during the COVID-19 pandemic.[18] Of the participants, 75% (n = 519) spent less than 2 h in a day in the open air and 71.4% (n = 494) spent time outside less than 3 days a week.

The data used in this research were collected via a questionnaire and the symptoms reported were not confirmed by a physician, which constitutes one of the limitations of our study. Furthermore, the questionnaire was completed by parents on behalf of their children, so it is possible they perceived their children's symptoms inaccurately under- or overestimated the symptoms. However, despite these limitations, the study evaluates the population affected by the COVID-19 pandemic deeply —school-aged children—using a larger and younger sample population.

Conclusion

This study exposes the increasing use of display devices and the higher prevalence of DES symptoms in children due to online learning. This phenomenon will have important consequences for children's ocular health and public awareness must be raised.

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Conflicts of interest

There are no conflicts of interest.

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