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

Bengi Demirayak, Büşra Yılmaz Tugan¹, Muğe Toprak², Ruken Çinik³

 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 ± 4.53 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.

Key words: Computer vision syndrome, COVID-19, digital eye strain, online learning

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. 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. 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”.[8] A study from India showed that the prevalence of DES among children has increased in the COVID-19 era.[9] 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 Segui 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
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 χ². 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 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

| Symptom                           | 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%).
In the literature, there are many studies about CVS and DES in young adults, but only a few studies have assessed DES-related symptoms and digital device usage characteristics. Statistically significant findings are shown in Table 6. A receiver operating characteristic analysis was conducted to investigate the association between DES-related symptoms and digital device usage characteristics. 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-related symptoms and digital device usage characteristics. A receiver operating characteristic analysis was conducted to investigate the association between DES-related symptoms and digital device usage characteristics. 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.

### Table 2: Demographical data and digital device usage characteristics

| Demography                        | Number (%) |
|-----------------------------------|------------|
| n=70 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: Frequencies and degrees of ocular symptoms

| Symptoms                | Sometimes (n) | Often (n) | Mild-moderate (n) | Severe (n) | None (n) |
|-------------------------|---------------|-----------|-------------------|------------|----------|
| 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%)|
The average screen time per day was found to be 0.049 Table for recreational 5 h

Table for recreational 4 h

Positive 0.013 0.009

In a meta-analysis reported in 2015, the prevalence of digital device use

Smartphone for online learning 0.045 0.001

[8] 0.040 0.003 0.001

High screen luminance 0.007 0.014 0.049 0.016

197 (28.6%) 0.571 0.020

4 h 0.550

Digital device use

Artificial light

Screen time without break

Screen time per day

Headache

Foreign body sensation

Watering

Eye pain

Eye fatigue

Eye redness

3 h 0.585 <0.001

4 h 0.571 0.003

4 h 0.549 0.030

4 h 0.550 0.027

5 h 0.607 <0.001

5 h 0.607 <0.001

Table 4: Frequencies of nonocular symptoms

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 0.002

Tablet for recreational 0.007

Smartphone for recreational 0.001

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.\cite{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.\cite{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.\cite{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.,\cite{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.,\cite{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.,\cite{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.,\cite{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.\cite{13} In a meta-analysis reported in 2015, the prevalence of DES was 19.7% in children.\cite{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.\cite{14,15} One study reported that no gender difference was found about DES.\cite{6} Mohan et al.,\cite{6} found that DES symptoms were more common in boys similar to our study.
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. In another study conducted with adults about DES, the younger age was reported as a risk factor for DES.

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.

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 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. 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 inaccurate 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.

**Acknowledgements**

Statistical analysis was performed by Sibel Balci. English editing was done by Scribendi Service. The authors would like to thank all the participants of the study.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. WHO W. (2020). WHO Director-General’s opening remarks at the media briefing on COVID-19.
2. Dain SJ, McCarth AK, Chan-Ling T. Symptoms in VDU Operators. Optom Vis Sci 1988;65:162–7.
3. Costanza MA. Visual and ocular symptoms related to the use of video display terminals. J Behav Optom 1994;5:31–6.
4. Blehm C, Vishnu S, Khattak A, Mitra S, Yee RW. Computer vision syndrome: A review. Surv Ophthalmol 2005;50:253–62.
5. Sumitha M, Sanjay S, Kemmanu V, Bhanumathi MR, Shetty R. Will COVID-19 pandemic-associated lockdown increase myopia in Indian children? Indian J Ophthalmol 2020;68:1496.
6. Mohamed A, Sen P, Shah C, Jain E, Jain S. Prevalence and risk factor assessment of digital eye strain among children using online e-learning during the COVID-19 pandemic: Digital eye strain among kids (DESK study-1). Indian J Ophthalmol 2021;69:140-4.
7. Segui Md M, Cabrero-Garcia J, Crespo A, Verdú J, Ronda E. A reliable and valid questionnaire was developed to measure Computer Vision Syndrome at the workplace. J Clin Epidemiol 2015;68:662-73.
8. Vilela MA, Pellanda LC, Fassa AG, Castagno DA. Prevalence of asthenopia in children: A systematic review with meta-analysis. J Pediatr Brazil 2015;91:320-5.
9. Moon JH, Lee MY, Moon NJ. Association between video display terminal use and dry eye disease in school children. J Pediatr Ophthalmol Strabismus 2014;51:87-92.
10. Badri M, Alnuaimi A, Al Rashed A, Yang G, Temsah K. School children’s use of digital devices, social media and parental knowledge and involvement – The case of Abu Dhabi. Educ Inf Technol 2017;22:645-64.
11. Ganne P, Najeeb N, Chaitanya G, Sharma A, Krishnappa NC. Digital eye strain epidemic amid COVID-19 pandemic—A cross-sectional survey. Ophthalmic Epidemiol 2021;28:285-92.
12. Portello JK, Rosenfield M, Bababekova Y, Estrada JM, Leon A. Computer-related visual symptoms in office workers. Ophthalmic Physiol Opt 2012;32:375-82.
13. Rosenfield M. Computer vision syndrome: A review of ocular causes and potential treatments. Ophthalmic Physiol Opt 2011;31:502-15.
14. Bahk IR, Grandee SS. Impact of the COVID-19 lockdown on digital device-related ocular health. Indian J Ophthalmol 2020;68:2378-83.
15. Jenny M, Robaei D, Rochtchina E, Mitchell P. Prevalence of eye disorders in young children with eyestrain complaints. Am J Ophthalmol 2006;142:495-7.
16. Moon JH, Kim KW, Moon NJ. Smart phone use is a risk factor for pediatric dry eye disease according to region and age: A case control study. BMC Ophthalmol 2016;16:188.
17. Alabdulkader B. Effect of digital device use during COVID-19 on digital eye strain. Clin Exp Optom 2021;104:698-704.
18. Xiong S, Sankaridurg P, Naduvilath T, Zang J, Zou H, Zhu J, et al. Time spent in outdoor activities in relation to myopia prevention and control: A meta-analysis and systematic review. Acta Ophthalmol 2017;95:551-66.