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ORIGINAL ARTICLE

PEDIATRIC OPHTALMOLOGY AND STRABISMUS

School-age visual impairment during remote education due to COVID-19 pandemic

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ABSTRACT

BACKGROUND: The pandemic from COVID-19 had a significant impact on education, imposing a distance learning then enhancing the risk of visual impairments, especially among school and university students encouraged to adopt a digital learning approach, increasing the incidence of visual fatigue.
METHODS: The study was conducted on primary school students immediately after the end of distance learning through a questionnaire and an eye examination comprehensive orthoptic screening to assess visual acuity, sensorial status, and motor function.
RESULTS: Results show that at the end of distance learning the vast majority of students reported experiencing DES with at least 1 symptom among eyestrain when reading, red eyes, burning sensation, tired eyes, itching etc.
CONCLUSIONS: It is necessary to use the tools and knowledge available to prevent during online teaching the onset of ocular symptoms in students, also because DES may affect educational achievement with severe social consequences.

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KEY WORDS: COVID-19; Orthoptics; Students.

The coronavirus disease 2019 (COVID-19) pandemic is a major challenge in every aspect of health care. Due to lockdowns and social distancing, teaching opportunities for trainees in school education have been drastically reduced and changed, to mitigate the spread of COVID-19 and to avoid health-care systems overload.[1] Governments and countries around the world, to ensure social distancing, imposed nationwide school closures leading to an unprecedented transition from face-to-face to digital and distance education.[2] UNESCO reported that 1.37 billion students from over 130 countries were affected by these interventions.[3] In Italy in particular, the transition to distance learning took places compulsorily at all educational levels in March 2020.[4]

The establishment of in-house quarantine led to a significant decrease in the amount of time spent engaged in outdoor activities, reduction in exposure to sunlight and increase in time spent doing near work. These factors can enhance the risk of visual impairments, especially among school and university students encouraged to adopt a digital learning approach. A growing dependence on e-learning and electronic devices has increased the incidence of visual fatigue, the onset and progression of myopia, dry eye, irregular astigmatism and acute concomitant esotropia among other ocular pathologies. During the COVID-19 lockdown, the increased need for electronic devices, digital screens and virtual classrooms might have caused previously healthy students to develop

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ocular symptoms. Digital screen use is considered a common risk factor for dry eye, characterized by the deterioration of tear film quality. The risk of dry eye and symptom severity can be exacerbated by increased digital screen time.[5] Unfortunately, as children use displays to take lessons remotely, eye strain increases progressively, leading to Computer vision syndrome (CVS) also known as DES (digital eye strain). This syndrome is characterized by a range of eye- and vision-related symptoms, reflecting the variety of display devices linked to potential eye problems. The ocular complaints experienced by students 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." A study from India showed that the prevalence of DES among children has increased in the COVID-19 era. In fact, 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.* 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).[6] Eye dryness and accommodative dysfunction may cause difficulty with the focusing system, resulting in blurred vision and double vision. Moreover, the irregular air-tear film interface may cause distorted reflections that may increase sensitivity to bright lights, and the perception of colored halos around lights. The problem of dry eye linked to digital device usage is not limited to adults. Recent studies based in South Korea have indicated that longer daily durations of both visual display terminal (VDT) and smartphone use are risk factors for DED in children. Cessation of smartphone use for a 4-week period in children with DED aged 7-12 years resulted in significant improvements in non-invasive tear breakup time, punctate epithelial erosion and OSDI scores, with all affected children no longer being classified as DED sufferers at the end of the abstinence period.[7] The global restrictions imposed due to COVID-19 have severely limited the hours spent outdoors and, consequently, reduced the exposure to sunlight and the exercises for far vision. If visual fatigue is not relieved promptly, it can further progress into myopia after prolonged online learning.[8] The pandemic-induced school closures and subsequent remote learning arrangements have resulted in extended duration of daily digital screen engagement among adolescents, and that risks of myopic symptom onset and progression increase with every additional daily hour of digital screen engagement. While myopia (nearsightedness) is often categorized as a benign disorder, its widespread prevalence among youths has been growing at an alarming rate, and the associated risks of severe vision impairment pathologies, including macular degeneration, posterior staphyloma, retinal detachment, cataract, and glaucoma, raise serious global public health concerns. Research has shown that myopic progression is influenced by environmental and lifestyle factors, particularly highlighting the critical role of prolonged proximate digital screen use. Notably, East Asia has been particularly affected by increased prevalence of myopia and early age of onset, due to rising school pressure, digitization of instruction, and consequent lifestyle changes.[9] The authors of several previous studies have proposed that increased time spent using digital devices is associated with decreased time spent outdoors and impaired retinal dopamine release, which is normally stimulated by daylight exposure. This suppresses axial expansion of the eye, preventing myopia progression. For instance, Wu *et al.* reported that children who spent more than 11 hours/week outdoors had a 53% decrease in myopia progression, and Ip *et al.* reported an increased incidence of progression in children living in apartment buildings compared with those living in detached houses. Additionally, Xu *et al.* found that the amount of time spent online was significantly positively associated with an increased incidence of myopia and progression

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in students.[5] The goal of this study is to observe in students, through a survey questionnaire and an orthoptic test, whether distance learning during the COVID-19 pandemic caused any visual symptoms, and if it caused them, which are mainly, then compare the results with the data observed in previous or other studies.

Materials and methods

The research was conducted on a specimen of 103 students, aged 6-11 years old, at a Primary School in L'Aquila, Italy. Study participants were visited on 7, 8 and 9 June 2021 right after the end of distance learning (after that schools resumed in face-to-face teaching). The students were administered a questionnaire and underwent a comprehensive orthoptic screening to assess visual acuity, sensorial status, and motor function. Students were asked the following questions:

- the number of hours spent in front of a screen (computer, mobile phone, television) during the lockdown both for distance learning and for entertainment;
- if they took any regular screen break;
- if they experienced any eye strain or other asthenopic symptoms such as: eyestrain reading, red eyes, burning sensation, itching, excessive blinking, gritty sensation;
- if they experienced any blurred or double vision reading on screens or after sustained near tasks.

The orthoptic screening was performed in the following order:

- measurement of visual acuity at distance recorded as LogMAR;
- stereopsis measurement – Lang II test performed at 40 cm in good daylight conditions;
- worth four light test – performed at 33cm, 2m and 5m;
- objective convergence – measurement of the near point of convergence in cm.

Results

Overall, 103 students, 48 males (46.6%) and 55 females (53.4%) aged 6-11 years, underwent the examination.

Results from the survey questionnaire

The questionnaire administered during the first eye screening in concomitance with remote learning showed that children spent on average 5.36 h/day in front of a screen. Among the students, 70 (73.79%) reported having breaks from the screen during distance learning, whereas 27 (26.21%) reported having no break. Regarding asthenopic symptoms, 71% of the students reported experiencing at least 1 symptom among the following seven symptoms: eyestrain when reading, red eyes, burning sensation, tired eyes, itching, excessive blinking, gritty sensation. Overall, 14.5% of the students reported having 1 symptom that in most cases was eyestrain when reading, 35% reported 2 or 3 symptoms, 15.5% reported 4 symptoms, 6% experienced 5-7 asthenopic symptoms, 29% reported no symptom during distance learning. Thirty-eight students (36,89%) reported double/blurred vision after prolonged screen time, whereas 65 (63.11%) did not experience it.

Results of the orthoptic test

The results of the orthoptic test were the following:

- visual acuity – 65.05% of the surveyed participants had monocular acuity of 0 LogMAR, 26.21% had 0.04 LogMAR, 5.83% had 0.09 LogMAR, 1.94% had 0.15 LogMAR, 0.97% had 0.3 LogMAR;
- stereopsis – 8 participants (7.77%) had an incomplete result at the Lang II stereotest, whereas 92.23% completed the test;
- worth four light test – at near fixation (33 cm), 98 participants (95.15%) showed flat fusion ability, 4 subjects (3.88%) suppressed the right or left eye, 1 subject (0.97%) reported vertical diplopia; at mean distance (2 meters) and at far (5 meters), 101 participants (98.06%) had flat fusion ability, 1 subject reported vertical diplopia (0.97%) and 1 subject (0.97%) suppressed the right or left eye;
- objective convergence – 26.21% of the subjects had the near convergence point at 3-5 cm, 21.35% at 5-10 cm, 50.48% at 10-12 cm and 1.94% >15 cm.

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Discussion

Digital learning has become a daily necessity during this COVID-19 pandemic, leading to a sharp increase in digital device use among students at school-going age. During online learning, spending too much time in front of a screen can reduce blinking frequency and tear film renewal. Blue light from electronic device can impact on tear film stability, thereby leading to eye discomfort, dryness, burning and foreign body sensation, photophobia, blurring vision, etc. Xu *et al.* reported that usage of VDTs can lower the stability of tear film. High-energy blue light from VDTs can be a risk factor in the ocular surface damage, but the damage is reversible.[10] Bahkir *et al.*, analyzed the responses to an online survey administered to 407 students in India, average age 27.4 years, and they reported that 90.42% had at least one visual symptom associated with the use of digital devices during online learning. The student population have logged an average increase in usage of 5.18±2.89 hours per day, bringing their daily usage to 8.9±3.63 hours. In total, 49.3% (73/148) of the student population mostly use digital devices for educational purposes (online classes, assignments, webinars). In total, 62.41% (254/407) of respondents have said that digital device usage prevented them from going to sleep at an optimal time. It is alarming that 65.68% (155/236) people below the age of 26 suffer from sleep pattern disturbances due to digital device usage. Students are most affected in this regard, with 66.9% (99/148) of the student population reporting an inability to fall asleep on time.[11] A further study carried out in Saudi Arabia using a self-administered survey questionnaire on 1939 participants has reported a DES incidence of 78% during the COVID-19 lockdown.[12] The increased prevalence of DES is probably due to the increased visual demand of digital device use in our cohort because of the online classes in this COVID era. There was a significant increase in the mean duration of digital device use during the COVID era (3.9±1.9 h) compared to the pre-COVID era (1.9±1.1 h, $P \leq 0.0001$). In the COVID era, 36.9% of children were using digital devices for >5 h compared to 1.8% of children before the COVID era. Mohan *et al.* conducted a study in India focused on DES among children through an online survey questionnaire completed by 217 parents. The mean age of the children was 13±2.45 years. The study showed that 36.9% of children were using digital devices for >5 h/day during COVID, the prevalence of DES was 50.23% and the most common symptoms reported were itching and headache, while smartphones were the most used digital device,[13] in keeping with our review. It should also be considered that contributing to the symptomatologic cortex caused by hours in distance teaching there is free time spent using electronic devices. The overall time spent on digital devices during the lockdown period was significantly greater than that during the pre-COVID period. The median number of hours spent using smartphones prelockdown period was 5 hours, which increased to 7.1 during the COVID pandemic. This increase in digital device usage is anticipated since people are increasingly dependent on smartphones and computers, especially during the lockdown, where they have no other medium to undertake their everyday activities. The curfew forced individuals to stay home, which increased their digital device usage significantly for vocational and nonvocational activities. Highly engaged individuals with digital devices spent 10 hours on a daily basis compared to less engaged individuals who spent 8 hours per day. The high number of hours spent using digital devices significantly increased the incidence of the investigated symptoms (include eye strain, eye pain, headache, diplopia, blurred vision, burning sensation, itchiness, tearing, dryness, etc.). It was expected that employed individuals and students would show DES since they were required to spend more time using their digital devices when working from home. These hours of work or study were added to other activities performed during the day, most likely using the same or other digital devices. Although students do rely on computers for normal schoolwork, during curfew, the usual live, face-to-face classroom hours were converted to virtual classes. These virtual classes necessitated additional usage of digital devices. Thus, the increase in the number of hours for the highly engaged group may have been an essential factor responsible for the in-

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creased odds of developing DES compared to the less engaged group.[12] Shantakumari *et al.*, administered a total of 500 questionnaires to students across two universities in Ajman. Four hundred and seventy-one (471) were returned, in which problems reported were headache, burning sensation in eyes and dry/tires/sore eyes with 53.3% (251/471), 54.8% (258/471) and 48% (226/471).[14] Findings from our study as to the ocular symptoms align with the existing literature. In our sample, 71% of the children who responded to the questionnaire and underwent the orthoptic examination reported asthenopic symptoms. The study shows that children were spending >5.36 hours of screen time per day and the most frequently reported symptom was eye fatigue when reading. This suggests that the prolonged usage of digital devices may impact convergence ability thus causing fatigue in extraocular muscles when looking at a screen. Several prior studies have investigated the potentially best precautions to reduce ocular symptoms following the use of digital devices for reading. However precise, univocal, and globally recognized guidelines have yet to be issued. Shantakumari N. *et al.*, steel says that visual complaints were more among students did not take frequent breaks from the computer. This can be explained by the fact that accommodation is an active process and stationary position of the eyes can lead to fatigue of accommodation. Relief can be obtained from continual visual accommodative spasm and glare from monitor by varying the focal point of the user at least once every ½ to 1 h. The results of this study show fewer incidences of dry eyes and headaches in users of screen filters. The blink rate reduces from a normal of 16-12 blinks/min to about 6-8 blinks/min while working on a computer, resulting in dry eyes. Screen filters are known to reduce reflection and glare from the computer screen. It has also been proven to prevent reduction in blink rates, usually associated with computer usage as the user focuses intently for visual processing of the image. This results in fewer asthenopic symptoms. Imbalance of light between the computer screen and the surrounding is another important factor to be considered. Bright illumination from surrounding can wash out screen character images. It can also be reflected and cause a glare which can reduce the reading time.[14] The American Academy of Ophthalmology has recommended the 20-20-20 rule that says that for every 20 minutes spent looking at a screen, a person should look at something 20 feet away for 20 seconds because refocusing on distant objects at regular intervals reduces the accommodative effort and prevents eye strain and headache.[15] Further precautions may be positioning the screen 4-5 inches below eye level protecting tear film against evaporation or blinking at regular intervals promoting secretion of lipids from the Meibomian glands for the tear film. Furthermore, improved physical ergonomics of the computer workstation has been proven to reduce ocular discomfort and improve performance. Taking a short break, stretching the muscles, change of scenery and a quick walk around the office have been shown to improve productivity and reduce ocular symptoms of stress. Working nonstop for more than 4 hours has been associated with eye strain. Frequent short break can restore and relax the accommodative system of the eyes and preventing ocular strain and visual fatigue. Workers who have recurrent symptoms of computer vision syndrome are encouraged to get proper optometrist review and assessment. Prevention remains the main strategy in managing of computer vision syndrome. Modification in the ergonomics of the working environment, patient education and proper eye care are important strategies in preventing computer vision syndrome.[16] Moreover, some studies recommend that the eyes should be higher than 36 inches from the screen (40 cm for smartphones) and that the screen should be placed 20 degrees below eye level. They also encourage the use of antireflective contact lenses and setting the night light mode in digital devices in the evening. Students are also encouraged to rest their eyes for 10 minutes after 30-40 minutes of educational screen time. The continuous use of digital devices for noneducational purposes should be limited to <15 minutes per day and a cumulative duration of <1 hour a day. In addition, regulations have been put in place to curb excessive online video gaming including restricting playing time and developing an age-based restriction system.[17]

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Conclusions

In conclusion, various types of measures can be suggested to prevent eye- and vision-related symptoms. Introducing appropriate screen and learning environment settings, making students aware about adequate postures and distances from screen devices, encouraging rest, sleep, correct nutrition, and outdoor activities could be pivotal in order to reduce eye strain ad prevent degeneration of preexisting visual condition. Educators, teachers, and parents should be aware of the potential damage that lies behind the excessive and improper use of digital devices and educate their children and students to pay attention to eye care habits during online lessons. Furthermore, online classes should be scheduled scientifically to increase eyesight protection, considering that eye computer-related visual symptoms and DES had already been described in pre-COVID studies such as the P.K. Portello *et al.*, and not born only with online learning with COVID-19. DES is a condition that can affect the development of children's vision. Furthermore, when combined with online learning, DES may affect also educational achievement with severe social consequences, therefore it cannot be underestimated.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

All authors equally contributed to the study conception, design and supervision, and to the performance of the experiment; Fabio De Luca, Lelio Sabetti, Paola Iorio and Chiara Cantelli have given substantial contributions to the manuscript draft. All authors read and approved the final version of the manuscript.

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