Review Paper

Indirect Effects of COVID-19 Pandemic on Children's Ocular Health (Myopia and Digital Eye Strain): A Narrative Review

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ABSTRACT

Background: The outbreak of COVID-19 has significantly affected people's lives worldwide. Governments have used various measures to contain the spread of the pandemic, including confinement policies that have changed children's lifestyles. Children had to limit their outdoor activities and daily routine to indoor activities. Alternative learning systems, such as online and offline teaching via digital devices have replaced traditional teaching methods. Therefore, children have to spend many hours in front of digital devices. As a natural side effect of the pandemic, these changes may influence children's ocular health who may not be able to complain about these problems as early as adults.

Objectives: This study reviews the literature regarding the effects of the COVID-19 pandemic on children's eye health, including myopia and digital eye strain.

Methods: For this narrative review, a comprehensive literature search was performed on December 30, 2021, in Google Scholar, PubMed, and Scopus using the following keywords: "COVID-19," "lockdowns," "children," "ocular health," "eye health," "visual health," "ocular complications," "myopia," " myopia progression," "digital eye strain," "computer vision syndrome," "quarantine," and "prevention." A total of 22 eligible studies were identified for review.

Results: Studies performed during the COVID-19 pandemic have shown an increase in myopia prevalence, incidence, and progression in children, especially among young children. Strategies imposed by governments to control the spread of COVID-19 during confinement have led to dramatic changes in children's lifestyles. These measures have compelled children to restrict outdoor activities and increase their near-work time (e.g., online e-learning), which contributes to the increase in digital eye strain and myopia progression.

Conclusions: Children's eye health can be influenced by the COVID-19 outbreak. These can serve as a warning to policymakers, health professionals, teachers, parents, and children about the effects of pandemics, such as COVID-19, on children's visual health and the need to implement preventive and therapeutic measures.

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1. Context

The coronavirus disease 2019 (COVID-19) was announced as a global pandemic on March 11, 2020, by the World Health Organization and designated as severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) by the International Virus Classification Board (1). The pandemic has caused great morbidity and mortality worldwide and as a newly emerging disease, research is continued on different aspects of the disease. However, the respiratory system is not the only organ or system affected by this disease. COVID-19 has a wide spectrum of symptoms and complications and can influence almost every organ (2). The eye is an important organ that may be affected primarily or secondary to this pandemic. Apart from the direct ocular involvement that occurs in the acute phase of the infection, the eye can be affected indirectly. Quarantine myopia and digital eye strain (DES) are examples of such complications (3).

To mitigate the spread of the pandemic, governments have implemented various measures, such as social distancing, confinement policies, and lockdown (3-5). Children have also been affected by these measures as they had to limit their outdoor activities and daily routine to indoor activities (5). Alternative learning systems, such as online and offline teaching via digital devices have replaced traditional teaching methods. Therefore, children have to spend many hours in front of digital devices. Moreover, the "Stay at Home" instruction forced children to spend their free time with screens (3, 4). All these changes might affect ocular health, such as refractive errors.

The prevalence rate of myopia is increasing across the globe (6). It was reported that 1.4 billion people were myopic in 2000, and it is predicted that by 2050, 4.8 billion people will have myopia (7). The highest rate of progression is in children (6, 8). Because outdoor play may have been reduced as a natural concomitant of the pandemic, indoor screen time may have increased; therefore, myopia progression may lead to visual impairment and increase the risk of eye complications later in life. So it is important to determine the impacts of the pandemic on myopia in children (7, 9, 10). A higher prevalence of DES has been found in individuals who use digital devices regularly and excessively (4, 11). Increased screen time is expected to affect children's eyes as a secondary ocular side effect of the COVID-19 pandemic (12). Since the diagnosis of DES in children may be delayed because they do not complain of it as early as adults, it is important to determine the prevalence and symptoms of DES in children during the pandemic.

Since the beginning of the pandemic, several studies, including case reports/series, original research articles, and reviews with or without meta-analysis, have addressed the ocular involvements and visual impacts of COVID-19, each with a different perspective. However, COVID-19 is a recent phenomenon and more studies can help in better identification of its different aspects to have a wider perspective about its exact pathophysiology, presentations, and complications. This helps in taking a step toward more efficient prevention and treatment to reduce the global consequences of COVID-19. Accordingly, in this review, after about 2 years since the pandemic started, we present the updated results of studies that address the indirect effects of the COVID-19 pandemic on children's eye health, including myopia and DES.

2. Evidence Acquisition

For this narrative review, a comprehensive literature search was performed on December 30, 2021, in Google Scholar, PubMed, and Scopus using the following keywords: "COVID-19," "lockdowns," "children," "ocular health," "eye health," "visual health," "ocular complications," "myopia," "myopia progression," "digital eye strain," "computer vision syndrome," "quarantine," and "prevention." References cited within the included articles were used to identify additional potentially relevant reports. Correspondence, editorials, letters to the editors and non-English articles were excluded. Children were considered persons below the age of 18 years. A total of 22 eligible studies were identified for review.

3. Results

Myopia

Prevalence and incidence of myopia before and after the COVID-19 pandemic

The prevalence of myopia in children during the COVID-19 pandemic is provided in Table 1. In In an intervention study from Wenzhou City, Zhejiang Province, China, the overall prevalence of myopia increased from 52.89% (95% CI: 52.79%-52.99%) in June 2019 to 53.9% (95% CI: 53.79%-54.01%) in December 2019, and 59.35% (95% CI: 59.24%-59.46%) in June 2020. This study showed that the incidence rate of myopia was 22.66% (95% CI: 22.52%-22.80%) within 1 year. The half-year incidence rate of myopia was 8.5% before the COVID-19 confinements, which reached 13.62% after the confinements (P<0.001) (13). Another study in China revealed that the incidence of myopia in children who experienced the COVID-19 pandemic was twice as high as the proportion of myopia in children before the pandemic (15.3 % vs 7.5 %, P<0.001). They also demonstrated that the prevalence of myopia in third grade students increased by 7.5% (20.8% in November and December 2020 vs 13.3% in November and December 2019; P<0.001) (14).

In Chongqing city, China, the prevalence of myopia increased significantly from 44.62% in 2019 to 55.02% in 2020 (P<0.05) (15). In addition, in 2020, in Shandong, Feicheng, China, a statistically higher prevalence of myopia (1.4 to 3 times) was reported for children in the age range of 6 to 8 years compared to the previous 5 years. A minimal increase was also observed in children the aged 9-13 years (16).

A study from Hong Kong revealed an increase in the overall incidence of myopia during the COVID-19 pandemic compared to the pre-COVID-19 period (36.57% vs 19.44%). In addition, myopia prevalence increased from 8.48% in the pre-COVID-19 period to 25.45% after the COVID-19 pandemic (5). Chang et al. conducted a cohort study that examined participants in early 2019 and repeated the exams at a 6-month interval (17). The study included 4 rounds and 3 periods. The lockdown occurred during the second period. They showed that the proportions of myopia and high myopia were 48.0%, 53.2%, 73.7%, and 67.9% and 1.3%, 1.9%, 2.8%, and 2.7%, respectively, in rounds 1 through 4. Using a covariate-adjusted formula for age, age squared, and gender, they demonstrated that differences in myopic proportion were significant in rounds 3 and 4 compared to round 1 (P<0.001). For high myopia, the difference was significant in round 3 (P<0.001). On the other hand, Alvarez-Peregrina et al. and Yang et al. found no difference in myopia percentage pre- and post-confinement (19). In the study of Yang et al. school-based preventive strategies promoting outdoor activities have been implemented since the 2014 academic year (19).

Prevalence and incidence of myopia in each age group before and after the COVID-19 pandemic

In a study performed by Zhang X. et al., the prevalence of myopia in pre-COVID-19 cohorts was 8.48%, 18.03%, and 29.51% in 6-, 7-, and 8-year-old groups, respectively, which increased to 25.45%, 36.80%, and 42.62% in COVID-19 cohorts (P<0.001) (5). In pre-COVID-19 cohorts, the estimated 1-year myopia incidence rates were 16.76%, 15.42%, and 14.66% in 6-, 7- and 8-year-old groups, respectively. In the COVID-19 cohort, the estimated 1-year myopia incidence rates were 27.64%, 26.47%, and 25.81% in 6-, 7- and 8-year-old groups, respectively, suggesting a higher myopia incidence during the COVID-19 pandemic.

Xu L. et al. revealed a significant stable association between the grade of education and myopia and high myopia (13). They showed that the mean prevalence of myopia increased by 8.54% during grades 1 through 6 (stage I) and 4.32% during grades 7 through 12 (stage II). There was an increase in the mean prevalence of high myopia from 4.46% (95% CI: 4.32%-4.6%) during grade 7 to 13.25% (95% CI: 12.95%-13.55%) during grade (12). They considered that grade stage I is a myopia-sensitive stage and grade stage II is a high-myopia-sensitive stage.

In a study carried out by Wang et al., the percentages of myopia equaled 84.89% in high school, 73.39% in junior school, and 39.27% in primary school in 2020 (15). These levels were statistically higher than those reported in 2019 (P<0.05). Wang et al. found an increase in the prevalence of myopia in 2020 compared to 2015-2019 for children at the age of 6 (21.5% vs. 5.7%), 7 (26.2% vs. 16.2%), and 8 (37.2% vs. 27.7%) years (16). The findings for children from the age of 9 to 13 years were insignificant.

As mentioned before, Chang et al. showed a general upward trend in the rates of myopia and high myopia in rounds 1 through 4 (17). They noticed that differences in myopic proportion among different rounds were more remarkable in younger students than older ones. Alvarez-Peregrina et al. compared the percentages of myopes in 2019 and 2020 by age and noticed that these percentages were similar for children from the age of 5 to 7 years (18).

Myopia progression before and after the COVID-19 pandemic

Zhang et al. showed that the estimated annual change in spherical equivalent refraction in the pre-COVID-19 cohort was -0.41 D, which reached -0.80 D in the COVID-19 cohort, indicating a faster progression of myopia during the pandemic (5). They also compared the results with demographically similar studies performed before the pandemic and revealed that the mean spherical equivalent refraction progression over 8 months (-0.50 D) was faster than results reported by Li et al. (-0.27 D) , Liao et al. (-0.31 D), and Hsu et al. (-0.42 D) (20-22). They also evaluated the mean spherical equivalent refraction progression by age. Changes in spherical equivalent refraction were -0.54 D, -0.53 D, and -0.44 D at 6, 7, and 8 years of age, respectively.

In a study performed by Xu et al., 6-month myopia progression increased from -0.23 D pre-confinement to -0.343 D post-confinement (13). Younger children (grades 1 to 6) suffered a faster progression during the pandemic. Wang et al. revealed a lower mean spherical equivalent refraction in 2020 than in 2019 (-1.94±2.13 D vs -1.64±5.49 D) (15). Wang et al. showed that the mean spherical equivalent refraction values from 2015 to 2019 were relatively stable (16). However, there was a substantial myopic shift in 2020, especially for children at the age of 6 (-0.32 D), 7 (-0.28 D), and 8 (-0.29 D) years.

In a study by Aslan et al. in Turkey, the mean annualized progression of myopia in myopic children from the age of 8 to 17 years was compared before and after confinement (23). The Mean±SD annual progression in 2017, 2018, and 2019 was 0.49±0.26 D, 0.41±0.36 D, and 0.54±0.43 D, respectively. This number reached -0.71±0.46 D in 2020 indicating a statistically significant progression (P<0.003).

A higher mean annual myopia progression was reported in a study by Mohan et al. during COVID19 pandemic as compared to the pre-COVID-19 period (0.90 D vs 0.25 D, P<0.00001) (24).

Ma showed a higher progression in myopia during COVID-19 compared to the pre-pandemic period (-0.93±0.65 vs -0.33±0.47 D; P<0.001) (25). In a study conducted by Erdinest et al., 14 children who had been under effective myopia control treatment by atropine 0.01% before the confinement were examined (26). The results showed a Mean±SD increase in spherical equivalent refraction (-0.73±0.46 D) during the COVID-19 lockdown year, implying a decrease in the effectiveness of 0.01% atropine treatment and subsequent myopia progression.

Chang et al. demonstrated that the rate of spherical equivalent refraction change was significantly more negative during the COVID-19 lockdown and more positive afterward (P<0.001) (17). The change was especially noticeable in younger participants. Another study of myopic children in China revealed a significantly greater change in spherical equivalent 4 months after the home quarantine compared to pre-confinement (-0.98±0.52 D vs -0.39±0.58 D; P<0.001) (27). Alvarez-Peregrina et al. showed a significant decrease in spherical equivalent refraction in 2020 compared to the previous year, which was especially remarkable in 5-year-old children (18).

Yum et al. also showed significant differences in the rate of myopic progression before and after the pandemic in children treated with low-concentration atropine (−0.047±0.042 D/m vs −0.067±0.046 D/m; P<0.001), which was most pronounced in lower-grade school-aged children (28).

In the study carried out by Hu et al., the myopic shift of spherical equivalent refraction was -0.31±0.46 D and -0.67±0.56 D in the pre- and post-COVID-19 period, respectively (P<0.001) (14).

Axial length change before and after the COVID-19 pandemic

A higher estimated annual change in the axial length was reported in a study by Zhang et al. in the COVID-19 cohort as compared to the pre-COVID-19 cohort (0.45mm vs 0.28mm, P<0.001) (5). Also, this statistically significant difference was observed when compared to previous demographically similar studies (20-22). The Mean±SD axial length in COVID-19 cohort was higher than the Mean±SD axial length in pre-COVID-19 cohort for children at the age of 6 (23.1±0.74 mm vs 22.70±0.73 mm, P<0.001), of 7 (23.25±0.87 mm vs 22.95±0.80 mm, P<0.001), and of 8 (23.52±0.92 mm vs 23.27±0.85 mm, P<0.001) years (5). Ma et al. compared the mean value of axial elongation before and during the COVID-19 pandemic and found no clinically significant difference (0.23±0.18 mm vs 0.24±0.19 mm) (25). Erdinest et al. reported that the average increase in axial length during the year of lockdown was greater than that in the year before (0.46±0.31 mm vs 0.24±0.21 mm, P<0.001) (26). Yum et al. compared the rates of axial elongation in children treated with low-concentration atropine between the pre- and post-COVID-19 period and showed a faster elongation in the post-pandemic period (0.024±0.015 mm/m vs 0.030±0·020 mm/m, P<0.001) (25). Hu et al. also revealed a faster axial length elongation in children who experienced the COVID-19 pandemic compared to the non-exposure group (0.22±0.21 mm vs. 0.31±0.24 mm, P<0.001) (14).

Table 1. The prevalence of myopia in children in the era of the COVID-19 pandemic.

Study	Methods	Region	Country	Partici-pants n	cyclople-gia	Age	Myopia incidence	Myopia prevalence
Zhang X et al. 2021 (5)	prospective longitudinal cohorts	Asia	Hong Kong	pre-COVID-19 cohort: 1084 COVID-19 cohort: 709	Yes	6-8 years	1 December 2019- 24 January 2020:19.44% 1 July- 31 August 2020:36.57%	pre-COVID-19 cohort: 8.48% COVID-19 cohort: 25.45%
Xu L et al. 2021 (13)	intervention study	Asia	China (Wen-zhou City, Zhejiang Province)	1 001 749	No	7-18 years	half-year incidence rate:pre confinement: 8.5% post confine-ment: 13.62%	June 2019: 52.89% December 2019: 53.9% June 2020: 59.35%
Hu et al. 2021 (14)	observa-tional study	Asia	China	2679	Yes	Grade 2-3 (mean age: 7.76±0.32)	Pre-exposure: 7.5 % Post-expo-sure: 15.3%	November and December 2019: 13.3% November and December 2020: 20.8%
Wang et al. 2021 (15)	survey	Asia	China (Chongqin)	2019:1,733 2020: 1,728	NA	NA	NA	2019: 44.62% 2020: 55.02%
Wang et al. 2021 (16)	prospective cross-sec-tional	Asia	China (Fe-icheng)	64 335	No	6 to 13 years	NA	2019: 5.7%(6 y), 16.2%(7 y), 27.7% (8 y) 2020: 21.5% (6 y), 26.2% (7 y),37.2%(8 y)
Chang et al. 2021 (17)	Cohort	Asia	China (Hangzhou)	29 719	No	NA	NA	R1: 48.0% R2: 53.2% R3: 73.7% R4: 67.9%
Alvarez-Peregrina et al. (18)	cross-sec-tional	Europe	Spain	5827	No	5-7 years	NA	2019: 21% (5y) 17 %(6y), 23 %(7y) 2020: 20 %(5y) 15 % (6y) 24 % (7y)
Yang et al (19)	retrospec-tive cross-sectional	Asia	Taiwan	21 761	Yes	5-6 years	NA	2019: 9.1% 2020: 10.3%

n: numbers; NA: not available; y: years; R: round .

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Changes in lifestyle factors before and after the COVID-19 pandemic and its effects on myopia

Zhang et al. demonstrated significant changes in children's lifestyle factors, including outdoor time, screen time, reading and writing time, and total near-work time during the COVID-19 pandemic (5). They showed that the time spent on outdoor activities decreased by 68% (from 1.27±1.12 to 0.41±0.90 h/day, P<0.001). In addition, screen time, reading and writing time, and total near work time increased dramatically (P<0.001). In the applied multiple logistic models, none of these factors were associated with myopia incidence during the 8-month follow-up period throughout the pandemic period, except for reading time, which was associated with changes in the axial length and spherical equivalent refraction.

Wang et al. showed a positive correlation between the average time spent on outdoor activities and spherical equivalent refraction incidence, reporting that decreased outdoor activity time is associated with myopia progression (15). In addition, they revealed a negative correlation between digital screen exposure time (r=-0.20, P<0.0001), the number of online classes per day (r=-0.33, P<0.0001), and the average duration of online classes (r=-0.27, P<0.0001) with spherical equivalent refraction. Furthermore, the mean spherical equivalent refraction in the computer group (-2.03±2.37 D, P=0.0017) and in the cell phone group (-2.02±2.09 D, P=0.0028) was worse than that in the television group (-1.10±1.49 D).

Ma et al. evaluated the relations of baseline spherical equivalent refraction and changes in lifestyle factors

Table 2. DES symptoms in children in the era of the COVID-19 pandemic

Study	Methods	Country	n	Age	Symptoms
Mohan et al. 2021 (11)	questionnaire-based cross-sectional study	India	217	10-18 years (13±2.45)	Headache (53.9%) Itching (53.9%) Burning (50.93%) Thinking of worsening of Eyesight (49.77%) Watering/tearing from eyes (48.39%) Redness in eyes (44.24%) Heaviness in eyelids (39.17%) Pain in eyes (39.17%) Excessive blinking (39.17%) Dryness in eyes (38.71%) Increased sensitivity to light (35.48%) Blurring of vision (33.18%) Foreign body sensation (29.49%) Difficulty in focusing near the target (27.65%) Seeing halos around objects (20.27%) Double vision (11.1%)
Mohan et al. 2021 (32)	NA	India	46	10 and 17 years (14.47±1.95)	Binocular Accommodation and Vergence Dysfunction
Mohan et al. 2021 (33)	Case series	India	8	12.5±4.2 y	Acute acquired comitant esotropia
Vagge et al. 2021 (34)	Case report	Italy	4	-	Acute acquired concomitant esotropia
Gupta et al. 2021 (30)	cross-sectional survey	India	654	5-18 year (12.02±3.9)	Heaviness of eyelids (79.7%) Heaviness of eye (69.7%) Eye redness (69.1%) Eye strain (68.2%) Eye pain (62.7%) Blinking (57.8%) Blurred vision (56.9%) Light sensitivity (56%) Stinging (47.1%) Burning (46.3%) Difficulty in focusing on near work (41.9%)

n=Participants number.

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(homework and reading, digital screen, and online learning) during the COVID-19 pandemic (25). Their findings showed that the difference in the spherical equivalent refraction alterations was associated with digital screen time (P<0.005) and online education (P=0.02). In another study conducted by Liu, a significant association was found between the progression of myopia symptoms and "Too Dim" or "Too Bright" indoor lighting (29). They also noticed a significant association between each diopter-hour increase in daily e-learning screen use and the progression of myopia symptoms (P<0.001). Furthermore, they found that children who spent more time exercising outdoors were less likely to experience myopia progression.

Alvarez-Peregrina showed a notable decrease in the time spent outdoors in 47% of children during COVID-19 quarantine (P<0.001) (18). A significant number of children increased the time spent on near-work or using electronic devices during home confinement (44% and 33%, respectively). The findings were similar in children of different ages (5, 6, and 7 years old). They also showed that children who spent more time outdoors were less myopic before and after confinement (P<0.001). On the other hand, they did not find any relationship between the time spent on near-work or using electronic devices and myopia post-confinement.

Mohan et al. revealed a statistically significant reduction in sun exposure (P<0.00001) during lockdown which was confirmed as the most important risk factor for the rapid progression of myopia in multivariate analysis (24). They also showed that the duration of mobile game playing increased significantly (P<0.0001) which is associated with rapid myopia progression.

Yum et al. showed that children spent more time on computers, smartphones, and reading and less time on physical activity and outdoor activity during the COVID-19 pandemic compared to the pre-pandemic period (28). They concluded that the quarantine and its related environmental risk factors are possible reasons for a dramatic increase in myopia progression even in children undergoing treatment to slow down the myopia progression.

Digital eye strain

Prevalence of digital eye strain before and after the COVID-19 pandemic

In a questionnaire-based cross-sectional study from India, the prevalence of DES during the COVID-19 pandemic was reported to be 50.23%, which is dramatically higher than that of previous studies before the COVID-19 outbreak. Of these, 26.3%, 12.9%, and 11.1% were of mild, moderate, and severe grades, respectively (11). Gupta et al. showed that 92.8% of children experienced DES symptoms during the COVID-19 pandemic (30). In another questionnaire-based cross-sectional study from China, the prevalence of computer vision syndrome during the COVID-19 pandemic was reported to be 77.0% (31).

Changes in lifestyle factors before and after the COVID-19 pandemic and its effects on digital eye strain

Mohan et al. showed that the time children spent on digital devices increased from 1.9±1.1h in the pre-COVID period to 3.9±1.9h in the post-COVID period (P≤0.0001) (32). In addition, compared to the pre-COVID period, more children spent 5h on digital devices (36.9% vs 1.8%). They found that DES was significantly associated with digital device distance <18 inches (P=0.09, OR=1.65), mobile games more than 1 h/day (P<0.0001, OR=16.69), using digital devices more than 5h (P<0.0001, OR=3.38), and using smartphones (P=0.01, OR=1.98). Independent risk factors for DES were determined by multivariate analysis and included playing mobile games for more than 1 h/day (P=0.0001), using digital devices for more than 5 h/day (P=0.0007), and using smartphones (P=0.003).

Mohan A. et al. showed a statistically significant increase in the mean duration of online classes during the COVID-19 pandemic (3.08±1.68 h/day vs 0.58±0.71 h/day, P<0.00001) (32). Furthermore, they concluded that online classes longer than 4hwere a significant risk factor (P=0.07) for abnormal binocular vergence and accommodation parameters.

In another study, Mohan A. et al. reported 8 cases of acute acquired comitant esotropia in the COVID era who spent a long time on digital devices (smartphone=4.6+0.7 h/day, online classes >4 h/day on the smartphone) (33). On the other hand, only 1 case with such a problem was reported 2 months before the confinement. Vagge A. et al. also reported 4 cases of acute acquired comitant esotropia in Italy because of excessive near-work time during the COVID-19 quarantine (34). Gupta et al. found a significant positive correlation between computer vision syndrome score and digital device time exposure (P<0.001) (30). In this study, 56.9% of children used digital devices more than 4 h/day during the COVID-19 quarantine.

Digital eye strain symptoms during the COVID-19 Pandemic

DES symptoms in children during the COVID-19 pandemic are provided in Table 2. Mohan A. et al. reported itching and headache as the most common symptoms among children using online e-learning during the COVID-19 quarantine (11). The most common DES symptoms in Gupta et al. study include the heaviness of eyelids (79.7%), the heaviness of the eye (69.7%), and eye redness (69.1%) (30). Two studies reported cases with acute acquired comitant esotropia during the COVID-19 lockdown in children with excessive near work. Mohan A. et al. reported abnormal binocular vergence and accommodation in children attending online classes during lockdowns because of the COVID-19 pandemic (32).

4. Discussion

Studies performed during the COVID-19 pandemic have shown an increase in myopia prevalence, incidence, and progression in children, especially in young children (5, 13-18, 23-28). Strategies imposed by governments to control the spread of COVID-19 during confinement have led to dramatic changes in children's lifestyles. These measures have compelled children to restrict outdoor activities and increase their near-work time (e.g., online e-learning), which contributes to the increase of DES and myopia progression (5, 11, 15, 18, 24, 25, 28-30, 32-34). These factors indicate that we are facing a new problem regarding children's visual health because of this pandemic, which may continue or repeat in the future.

To prevent structural and functional disabilities because of the abovementioned problems, we should obtain detailed information about these problems and introduce appropriate approaches to resolve them. Therefore, we should consider some specific points. Several studies reviewed in this paper were performed without cycloplegia, biometric, or keratometric examinations (13, 16-18). Considering these factors would result in a more accurate measurement of myopia prevalence and distinguishing myopia from pseudomyopia, which requires different approaches. The data on children's lifestyles, including time spent performing near-work and outdoor activities, were acquired by questionnaires or self-reports (5, 11, 15, 18, 19, 24, 25, 28, 29, 32-34). This means there could be recall bias, which should be dealt with in future studies. Moreover, the majority of studies did not include very young children, such as preschool children, as a sensitive group to myopia progression (5, 13-18, 23-27). Furthermore, other risk factors for myopia progression, such as baseline spherical equivalent refraction, baseline axial length, the family history of myopia, different seasons, low sleeping hours, lack of physical activity, and abnormalities in the nutritional intake should be considered. In addition, the majority of the studies reviewed in this study are conducted in East Asian countries (5, 13-17, 25, 27, 28). Since the prevalence of myopia in East Asian countries is significantly greater than those of other countries, additional studies should be conducted on other ethnicities to obtain more accurate epidemiological data. It seems that conducting well-designed multicenter and large-sample studies in the future considering these limitations can provide more conclusive results.

This review can serve as a warning to policymakers, health professionals, teachers, parents, and children about the effects of pandemics, such as COVID-19, on children's visual health. Defining guidelines for the duration and type of digital device usage, preparing a creative holistic home-based learning curriculum, digital detox, shaping long-term behavioral modifications, replacing intelligent lockdown with traditional ones, and preparing post-pandemic ophthalmological surveillance programs for children with DES and myopia might be helpful to reduce these problems (5, 25, 35, 36).

5. Conclusion

Children's eye health can be influenced by the COVID-19 outbreak. The prevalence, incidence, and progression rates of myopia, as well as DES prevalence, have been demonstrated to increase in children during the COVID-19 pandemic. Lifestyle changes imposed by confinement (including restricted outdoor activities and increased near-work time) seemingly contributed to these changes. All of these can serve as a warning to policymakers, health professionals, teachers, parents, and children about the effects of pandemics, such as COVID-19, on children's visual health and the need to implement preventive and therapeutic measures. However, considering the limitations mentioned above, It seems that conducting well-designed multicenter and large-sample studies in the future can provide more conclusive results.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflicts of interest

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