



Stay-at-home myopia among school children during the COVID-19 pandemic

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ABSTRACT

Background: Uncorrected myopia represents a major cause of visual disability in children, especially in low-income and middle-income countries. However, there is still debate about the effect of e-learning and “stay-at-home” guidelines on the refractive status of school children, especially in the absence of long-term follow-up data. This study aimed to assess the impact of stay-at-home enforcement during the COVID-19 pandemic on myopia development or progression in students in the Suez Canal Area, Egypt.

Methods: This longitudinal observational study included 1650 students. All students aged 8–15 years with visual complaints, who had attended routine annual vision checks since 2018, were enrolled and assessed annually for myopia development and progression until 2021. Cycloplegic and noncycloplegic refraction, axial length (AL), corneal curvature, and uncorrected and best-corrected distance visual acuity were measured. The participants were administered a questionnaire that focused mainly on collecting information on their visual habits.

Results: Our study included 3,300 eyes of 1,650 school students with myopia during the 4-year study period from 2018 to 2021. The mean cycloplegic spherical equivalents (CSE) were - 1.02, - 1.52, - 2.00, and - 3.50 diopters (D) in 2018, 2019, 2020, and 2021, respectively. This myopic shift in CSE over time was significant ($P < 0.001$). The average keratometric reading (Avg K) increased significantly during the follow-up period ($P < 0.001$). The Avg K measurements were 42.32, 42.62, 43.02, and 44.19 D in 2018, 2019, 2020, and 2021, respectively. The changes in Avg K were significant ($P < 0.001$). The mean AL measurements were 22.53, 22.59, 22.69, and 22.71 mm in 2018, 2019, 2020, and 2021, respectively. Although statistically significant ($P < 0.001$), changes in AL were clinically insignificant throughout the study period. The mean durations spent on electronic devices at home were 2.12, 2.46, 3.10, and 6.00 hours in 2018, 2019, 2020, and 2021, respectively. The changes over time were significant ($P < 0.001$).

Conclusions: During the COVID-19 pandemic, studying at home accelerated the degree of refraction toward myopia in school children in Egypt. Further studies are needed to assess the academic performance of students with progressive myopia.

KEYWORDS

myopia, stay at home orders, health lockdown, COVID-19 pandemic, corneal topography, eye axial length, visual acuity, ocular refraction

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INTRODUCTION

With the increasing adoption of technology and digital devices in education, e-learning has become prevalent worldwide and mandatory during the coronavirus disease 2019 (COVID-19) pandemic [1]. E-learning has become a daily activity for students and teachers, rapidly overcoming the time spent outdoors in most life aspects [2].

The prevalence of myopia has progressively increased in recent decades. Lifestyle factors, such as urbanization, lack of outdoor exposure, near work duration, and near working distance, are risk factors for myopia [3, 4]. Moreover, eye fatigue and asthenopia have been associated with online learning [5]. The earlier myopia begins, the greater the myopic shift and burden of myopia [6].

During the COVID-19 pandemic, governments worldwide provided distance education for children to study at home [7]. According to the United Nations, the COVID-19 pandemic has created the largest disruption of education systems in history, affecting approximately 1.6 billion learners in over 190 countries [8]. Home confinement affects children's eye health in the form of myopia development or progression [9]. A recent study suggested that COVID-19 pandemic-related home confinement was associated with a substantial myopic shift in school children [10, 11].

Uncorrected myopia, especially in low- and middle-income countries, is a major cause of visual disability in children [12]. The high rate of myopia in the current pediatric population may lead to a high risk of sight-threatening complications in the future elderly generation [9]. However, there is still debate about the effect of e-learning and stay-at-home guidelines on the refractive status of school children, especially in the absence of long-term follow-up data [13].

In this study, we investigated the effect of long-term online learning and the use of electronic devices during the COVID-19 pandemic on refractive changes among school children in the Suez Canal area.

METHODS

This longitudinal observational study initially included 1850 school students within the Suez Canal area, Port-Said, Ismailia, and Suez Governorates. The climate, socioeconomic status, diet, and culture of the three cities are similar [14]. All students aged 8–15 years with complaints of blurred vision or eye strain, and who had attended routine annual vision checks since 2018, were enrolled and assessed for myopia development and progression until 2021. In 2020, schools were closed from March to October, and hybrid education strategies have been applied from October 2020 to the present. Online learning was the main educational tool used at the beginning of the pandemic lockdown.

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Suez Canal University, and was conducted in accordance with the tenets of the Declaration of Helsinki. After an explanation of the study design to the parents and children, informed written consent was obtained from the parents of the children who participated in the study.

Students were included if they had myopia ranging from -0.50 to -5.00 diopters (D) on initial examination, or a spherical equivalent up to -5.50 D. Students were excluded from analysis if they had hyperopia, anisometropia > 2 D, myopia > -6 D at the start of the study, an average keratometric reading (Avg K) > 47 D, amblyopia, strabismus, or convergence insufficiency; were using eye drops for chronic ocular disease; wore contact lenses; or had a history of ocular surgery. A total of 1650 students (3300 eyes) out of the initial 1850 students (3700 eyes) were eligible for enrollment in the study (Figure 1).

A comprehensive eye examination was performed for each eye of each student, including the measurement of uncorrected and best-corrected distance visual acuity (UCDVA and BCDVA, respectively), auto-refractometry, assessment of ocular motility, slit-lamp examination of the anterior ocular segment, and fundus examination. Visual acuity was measured using a tumbling-E optotype chart and decimal notation. Refraction and keratometric readings were assessed in noncycloplegic and cycloplegic states using auto-refractokeratometry (auto-refractor KR-8900, Topcon, Tokyo, Japan; Huvitz HRK-7000A Autorefractor/Keratometer, Huvitz Co., Ltd., Gunposi, Gyeonggi-do, Korea). The same auto-refractokeratometry instrument was used during the follow-up period for any given student.

Axial length (AL) was measured using a LENSTAR 900 optical biometer (Haag-Streit, USA). Cycloplegia was induced using topical cyclopentolate 1% eye drops (Plegica 10 mg, EPCI Pharmaceutical, Egypt) applied as one drop every 10 min for 30 min. The manifest spherical equivalent (MSE) and cycloplegic spherical equivalent (CSE) of the refractive error were calculated as the spherical refractive error added to the 1/2 cylindrical refractive error. All examinations were performed by an experienced ophthalmologist at baseline and follow-up.

Owing to the COVID-19 pandemic, all examiners were trained to perform the examination observing all the recommended safety measures. The average numbers of daily outdoor and indoor activity hours were recorded for each student, based on the history taken from the parents.

Statistical analyses were performed using a commercially available statistical software package (SPSS for IOS, version 26.0, IBM Corp., Armonk, NY, USA). The sociodemographic and clinical characteristics of all the participants are presented. Normality of data distribution was assessed using the Kolmogorov–Smirnov test. The variables are presented as mean (range). The chi-square test was applied for categorical variables and the Student's *t*-test for quantitative variables. Serial changes in outcome measures were compared using repeated-measures analysis of variance and Tukey's honestly significant difference post-hoc analysis. The correlations between CSE and changes in Avg K, AL, and student age were determined using Pearson's product-moment correlation. Statistical significance was set at $P < 0.05$.

RESULTS

Over the study years of 2018 to 2021, a total of 1850 students were recruited; 150 were excluded from the initial screening, as detailed in Figure 1. Furthermore, 50 students were excluded because of amblyopia ($n = 20$), an Avg K reading > 47 D ($n = 10$), or loss to follow-up ($n = 20$). Finally, 1650 students (3300 eyes) were included in the analysis (Figure 1).

Table 1 summarizes the clinical and demographic characteristics of the study participants at baseline and follow-up. There was a significant decrease ($P < 0.001$) in UCDDVA from 2018 to 2021. Additionally, the number

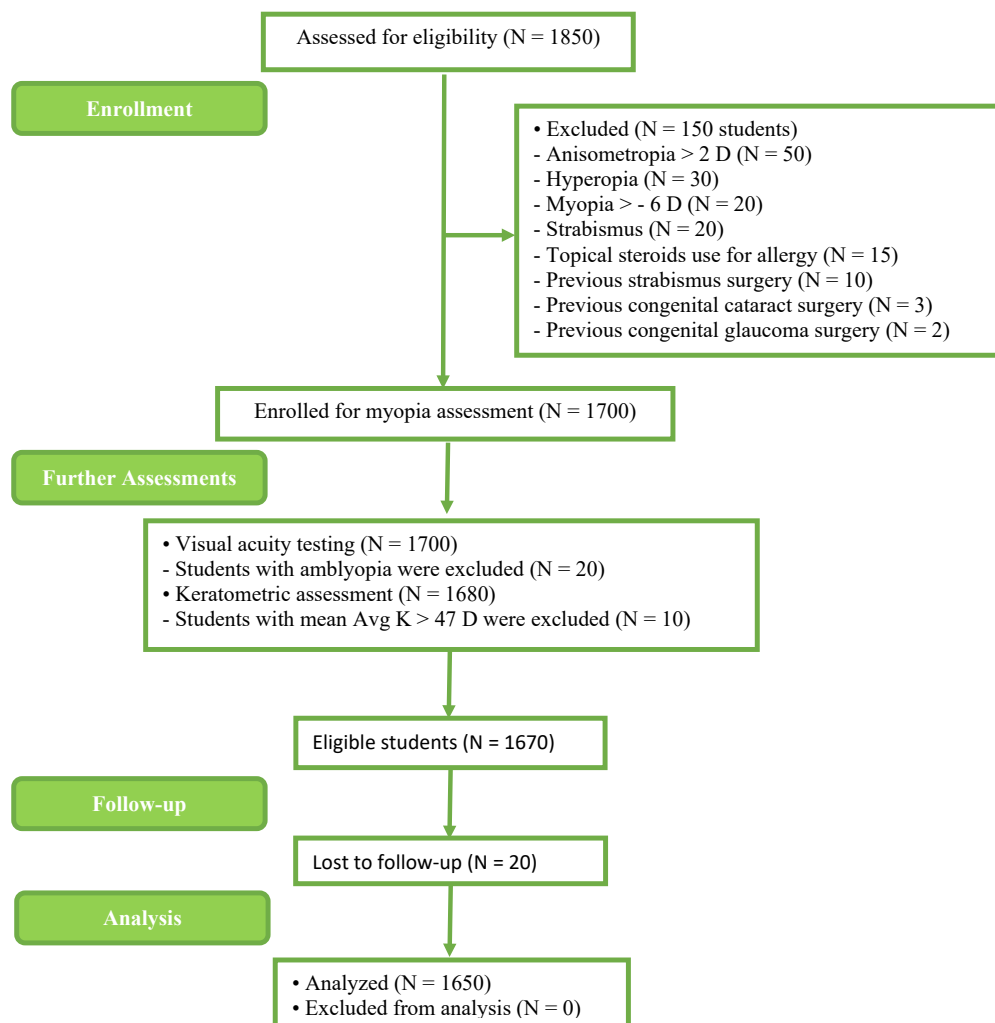


Figure 1. Flow chart outlining the study profile. Finally, 1650 students were valid for the analysis. Abbreviations: N, number of students; D, diopters; Avg K, average keratometric reading.

Table 1. Demographic and clinical characteristics of the participants throughout the study years

Variable	Year of Study	Value
Participants (n), Students / Eyes	2018–2021	1650 / 3300
Sex (Male / Female), n (%)	2018–2021	750 (45.5) / 900 (54.5)
Laterality (OD / OS), n (%)	2018–2021	1650 (50) / 1650 (50)
Age (y), Mean (Range)	2018	9.82 (8 to 12)
	2019	11.21 (9 to 13)
	2020	11.84 (10 to 14)
	2021	13.37 (11 to 15)
Daytime electronic device use (h), Mean (Range)	2018	2.12 (1 to 3)
	2019	2.46 (1 to 3)
	2020	3.10 (1 to 4)
	2021	6.00 (4 to 8)
UCDVA (decimal), Mean (Range)	2018	0.38 (0.0 to 0.9)
	2019	0.35 (0.0 to 0.9)
	2020	0.28 (0.0 to 0.8)
	2021	0.17 (0.3 to 0.5)

Abbreviations: n, number; %, percentage; OD, right eye; OS, left eye; y, years; h, hours per day; UCDVA, uncorrected distance visual acuity. Note: The mean best-corrected distance visual acuity was 0.0 in decimal at all follow-ups.

Table 2. Comparison of the yearly differences in UCDVA, hours of electronic device activities, CSE, Avg K, and AL among study participants

Variables	2018–2019 Mean (Range)	2019–2020 Mean (Range)	2020–2021 Mean (Range)	P	P ₁	P ₂	P ₃
UCDVA (Decimal)	0.03 (0.01 to 0.06)	0.7 (0.6 to 0.8)	0.11 (0.8 to 0.14)	0.045	< 0.001	< 0.001	< 0.001
Daytime Electronic Device Use (h)	0.52 (0.26 to 1.10)	0.64 (0.32 to 1.28)	2.9 (1.45 to 5.80)	< 0.001	< 0.010	< 0.001	< 0.001
MSE (D)	-0.58 (-1.16 to -0.29)	-0.67 (-1.35 to -0.34)	-2.25 (-4.50 to -1.13)	< 0.001	< 0.005	< 0.001	< 0.001
CSE (D)	-0.51 (-1.00 to 0.00)	-0.48 (-1.00 to 0.00)	-1.50 (-2.25 to -0.50)	< 0.001	0.002	< 0.001	< 0.001
Avg K (D)	0.30 (0.25 to 0.50)	0.40 (0.25 - 0.50)	1.26 (1.00 to 2.00)	< 0.001	0.006	< 0.001	< 0.001
AL (mm)	0.05 (0.02 to 0.15)	0.10 (0.03 to 0.22)	0.11 (0.03 to 0.36)	< 0.001	0.004	< 0.001	< 0.001

Abbreviations: UCDVA, uncorrected distance visual acuity; CSE, cycloplegic spherical equivalent; Avg K, average keratometric reading; AL, axial length; h, hours per day; MSE, manifest spherical equivalent; D, diopters; mm, millimeters. Note: P-values < 0.05 are shown in bold; P-values are based on post-hoc analysis: Tukey's honestly significant difference (HSD); P (based on ANOVA test), comparisons across all groups; P₁, comparison between 2018–2019 versus 2019–2020; P₂, comparison between 2018–2019 versus 2020–2021; P₃, comparison between 2019–2020 versus 2020–2021.

of hours during which students engaged in electronic device activities had increased significantly ($P < 0.001$) at the end of follow-up (Table 1).

The mean (range) CSE was -1.02 (-2.5 to 0.0), -1.52 (-3.00 to 0.0), -2.00 (-3.75 to 0.0), and -3.50 (-5.5 to -1.75) D in 2018, 2019, 2020, and 2021, respectively, indicating a significant myopic shift over the years ($P < 0.001$). Avg K increased over the follow-up period. The mean (range) Avg K was 42.32 (40.5 – 45.00) D in 2018, 42.62 (40.75 – 45.50) D in 2019, 43.02 (41.25 – 46.00) D in 2020, and 44.19 (41.25 – 47.00) D in 2021; the changes in Avg K were significant ($P < 0.001$). The mean (range) AL was 22.53 (21.35 – 23.50), 22.59 (21.45 – 23.55), 22.69 (21.56 – 23.60), and 22.71 (21.60 – 23.65) mm in 2018, 2019, 2020, and 2021, respectively. The increase in AL from 2018 to 2021 was statistically significant ($P < 0.001$) but clinically insignificant.

Linear regression analysis revealed that CSE had a significant low positive correlation with changes in Avg K ($r = +0.35$; $P < 0.001$) and AL ($r = +0.38$; $P < 0.001$), but not with student age ($r = 0.00$; $P = 0.994$).

Post-hoc analyses of the differences in UCDVA, hours of electronic device activities, MSE, CSE, Avg K, and AL over the follow-up years are presented in Table 2. There was a significant increase in the number of hours spent on electronic device activities ($P < 0.05$) throughout the 4-year observation period. Moreover, changes in MSE, CSE, AL, and Avg K were significant during the same period ($P < 0.001$) (Table 2). Pairwise comparisons between the two groups showed significant differences in the above variables (Table 2).

DISCUSSION

This longitudinal observational study included 3300 eyes of 1650 school students who were followed for myopic progression over a 4-year period (2018–2021). Our observations confirmed that online e-learning activities and the use of electronic devices impacted myopia progression among school children aged 8–15 years. We measured refraction using an autorefractor, and we used cycloplegic refraction as an indication of the true refractive state of the students' eyes. The use of an autorefractor without cycloplegia in children with more powerful accommodation than older people may overestimate myopia [15, 16].

In Egypt, according to the instructions of the Ministry of Education, schools closed early in the pandemic on March 14, 2020, and moved to complete online learning at the end of the academic year. Subsequently, a hybrid education strategy was applied during the second academic year until June 2021 [17].

Our results indicated a significant increase in the hours spent by students on electronic device activities, either by e-learning or playing games, in the pandemic year (2020). Previous studies have reported an increase in children's indoor activities and screen time, and a decrease in outdoor activities, often to none [18, 19]. Decreasing outdoor activities was significantly associated with a higher incidence of myopia in school-aged children [20, 21].

The UCDDVA of our students significantly decreased during the pandemic year compared to that recorded in previous years. In a study conducted in China to assess the effects of an e-learning environment on the visual function of students, the authors reported that an e-learning environment resulted in higher grades but worse visual acuity [22]. However, Wang et al. found that younger children were more sensitive to the environmental changes associated with e-learning than older children [10].

Our study revealed that female myopes (54.5%) were more common than male myopes (45.5%). Similar sex differences in myopia development or progression have been reported in other studies [10, 23]. In a series of population-based prevalence surveys conducted over a 13-year period, female sex was found to be an important risk factor for myopia [24]. Other studies showed that girls had steeper corneas, shallower anterior chambers, steeper lens powers, and shorter ALs than boys [25, 26]. This may be related to estrogen level changes and the development of puberty [27].

Myopia, measured by CSE in our study, progressed during the last follow-up year (the year of the lockdown) compared to measurements of the previous years. This concurs with the results of Wang et al., who reported a slight overall myopic shift among school children from 2015 to 2019, but a substantial myopic shift (approximately 3.00 D) during the 2020 lockdown [10]. Additionally, Enthoven et al. concluded that increased computer use was associated with myopia development [28]. Moreover, a prospective controlled study conducted by Hepsen et al. suggested that environmental factors such as reading and near work might cause refractive myopic shifts in emmetropic students [29].

In our study, we measured Avg K and AL for all students during the study period to determine which variable might have a larger impact on myopic progression during the 2020 pandemic year. We found a statistically significant elongation in AL and steepening of Avg K. However, the changes in AL were clinically insignificant in contrast to the changes in Avg K. Moreover, large sample sizes tend to decrease *P*-values toward 0; thus, solely relying on *P*-values can lead to unjustified support for results of limited to no clinical significance [30]. Additionally, Bach et al. concluded that a major increase in AL occurred during the first 10 months of life. After 36 months, there was no statistically significant AL increase [31].

Epidemiologic population-based studies in children under the age of 15 years have shown that corneal power reaches a stable level after the age of 3 years and during school-age years, while no significant changes occur thereafter [32]. Other studies have reported that the mean keratometric power ranges between 42 and 44 D from birth to 10 years of age, and corneal power does not change with age [32, 33]. Based on these facts, together with the clinically insignificant change observed in AL among our students, the change in refraction could be attributed to the increase in Avg K due to the efforts spent by the students during near work activities. Ocular surface dryness and frequent rubbing, both of which are associated with prolonged electronic device and screen use, might be the cause of the change in keratometry [34–36]. Lu et al. concluded that tear film disruption makes the optical surface irregular and may cause aberrations or unpredictable keratometry measurements [37]. Additionally, Chervenkov et al. reported a significant change in central anterior K readings in healthy eyes following eye rubbing [38].

Our study confirmed a significantly larger MSE than CSE when compared annually during the follow-up period. Additionally, the myopic difference between MSE and CSE during the 2020 pandemic year was nearly double that recorded in previous years. This indicates that asthenopia that developed due to ciliary spasm occurred as a result of prolonged e-learning and screen time [39].

A strength of our study is its longitudinal design, as students were followed up over a 4-year period, and all parameters were measured at each visit. Additionally, we used cycloplegic refraction as a true indicator of the refractive state of our study participants. Another strength is that our study provides information about biometric measurements of the eye and their effects on indoor and e-learning activities. We use the term “stay-at-home myopia,” as this progression of myopia was linked to the prolonged time spent at home by students in the last two years as a strategy to control the spread of COVID-19. This lockdown affected nearly 1.6 billion learners in more than 190 countries, and the effects are expected to continue for many years as we grapple with the ever-evolving pandemic [8, 40].

Our study had certain limitations. First, due to technical difficulties and difficulty in assessing refraction, Avg K, and AL, preschool-aged children were excluded. However, it would be beneficial for future studies to determine the responses of younger children to the environmental changes. Second, our study did not assess the impact of myopic progression on students’ academic performance. Future studies addressing these limitations could improve our understanding of the risk factors associated with myopia progression in childhood due to home confinement.

CONCLUSIONS

E-learning and electronic device activities during the COVID-19 pandemic accelerated the myopic shift in the 4-year follow-up among school children in Egypt. Further studies are needed to assess the academic performance of students with progressive myopia.

ETHICAL DECLARATIONS

Ethical approval: This study was approved by the Research Ethics Committee of the Faculty of Medicine, Suez Canal University, and was conducted in accordance with the tenets of the Declaration of Helsinki. After an explanation of the study design to the parents and children, informed written consent was obtained from the parents of the children who participated in the study.

Conflict of interests: None

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