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Effect of COVID-19 lockdown on refractive errors in Italian children aged 5–12 years: A multi-center retrospective study

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Abstract

Purpose: to explore the potential consequences of the COVID-19 lockdown on the prevalence of myopia among Italian children aged 5–12 years.

Materials and Methods: retrospective multicenter study conducted in Italy. Population: children aged 5–12. Selection: random selection of children who received an eye exam between 2016 to 2021. Inclusion criteria: healthy children presenting for a routine eye exam. Exclusion criteria: presence of ocular comorbidities other than refractive error, such as blepharoptosis, media opacities, corneal or retinal dystrophies, strabismus, amblyopia, or concurrent therapy with atropine 0.01%. Outcome measure: age and spherical equivalent (SE) measured in diopters (D) in the right eye (RE) in cycloplegia. Statistical analysis: ANOVA test.

Results: total of 803 children. In the years prior to COVID-19, the mean SE $\pm$ SD of healthy age-school children was: 0.54 $\pm$ 1.49 D in 2016; 0.43 $\pm$ 1.84 D in 2017; 0.34 $\pm$ 1.41 D in 2018; 0.35 $\pm$ 1.75 D in 2019 (ANOVA, $p = .659$). In 2021, the mean SE changed to –0.08 $\pm$ 1.44 D (ANOVA, $p = .005$). Mean age was comparable in all groups (ANOVA, $p = .307$). The prevalence of myopes (SE $\leq$ –0.5D) and hyperopes (SE $\geq$ 2D) was respectively 24.10% and 9.64% among children aged 60–96 months, and 63.86% and 6.02% among children aged 97–144 months. These values represent a statistically-significant increase in the number of myopes (Chi-square, $p = .016$) and decrease in the number of hyperopes (Chi-square, $p = .001$), as compared to previous years (.06 and.48 respectively).

Conclusion: this retrospective study shows a statistically-significant decrease in the mean SE in children aged 5–12 in the year following the COVID-19 lockdown. The percentage of myopes has increased significantly, while the percentage of hyperopes has decreased. The lifestyle changes caused by the lockdown led children to spend more time on near-work activities and digital devices, and less time outdoors. These are known risk factors for the development and progression of myopia. Studies in different countries are encouraged.

Keywords

covid19, lockdown, near-work, myopia, myopization, children

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Key points

Question: has the COVID-19 quarantine increased the prevalence and/or incidence of myopia among Italian age-school children?

Findings: this multi-center retrospective study analyzed the mean spherical equivalent of groups of age-school children each year since 2016. In 2021, the mean spherical

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equivalent decreased by 0.619 and 0.501 diopters, as compared to 2016 and 2017 respectively. This change was associated with an increase in the percentage of myopes from 25.63% (in 2016) and 33.10% (in 2017) to 40.56% in 2021.

Meaning: home confinement due to COVID-19 substantially increased the incidence of myopia among age-school children. Stratified analysis showed that children aged 9–12 were the most affected.

Introduction

Myopia is currently affects 2.5 billion people worldwide and its prevalence continues to increase.[1] The World Health Organization (WHO) has estimated that around half of the world's population will be myopic and 9.8% will be highly-myopic by 2050.[2,3] High-myopia, which is generally defined as spherical equivalent (SE) of −6 diopters (D) or less, leads to significant visual impairment without refractive correction, and increases the risk for sight-threatening comorbidities, such as glaucoma, cataract, retinal tears, myopic maculopathy, and myopic macular degeneration.[4,5] The causative factors of myopia are still poorly understood, but probably include both genetic and environmental elements. Prolonged near-vision eye use has been found to be an important indipendent risk factor.[6–9] It causes ciliary muscles to thicken and is associated with an increase in axial length.[7,10] Near-vision electronic display stimulation can result in extended exposure to hyperopic defocus, which has been shown to trigger compensating axial myopic eye growth.[11,12] Among the general population, digital screen use has been identified as an important risk factor causing vision disorders among children.[13] Duration of computer use is in fact positively associated with vision disorder progression.[14–17]

In 2019, several countries had to adopt drastic measures to limit the spread of the SARS-CoV-2 virus. During the peak months of viral transmission, 192 countries/territories elected to close schools and about 1.5 billion children were instructed to stay at home to minimize contacts with others. Schoolwork continued remotely with the aid of computers and tablets. This represented a major change in children's lifestyles. The average child increased digital screen use, as well as the overall time spent on near-work activities.[18] As stated previously, these are all recognized risk factors for the development and progression of myopia.[19–23] Some authors already suspected possible consequences of home confinement on the refractive errors of children. Klaver C.C.W. et al. (2021)has been the first scientist to coin the term "quarantine myopia" to describe this alarming phenomenon.[24]

The above considerations and hypotheses led the authors to conduct a multi-center retrospective study to estimate the prevalence of myopia among Italian age-school children in 2021 and compare this value with that in the years before the COVID-19 pandemic.

Materials and methods

Study type

Multi-center retrospective study

Population. Healthy children aged 5 to 12. Children with organic pathologies, such as blepharoptosis, media opacities, strabismus, amblyopia, corneal and retinal dystrophies have been excluded. Patient enrollment was conducted using the criteria listed below.

Power size estimation. Estimating a power of 80%, alpha error of 0.05 and an expected difference of 0.25 in the mean SE before and after the lockdown, it was estimated a priori that 120 subjects would be needed in each group to detect a statistically-significant difference between years.

Patient selection and data collection. Authors first obtained a numbered list of all outpatient visits of each calendar year since 2016. The year 2020 was purposefully excluded from this analysis for two reasons: 1) scarcity of data that could introduce a selection bias, and 2) the likelihood that most children had an accommodative spasm during the lockdown year, as suggested by a Singapore study.[25] The number of visits in a given year (e.g. 10,000) was converted in range format: e.g. 1–10,000. The online tool "Research Randomizer" (https://www.randomizer.org/) was used to draw participants from the given range. Each child was verified to meet the inclusion and exclusion criteria listed below. Data of the right eye (RE) only were retrieved from each patient.

Inclusion criteria

- Age 5–12 years (60–144 months);
- Any gender and race;

Exclusion criteria

- Best corrected visual acuity greater than 0 LogMAR;
- Spherical equivalent greater than 4D or lower than −4D in the RE;
- Presence of heterotropia, amblyopia or nystagmus;
- Presence of ocular or systemic conditions that can affect the refractive error of the eye or its axial development;
- Presence or family history of keratoconus;
- Presence of ptosis;
- History of ocular surgeries;
- Astigmatism greater than 3D;
- Use of 0.01% atropine drops;
- Cycloplegic refraction not available;

Outcome variables

- Age (in months) at the time of the visit;
- Sphero-equivalent (SE) in the right eye (RE) under cycloplegia;

Definitions

Myopia is defined as a SE of −0.50D or less under cycloplegia;
Hyperopia is defined as a SE of + 2.00D or more under cycloplegia;

To achieve cycloplegia, two drops of 1% cyclopentolate were instilled 5 min apart, and a third drop was administered if a pupillary light reflex was still present after 15 min. Cycloplegia was determined as the absence of pupillary light reflex. Cycloplegic refraction was performed by means of retinoscopy by the same refractionist and autorefraction (Nidek ARK1-S, Nidek, San Jose, CA, USA).

For the sake of simplicity, the groups labeled as “2016”, “2017”, “2018”, “2019”, will also be referred to as the pre-lockdown groups. On the other hand, the “2021” group will also be referred to as the post-lockdown group.

Ethnic grouping. Ethnic stratification was performed to account for the different prevalence of myopia in different ethnicities. For this reason, subjects were grouped by their ethnic descent (as reported in their medical records or presumed by their family name). Those with reported or presumed family origins in Far East Asia or Southeast Asia were labeled as “Asians”.

Statistical analysis. ANOVA, Chi-square, and post-hoc Tukey tests. Significance was set at $P < 0.05$. The statistical analysis was conducted using JASP 0.16.[26]

Results

Demographic and baseline data

Table 1 includes the baseline demographic characteristics of each of the five groups. A total of 803 healthy children were recruited in this study. The proportions of males and females were comparable among groups (Chi-square, $p = .775$). The same applies to the mean age (ANOVA, $p = .307$). The percentages of myopes and hyperopes were comparable in each year prior to the lockdown (Chi-square, $p = .063$ and.488 respectively). The percentage of “Asians” was also comparable (Chi-square, $p > .05$). However, the percentage of myopes and hyperopes in the post-lockdown group is statistically different from that of previous years. The post-lockdown group, in fact, shows a higher percentage of myopes (Chi-square, $p = .016$) and a lower percentage of hyperopes (Chi-square, $p = .001$). These findings correlate with a decrease in the mean spherical equivalent in the post-lockdown group, as compared to previous years, as shown in Figure 1 (ANOVA, $p = .005$).

Different results were obtained after subgroup analysis. Table 2 and 3 show respectively the percentages of myopes and hyperopes among children aged 60–96. The change in the mean SE between pre-lockdown and post-lockdown children was not significant (ANOVA, $p = .150$). Accordingly, the percentage of myopes, defined as SE ≤ -0.50D, did not change significantly (Chi-square, $p = .267$). However, the percentage of hyperopes defined as SE $\geq + 2.00$D in 2021 was lower as compared to previous years and this change was statistically significant (Chi-square, $p = .016$).

Table 4 and 5 show respectively the percentages of myopes and hyperopes among children aged 97–144. The change in the mean SE between pre-lockdown and post-lockdown children was statistically significant (ANOVA, $p = .038$). The same significance applies to the increase in percentage of myopes (Chi-square, $p = .038$). The percentage of hyperopes defined as SE $\geq + 2.00$D did not change significantly (Chi-square, $p = .109$).

Figures 2–6 show the correlation between age and spherical equivalent in each group. All charts show a negative correlation between age and spherical equivalent ($p < .001$). However, Figure 6 shows that the post-lockdown group has more negative correlation coefficients, as compared to those of previous years.

The post-hoc analysis using the Tukey’s test showed a statistically-significant decrease of the mean SE in the post-lockdown year, as compared to the pre-lockdown years 2016 and 2017. The mean change was calculated as −0.619 D [-1.091, −0.147] 95% C.I. and −0.501 D [-0.986, −0.016] 95% C.I. respectively (Table 5) (Tukey, $p < .05$).

Table 1. Demographic data of each group prior to age stratification.

Group	Size	M-F (%)	Asians (%)	Age ± SD (months)	SE ± SD (D) in the RE	Myopes (%)	Hyperopes (%)
2016	160	55-45%	8 (5.0%)	97.83 ± 22.91	0.54 ± 1.49	25.63%	20.00%
2017	145	52.4-47.6%	7 (4.8%)	99.33 ± 23.76	0.43 ± 1.84	33.10%	23.45%
2018	152	48-52%	8 (5.3%)	98.20 ± 23.20	0.34 ± 1.41	28.29%	16.45%
2019	166	52.4-47.6%	10 (6.0%)	102.21 ± 22.22	0.35 ± 1.75	38.55%	18.68%
2021	180	50-50%	9 (5.0%)	97.33 ± 22.72	-0.08 ± 1.44	40.56%	7.22%

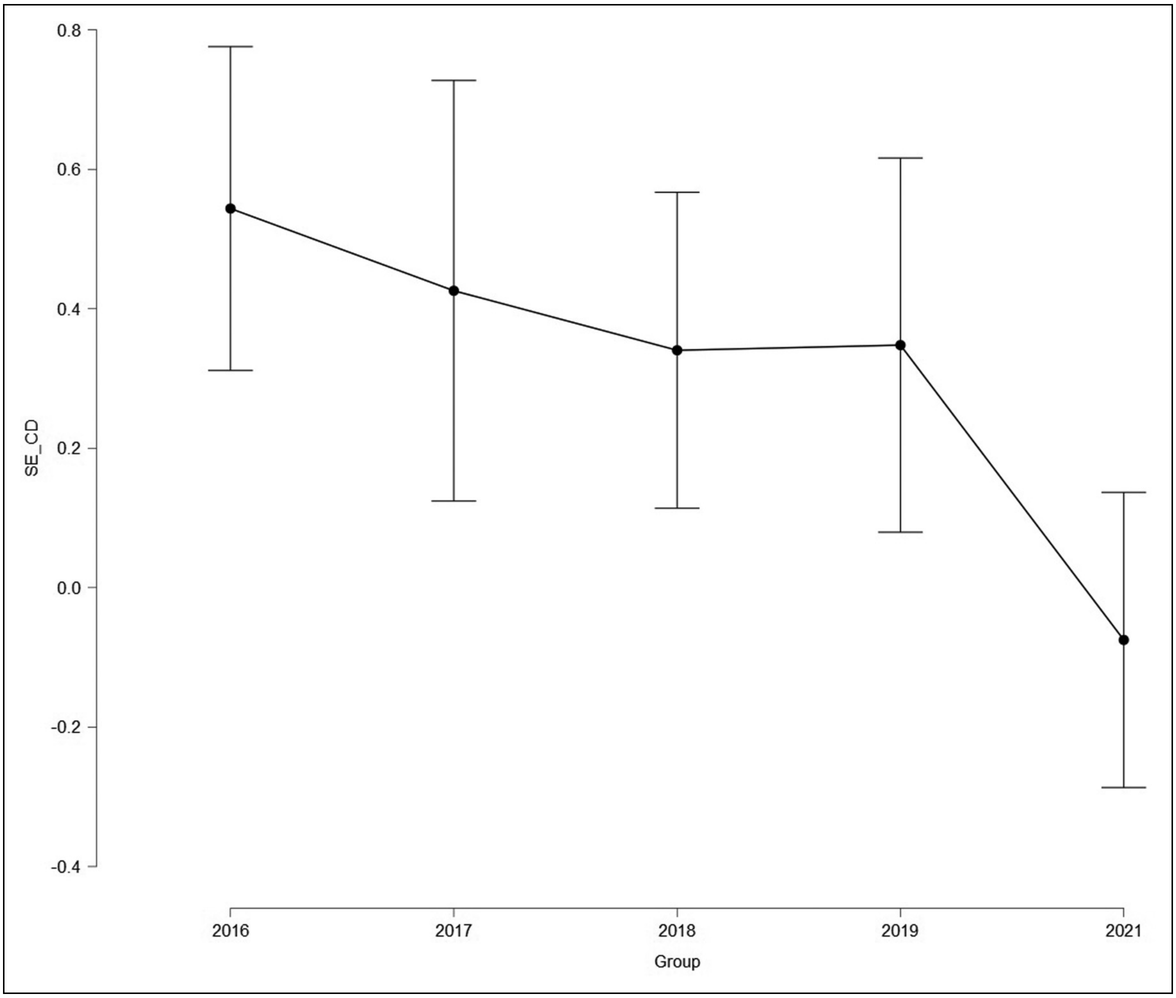

Figure 1. Descriptive plot of mean SE in right eye and 95% C.I.

Table 2. Myopes and non-myopes aged 60–96 months.

Myopes		Group 2016	2017	2018	2019	2021	Total
No	Count	62.000	54.000	58.000	47.000	63.000	284.000
	% within column	80.519 %	75.000 %	85.294 %	70.149 %	75.904 %	77.384 %
Yes	Count	15.000	18.000	10.000	20.000	20.000	83.000
	% within column	19.481 %	25.000 %	14.706 %	29.851 %	24.096 %	22.616 %
Total	Count	77.000	72.000	68.000	67.000	83.000	367.000
	% within column	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %

Table 3. Hyperopes and non-hyperopes aged 60–96 months.

Hyperopes		Group 2016	2017	2018	2019	2021	Total
No	Count	58.000	49.000	54.000	53.000	75.000	289.000
	% within column	75.325 %	68.056 %	79.412 %	79.104 %	90.361 %	78.747 %
Yes	Count	19.000	23.000	14.000	14.000	8.000	78.000
	% within column	24.675 %	31.944 %	20.588 %	20.896 %	9.639 %	21.253 %
Total	Count	77.000	72.000	68.000	67.000	83.000	367.000
	% within column	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %

Table 4. Myopes and non-myopes aged 97–144 months.

Myopes		Group 2016	2017	2018	2019	2021	Total
0	Count	57.000	43.000	51.000	55.000	44.000	250.000
	% within column	68.675 %	58.904 %	60.714 %	55.556 %	45.361 %	57.339 %
1	Count	26.000	30.000	33.000	44.000	53.000	186.000
	% within column	31.325 %	41.096 %	39.286 %	44.444 %	54.639 %	42.661 %
Total	Count	83.000	73.000	84.000	99.000	97.000	436.000
	% within column	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %

Table 5. Hyperopes and non-hyperopes aged 97–144 months.

Hyperopes		Group 2016	2017	2018	2019	2021	Total
0	Count	70.000	62.000	73.000	82.000	92.000	379.000
	% within column	84.337 %	84.932 %	86.905 %	82.828 %	94.845 %	86.927 %
1	Count	13.000	11.000	11.000	17.000	5.000	57.000
	% within column	15.663 %	15.068 %	13.095 %	17.172 %	5.155 %	13.073 %
Total	Count	83.000	73.000	84.000	99.000	97.000	436.000
	% within column	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %	100.000 %

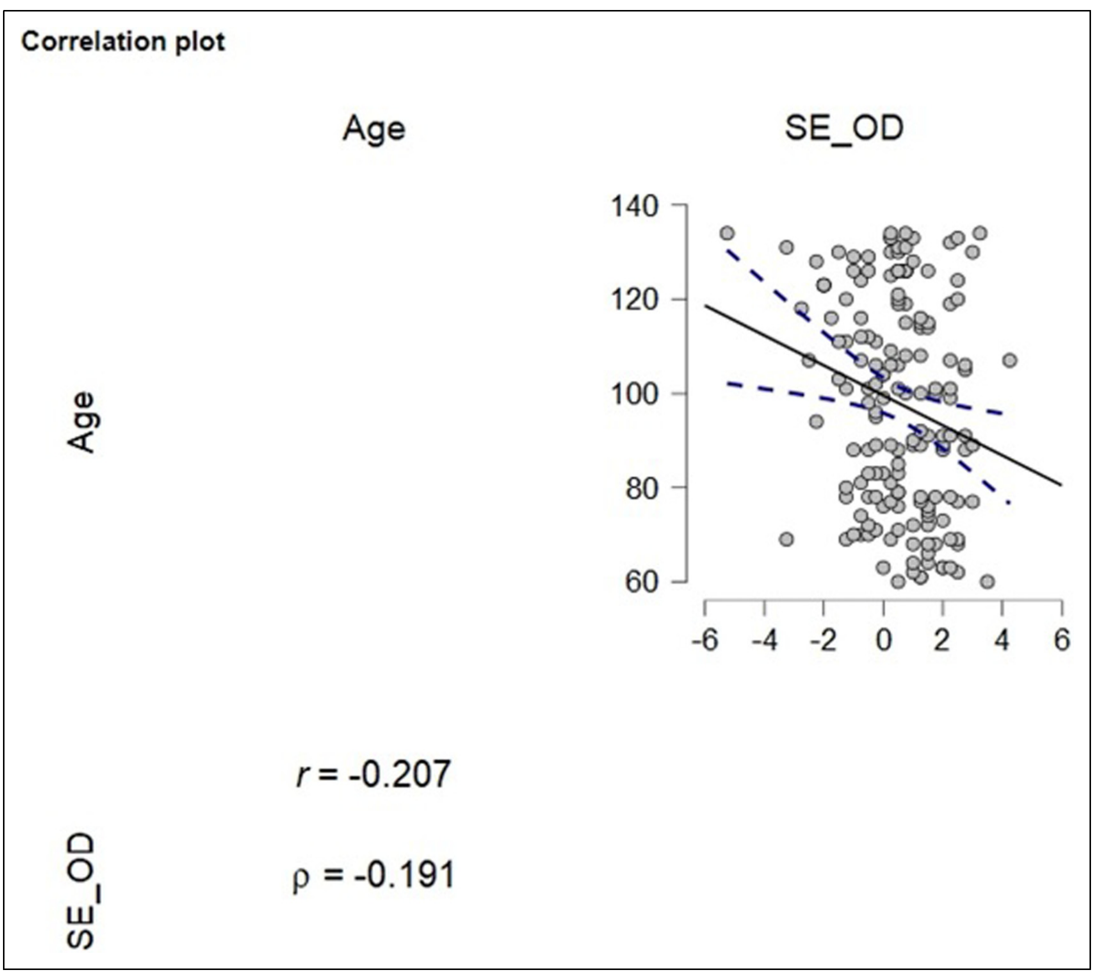

Figure 2. Plot correlating age and spherical equivalent in the right eye in the 2016 group.

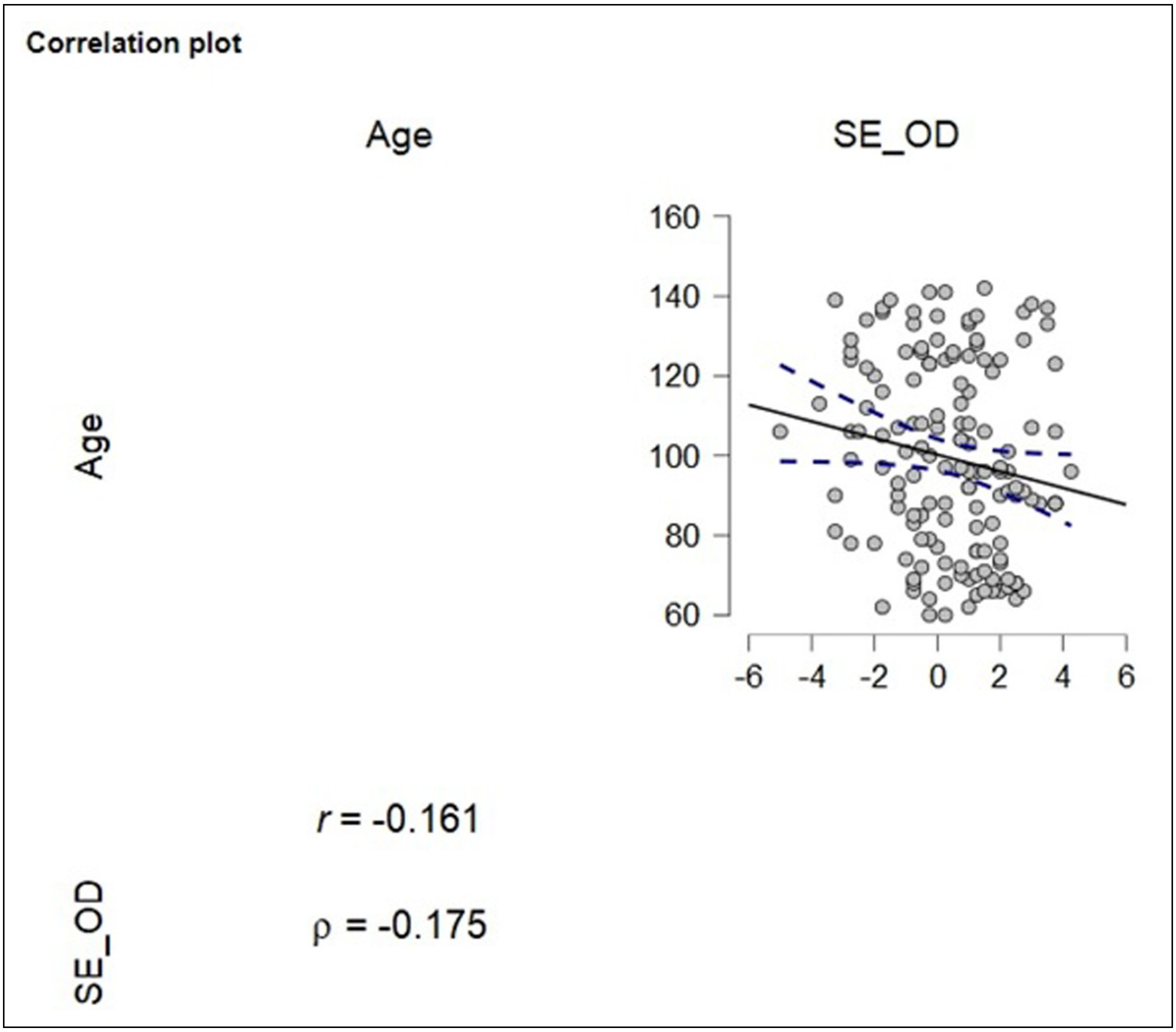

Figure 3. Plot correlating age and spherical equivalent in the right eye in the 2017 group.

Discussion

This retrospective study has shown that the mean SE of age-school children has become lower in 2021, the "post-lockdown year", as compared to the pre-lockdown years (ANOVA, $p = .005$). The mean SE of children between 5 and 12 years of age was found to be -0.08 ± 1.44 in 2021. Tukey's post-hoc analysis has shown that this mean value has decreased by a factor of 0.619 and 0.501 D, as compared to the mean SE in 2016 and 2017 respectively (Table 5) (Tukey, $p < .05$). This change is also reflected as an increase in the percentage of myopes from 25.63% (in 2016) and 33.10% (in 2017) to 40.56% in 2021 (Chi-square, $p = .016$). Myopes were defined as children with a spherical equivalent of −0.5 D or lessunder cycloplegia. Age stratification has shown that children aged 9–12 years are the ones most significantly affected. Children in this age group were 7 to 11 years old in the lockdown year (2020). Not surprisingly, previous research has indicated that myopia is more likely to progress between the ages of 7–9 and 10–12 years.[27] Our study has shown that children in that age group were the most severely affected in terms of refractive change. Authors believe that the prolonged lockdown was most likely responsible for this refractive shift. This change was also observed in a Singapore study.[25] From our analysis, the percentage of myopes in 2021 was the highest among the preceding 5 years. Figure 1 shows that the downtrend in the mean SE has accelerated in the last 2 years. This downtrend is consistent with the WHO predictions onthe increasing prevalence of myopia among the general population.[2]

Previous observational studies reported similar findings. Other authors have also attributed the increased prevalence of myopia to the prolonged home confinement. A Spanish study (Alvarez-Peregrina C. et al., 2021) showed a decrease in the mean SE in 1600 children aged 5–7 years. The SE changed from +0.66 D in 2019

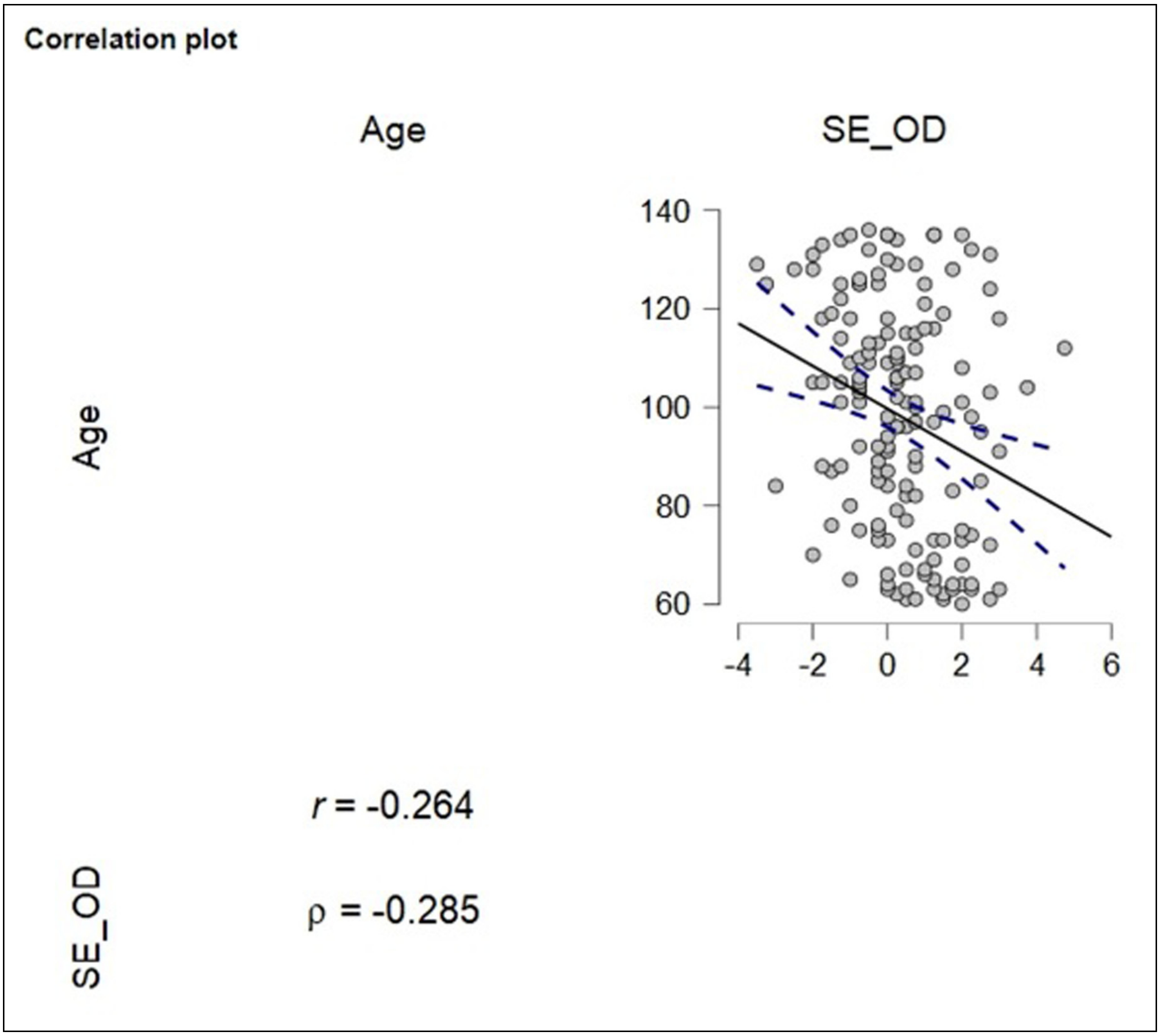

Figure 4. Plot correlating age and spherical equivalent in the right eye in the 2018 group.

to +0.48 D in 2020 in the sameage group. The Spanish authors used a questionnaire to document an increase in the number of hours spent on near-work activities and digital devices, as well as a decrease in outdoor time. The percentage of children who spent 3 or more hours a day on near distance activities increased from 18% in 2019 to 42% in 2020. A questionnaire was not used in the current study as authors believed there was already substantial evidence on this topic.[21,28] A Chinese study (Liu J. et al., 2021) conducted on 3831 adolescents confirmed an increase in digital screen engagement during the pandemic. Authors found that each diopter hour increase in daily e-learning screen use was significantly associated with progression of myopia symptoms (OR: 1.074, 95% CI: 1.058–1.089; $p < 0.001$), whereas engaging in outdoor exercise four to six times per week (OR: 0.745, 95% CI: 0.568–0.977; $p = 0.034$) and one to three times per week (OR: 0.829, 95% CI: 0.686–0.991; $p = 0.048$) was associated with a lower likelihood of myopia progression than none at all.[28] Another Chinese study (Wang J. et al., 2021) recruiting 123,535 participants found that the prevalence of myopia among children was 55.02% in 2020, up from 44.62% in 2019. The mean SE in 2020 (-1.94 ± 2.13 D) has become more negative as compared to the previous year (-1.64 ± 5.49 D, $P < 0.001$). This represents a change of −0.3 D in children aged 6–8 years, which is similar to the value of −0.27 D observed in the current study. Wang J. et al. (2021) concluded that the average duration of online classes, the number of online classes per day, as well as total digital screen exposure time were negatively correlated with SE, while the average time of outdoor activity was positively correlated.[29]

The genes responsible for myopia are believed to have low expressivity and penetrance. However, the environmental conditions play a significant role in their expression.

The findings reported in the studies above as well as the current study increase the likelihood that home

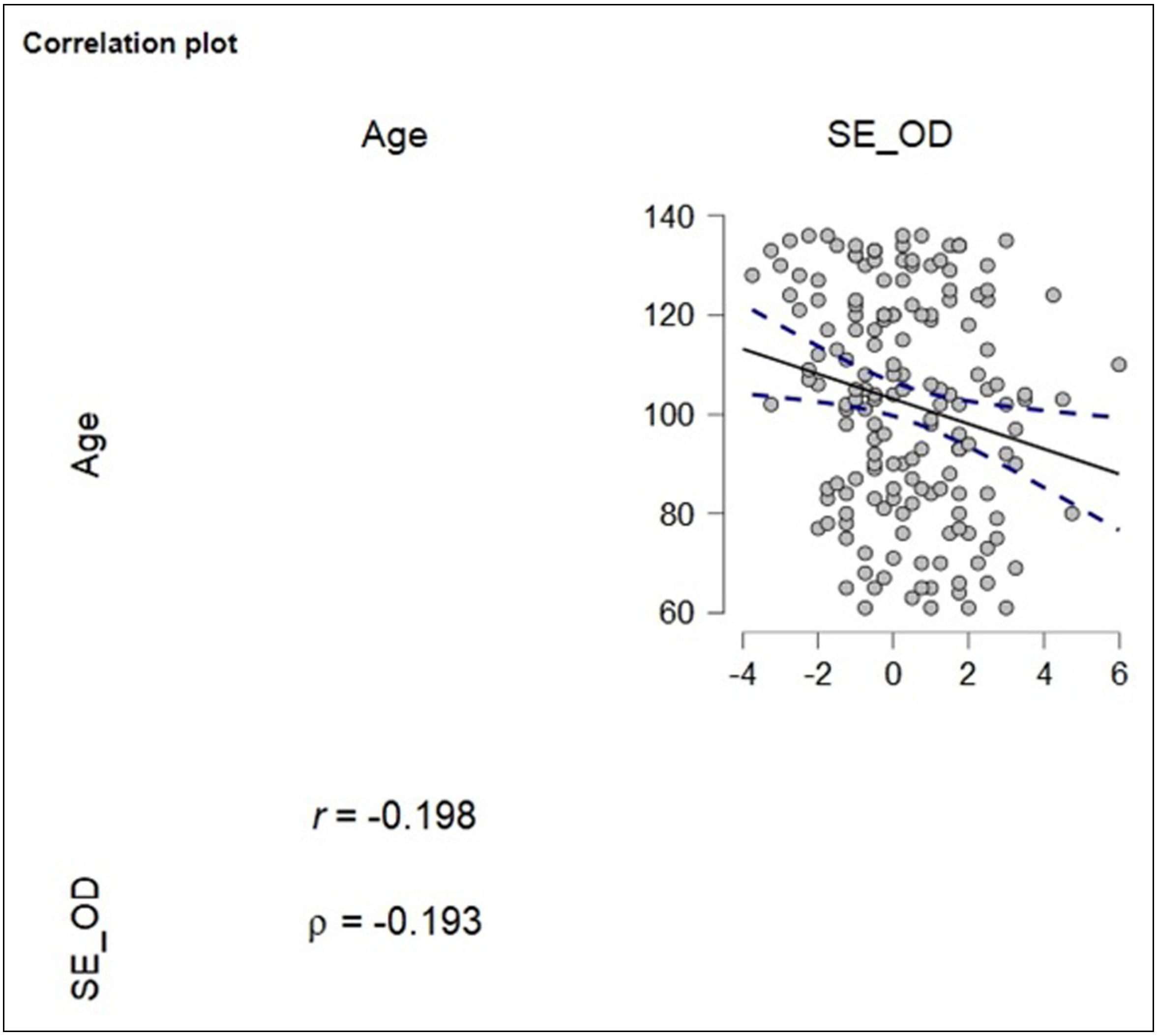

Figure 5. Plot correlating age and spherical equivalent in the right eye in the 2019 group.

Table 6. Post Hoc comparisons.

			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	p_{tukey}
2016	2017	0.118	−0.380	0.616	0.182	0.647	0.967
	2018	0.203	−0.289	0.696	0.180	1.129	0.791
	2019	0.196	−0.286	0.677	0.176	1.112	0.800
	2021	0.619	0.147	1.091	0.173	3.582	0.003 **
2017	2018	0.085	−0.419	0.590	0.185	0.463	0.991
	2019	0.078	−0.416	0.572	0.181	0.431	0.993
	2021	0.501	0.016	0.986	0.177	2.823	0.039 *
2018	2019	−0.007	−0.495	0.480	0.178	−0.042	1.000
	2021	0.415	−0.063	0.894	0.175	2.373	0.124
2019	2021	0.423	−0.045	0.891	0.171	2.472	0.098

* p <.05, ** p <.01.
Note. P-value and confidence intervals adjusted for comparing a family of 5 estimates (confidence intervals corrected using the tukey method).

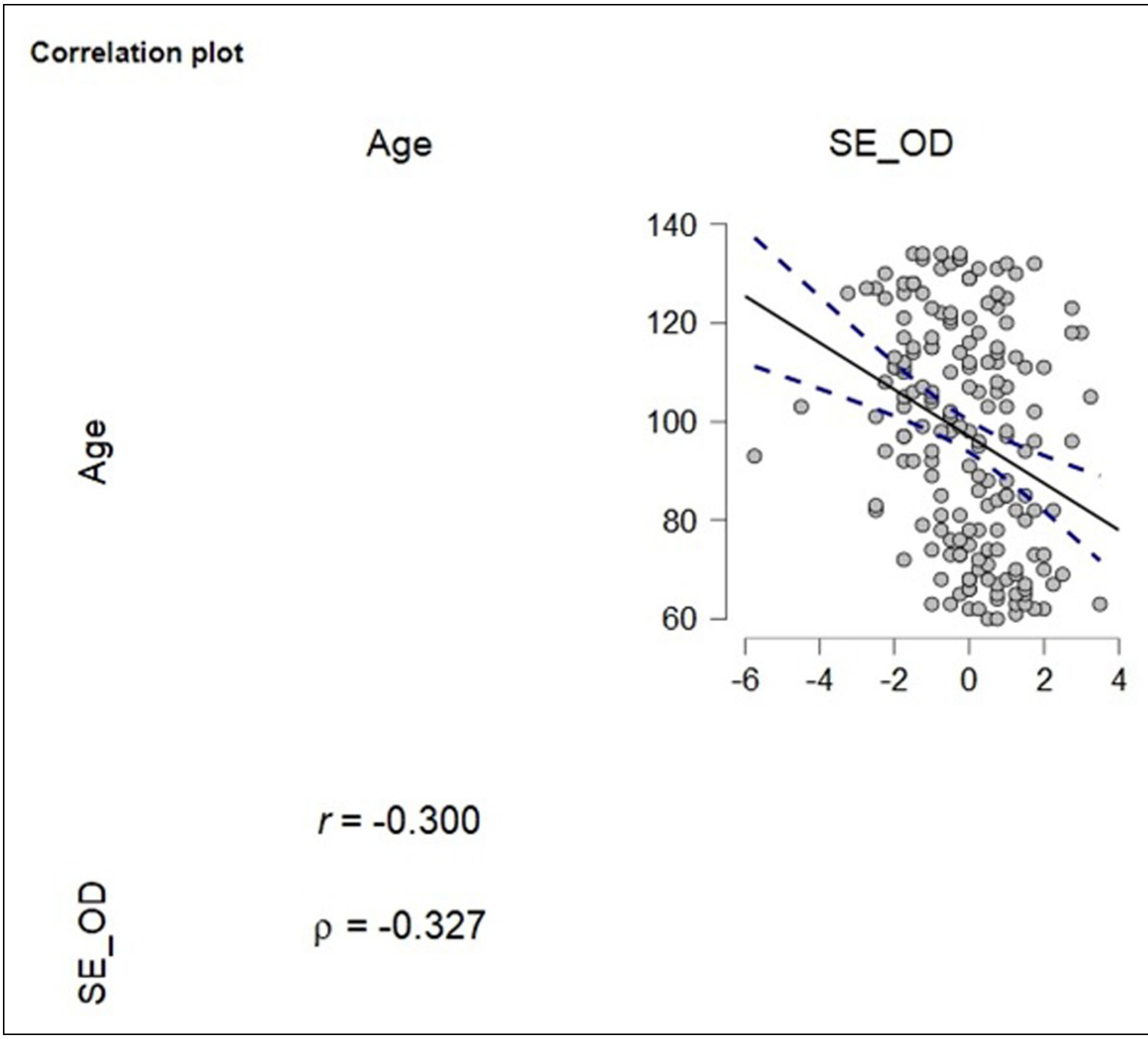

Figure 6. Plot correlating age and spherical equivalent in the right eye in the 2021 group.

confinement was indeed responsible for the increase in prevalence of adolescent myopia observed in 2021. Alvarez-Peregrina C. et al. (2021) questioned whether this post-confinement myopic shift would be temporary (as a result of ciliary spasm) or permanent (as a a result of axial elongation). [30] Our study shows that this change has persisted throughout 2021. It is important to note that it is not possible to determine what was the role of other concurrent causative factors, such as indoor lighting conditions, nutrition, and genes. This also explains the difficulty in defining the exact mechanisms responsible for the onset and progression of myopia in both genetically predisposed and non-predisposed subjects.

Limitations

This study has a few limitations. First, data on keratometry and axial length was not available. This has limited the ability of this study to describe the underlying pathophysiological process. Second, the sample size was limited to groups of 150–180 children each year. This is not small, but larger samples are surely desirable. In addition, factors other than near-work might have played a role in the observed myopic shift. These include changes in lighting conditions, poor eating habits, and genes.

Conclusions

Italian age-school children aged 5–12 years are now more myopic, as compared to peers of the same age before the COVID-19 lockdown. Children aged 8–12 were the most severely affected. The mean change in SE has been quantified as −0.619 and −0.501 D, as compared to 2016 and 2017 respectively. This myopic shift might have been caused by the increased time spent on close-distance activities and digital devices during the COVID-19 lockdown in 2020. Public health measures should be adopted to avoid the consolidation of these unhealthy behaviors among children. Without such measures, we might observe a faster-than-expected rise in the prevalence of both non-pathological and pathological myopia among young adults. Pathological myopia is also associated with sight-threatening ocular comorbidities, such as retinal detachment and glaucoma. More studies on this topic are encouraged.

Ethical statements

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research regulation and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Parents of participants agreed for data to be collected anonymously for the purpose of this study.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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