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ORIGINAL ARTICLE

The prevalence of myopia remains stable under tighter COVID-19 social restriction in preschoolers receiving a school-based eyecare program

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Abstract

Purpose: This study investigated the impact of different levels of COVID-19 social restrictions (social distancing in 2020, large-scale home confinement in 2021) on myopia prevalence and behaviours in a preschool population with school-based eyecare programme.

Methods: Repeated cross-sectional surveys were conducted between August and December in 2019, 2020 and 2021. Children aged 5–6 years received ocular examinations, and questionnaires were answered by caregivers before the day of the examination. The main outcome measures were the changes in after-school time spent on homework, screen-based devices and outdoors. Secondary outcome was the change in myopia prevalence (spherical equivalent [SE] ≤ −0.5 D in either eye after cycloplegia).

Results: A total of 9997 preschoolers were included in the analysis. Under tighter restrictions, more preschoolers spent ≥1 h/day on screen-based devices (42.8% in 2019, 45.2% in 2020, 48.9% in 2021, $p<0.001$), and fewer preschoolers spent ≥30 min/day on after-school outdoor activities (49.5% in 2019, 46.0% in 2020, 41.0% in 2021, $p<0.001$) on weekdays. A similar trend was found on weekends. While more preschoolers spent ≥2 h/day on screen-based devices (35.3% in 2019, 38.5% in 2020, 43.0% in 2021, $p<0.001$), fewer preschoolers spent ≥2 h/day on outdoor activities (41.7% in 2019, 41.7% in 2020, 34.0% in 2021, $p<0.001$). The mean SE and myopia prevalence were stable (9.1% in 2019, 10.3% in 2020, 9.4% in 2021, $p=0.707$).

Conclusion: Our study showed dose-dependent effect of social restrictions on near-work and outdoor behaviours at home. The prevalence of myopia did not increase significantly with short-term cessation of school-based eyecare programmes.

KEYWORDS
COVID-19, home confinement, myopia, outdoor activity, screen time, social restrictions

1 | INTRODUCTION

Myopia is one of the major causes of impaired vision, especially in East Asia (Grzybowski et al., 2020). Several modifiable risk factors have been linked with the development of myopia at a young age, including insufficient time spent outdoors, reading at a near distance, and excessive near work (Guan et al., 2019; Hsu et al., 2016; Saxena et al., 2017). In addition, many studies have demonstrated that increasing outdoor time may partially prevent myopic development and progression (He et al., 2015; Wu et al., 2018). Hence, outdoor activities are promoted as an eyecare strategy.

Since the coronavirus disease (COVID-19) outbreak in 2019, it has caused a heavy burden worldwide, and the WHO has identified it as a global pandemic. Different levels of social restriction measures have been imposed during the pandemic, ranging from social distancing and avoiding gathering to absolute home confinement. These restrictions have affected

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children's daily lives, especially when schools were shut down and widely replaced by online learning. The new term 'quarantine myopia' describes the phenomenon of increased myopic progression during the COVID-19 pandemic. In a large-scale cross-sectional study, Wang et al. first reported evidence of a significant myopic shift in schoolchildren after school closure for 5 months in Shandong, China (Wang, Li, et al., 2021). Xu et al. later found more half-year myopic progression during the COVID-19 pandemic that was more prominent in younger students aged 7–12 years (Xu et al., 2021). These researchers also found increased online time and decreased outdoor time in students (Xu et al., 2021). These studies showed the need to increase awareness among parents and teachers for better myopia control during the pandemic.

While some studies have found a more myopic shift in younger children after the COVID-19 quarantine (Wang, Zhu, et al., 2021; Xu et al., 2021), other recent studies have reported contrary results (Ma, Luo, et al., 2022), which may be related to different patterns of near-work behaviours in different age groups. In recent years, early-onset myopia has become more common in young children (Fan et al., 2011; Tsai et al., 2021; Yang, Hsu, et al., 2022). Children who have myopia at a young age are at higher risk of developing high myopia in the future (Hu et al., 2020). In previously published studies, near-work behaviours, such as spending more time on screen-based devices, were found to increase in preschool children during the pandemic, but the effect of behaviour change on refractive status is uncertain (Aguilar-Farias et al., 2020; Yang, Hsu, et al., 2022). Thus, it is important to focus on the young population to understand myopia development and progression at this moment.

Recently, several studies have examined lifestyle modification and refractive changes during quarantine (Aguilar-Farias et al., 2020; Alvarez-Peregrina et al., 2021; Aslan & Sahinoglu-Keskek, 2022; Chang et al., 2021; Chen et al., 2022; Hu et al., 2021; Ma, Wei, et al., 2021, 2022; Ma, Xiong, et al., 2021; Mohan et al., 2022; Picotti et al., 2021, 2022; Saxena et al., 2021; Wang, Li, et al., 2021; Xu et al., 2021; Yang, Fan, et al., 2022; Yao et al., 2022; Zhang et al., 2022) (listed in Tables S1 and S2). However, most of them focused on schoolchildren with long digital learning hours during the pandemic. With much less extensive e-learning, it is questionable whether preschool children would demonstrate similar myopic shifts. In Taiwan, preschool provides informal education before children start elementary school. Our previous study found that fewer preschoolers spent time outdoors after school under low-level social restrictions in 2020, but the prevalence of myopia did not increase significantly (Yang, Hsu, et al., 2022). After higher levels of social restrictions were imposed in 2021, all preschools in Taiwan were closed from May to July 2021, and only some of them adopted online courses. In this study, we aim to investigate the change in behaviours and refractive status in a preschool population in Taiwan under different levels of social restrictions during the COVID-19 pandemic.

2 | MATERIALS AND METHODS

2.1 | Study design

Since 2014, the Yilan Myopia Prevention and Vision Improvement Program (YMVIP) has been a population-based screening programme that aims to investigate the epidemiology of myopia and promote myopia prevention strategies in preschool children. In addition to ensuring adequate table height and classroom lighting, the programme promotes eyecare strategies, including encouraging 120 min of daily outdoor time and avoiding excessive near work. The screening programme of YMVIP recruited all preschoolers aged 5–6 years who were in the final year of preschool education in Yilan County, Taiwan, every year. Details of the methodology are reported elsewhere (Yang, Hsu, et al., 2022). The study protocol was approved by the Institutional Review Board of National Yang Ming Chiao Tung University Hospital (RD2021-010&RD2023-006) and adhered to the tenets of the Declaration of Helsinki.

In Taiwan, the first year in preschool is for 3- to 4-year-olds, the second year is for 4- to 5-year-olds, and the final year is for 5- to 6-year-olds. Children usually attend preschool 5 days a week. They spend 8–9 h per day at preschool, and a typical curriculum includes activities in the classroom and outdoors. While the content of homework varies between preschools, some may teachers assign tasks such as reading or drawing. Under low-level social restrictions since January 2020, social distancing and face masks were encouraged in preschools. Under high-level restrictions from May 2021 to July 2021, all preschools in Yilan were closed, and only some of them adopted online courses. Children were allowed to leave the house with face masks, but outdoor gatherings were discouraged. Preschools in Yilan reopened after high-level restrictions were lifted on July 27, 2021.

2.2 | Data collection

Figure 1 shows the timeline of data collection and the levels of restrictions in Taiwan. Data before (2019) and during the pandemic (2020, 2021) in the YMVIP database were included. Between annual screenings of YMVIP, low-level restrictions, including social distancing and avoiding unnecessary gatherings, were announced in Taiwan in January 2020. High-level restrictions, including closing public places and cancelling gatherings of more than 5 people, were announced in May 2021. Key differences in social restriction measures between COVID-19 alert levels are listed in Table S4. Children with incomplete refraction or questionnaire data were excluded from the analysis. Children who used orthokeratology lenses were also excluded because the refractive measurement was unreliable.

2.3 | Ocular examination

The YMVIP faculty and qualified ophthalmologists visited the preschools in Yilan and conducted ocular examinations from August to December every year.

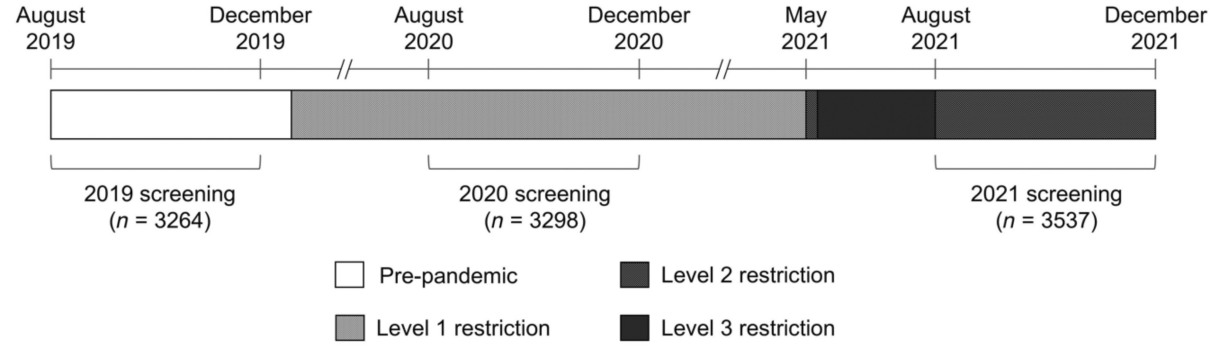

FIGURE 1 Timeline of social restriction levels in Taiwan and data collection.

Cycloplegic autorefraction was performed with 3 drops of 1% tropicamide at 5-min intervals. Pupillary response was checked after 30 min, and 1 extra drop of tropicamide was instilled if pupils were not well dilated. We obtained three autorefraction readings (Topcon KR-1; Topcon, Japan) for each child after cycloplegia.

2.4 | Questionnaires

The YMVIP questionnaires (Table S3) were delivered by preschool teachers 1 week before the ocular examination and collected on the day of the examination. Questionnaires were answered by one of the parents or key caregivers of each child. We asked about the myopic status and educational level of the caregivers, the medical history of children, and the treatment that the children had undergone. We also collected information about the children's behaviours at home over the past week, including the time spent on near-work activities (writing homework and using screen-based devices, respectively) and time spent outdoors outside of school hours on weekdays and weekends. The caregivers were asked to choose the option that best fit each question. The frequency options ranged from 'never', '<30 min per day', '30 min or more but <1 h per day', '1 h or more but <2 h per day', '2 h or more but <4 h per day', to '4 h or more per day'.

2.5 | Statistical analysis

Spherical equivalent (SE) was defined as the spherical power plus half the cylindrical power. Myopia was defined as SE of −0.50 dioptre or less in either eye. Continuous variables between groups were compared using analysis of variance with the Bonferroni post hoc test, while categorical variables were compared using the chi-square test for trend. A p value <0.05 was considered statistically significant. Statistical analysis was performed using IBM SPSS Statistics for Macintosh, Version 26 (IBM 167 Corp.).

3 | RESULTS

Between 2019 and 2021, we completed eye examinations and collected questionnaires for 10 099 participants. A total of 9997 participants (3246 in 2019, 3224 in 2020, 3527 in 2021) were included in the analysis. Figure S1 shows the flowchart of participation. The mean age of the participants was 5.20 ± 0.41 years, and 5151 (51.5%) of them were boys. A total of 5008 (50.1%) children lived in suburban areas, and 4989 (49.9%) lived in rural areas. The mean SE was +0.82 ± 1.12 dioptres (D) for right eyes, +0.84 ± 1.13 D for left eyes and +0.65 ± 1.13 D for the eye with less SE of each child.

Demographic data are shown in Table 1. The mean age of the participants in 2020 was slightly older than that of the other two groups (5.12 ± 0.37 years in 2019, 5.35 ± 0.48 years in 2020, 5.13 ± 0.34 years in 2021, p < 0.001). Distribution by gender or living area remained unchanged for three different years. The proportion of myopic caregivers was also similar between groups. The proportion of caregivers with an educational level of college or above gradually increased over time (60.0% in 2019, 63.7% in 2021, p = 0.005).

Table 2 shows the change in the preschoolers' near-work and outdoor behaviours prior to and during the pandemic. Under higher levels of restrictions, more preschoolers spent ≥1 h/day on screen-based devices at home (42.8% in 2019, 45.2% in 2020, 48.9% in 2021, p < 0.001) on weekdays, and fewer preschoolers spent ≥30 min/day on after-school outdoor activities (49.5% in 2019, 46.0% in 2020, 41.0% in 2021, p < 0.001). Strictness of restrictions was found to be associated with the distribution of after-school behaviours (Figure 2). A similar change was found with behaviours on weekends. More preschoolers spent ≥2 h/day on screen-based devices (35.3% in 2019, 38.5% in 2020, 43.0% in 2021, p < 0.001) under tighter social restrictions, and fewer preschoolers spent ≥2 h/day on outdoor activities (41.7% in 2019, 41.7% in 2020, 34.0% in 2021, p < 0.001). The change in percentages of preschoolers spending ≥30 min/day on homework was not significant on either weekdays (38.6% in 2019, 39.1% in 2020, 41.1% in 2021, p = 0.122) or weekends (38.2% in 2019, 37.3% in 2020, 40.1% in 2021, p = 0.344).

Table 3 shows the refraction measurement data. There was no statistical difference between annual measurements in spherical equivalent, nor did the prevalence of myopia (9.1% in 2019, 10.3% in 2020, 9.4% in 2021, p = 0.707).

4 | DISCUSSION

Our study showed that social restrictions during the COVID-19 outbreak significantly affected preschoolers'

TABLE 1 Characteristics of participants by screening years.

	2019 (n=3246)	2020 (n=3224)	2021 (n=3527)	p-value
Age, mean years (SD)	5.12 (0.37)[a]	5.35 (0.48)[a,b]	5.13 (0.34)[b]	**<0.001**
Gender, n (%)				
Girl	1564 (48.2%)	1570 (48.7%)	1712 (48.5%)	0.774
Boy	1682 (51.8%)	1654 (51.3%)	1815 (51.5%)	
Area, n (%)				
Rural	1621 (49.9%)	1612 (50.0%)	1756 (49.8%)	0.899
Suburban	1625 (50.1%)	1612 (50.0%)	1771 (50.2%)	
Myopic caregiver, n (%)				
Yes	2087 (64.3%)	2143 (66.5%)	2307 (65.4%)	0.571
No	1033 (31.8%)	949 (29.4%)	1089 (30.9%)	
Unknown	126 (3.9%)	132 (4.1%)	131 (3.7%)	
Caregiver education				
College or above	1946 (60.0%)	2003 (62.1%)	2247 (63.7%)	**0.005**
High school or less	1259 (38.8%)	1146 (35.5%)	1239 (35.1%)	
Unknown	41 (1.3%)	75 (2.3%)	41 (1.2%)	

Note: p-values <0.05 are in bold type.
[a]p<0.001 for post hoc Bonferroni test.
[b]p<0.001 for post hoc Bonferroni test.

near-work behaviour at home and outdoor after-school activity, which was similar to previous studies (Aguilar-Farias et al., 2020; Alvarez-Peregrina et al., 2021; Saxena et al., 2021; Xu et al., 2021; Zhang et al., 2022). Nevertheless, the prevalence of myopia and mean spherical equivalence did not vary significantly despite 3 months of high-level restrictions and the cessation of school-based eyecare programmes in our study population. As tighter COVID-19 social restriction measures were imposed, preschoolers spent longer times on screen-based devices and homework but less time on outdoor activities. This dose–response relationship provides good evidence of a causal relationship between COVID-19 social restriction measures and behaviour for preschool-aged children.

In our study, the prevalence of myopia in preschoolers remained stable between 2019 and 2021. This differed from several studies previously conducted in other countries (see Tables S1 and S2). It is difficult to directly compare our results to those of other studies due to different study populations, cycloplegic methods, investigation time points, and regulations of home confinement. However, the limited interruption of school-based eyecare programmes could partially explain our findings. Since 2014, YMVIP has promoted myopia prevention strategies for all preschoolers in Yilan, Taiwan. One of the main focuses of the programme is to promote daily outdoor activity for 2 h at school. Teachers were encouraged to incorporate the time for outdoor activity into the school curriculum because preschoolers spend most of their daytime in preschool, and school-based interventions seem to be executed better than those at home. Our previous study showed that the prevalence of myopia decreased from 15.5% in 2014 to 10.3% in 2020 after the programme was initiated (Yang, Hsu, et al., 2022), and the duration of exposure to preventive strategies was the strongest protective factor against myopia (1-year exposure, OR 0.86, 95% CI 0.74–0.99; 2-year exposure, OR 0.56, 95% CI 0.50–0.63) (Yang, Hsu, et al., 2022). In the current study, a number of the preschoolers recruited were exposed to the school-based eyecare programme for up to 2 years, and the programme was halted only under level-3 restrictions in Taiwan, that is, from May to July 2021. By the time we started our survey in September 2021, children had returned to preschools. Our finding can be compared to previous study that explored the impact of daylight exposures on myopia in high-latitude countries. In the study by Hagen et al., although the protective effect of outdoor activity was interrupted by insufficient daylight in Norway during mid-winter (6–8 h per day), the myopia prevalence of Norwegian teenagers was still relatively low (13.4%) (Hagen et al., 2018). Together with our result, we deduced that brief interruption of light exposure may not eliminate the benefit of outdoor activity against myopia. In our study, although the participants' at-home near-work time increased and outdoor time decreased under social restrictions for the pandemic, the <3-month interruption of the school-based eyecare programme did not eliminate its protective effect, which helps to explain the stable prevalence of myopia.

Several other factors may also account for the stable prevalence of myopia in our study. First, our study focused on preschool children, who are younger than the previously studied population (see Tables S1 and S2). Although an age-dependent decline in refractive plasticity can be found in the study of defocus-induced refractive errors in developing chick eyes (Irving et al., 1992), whether younger children tend to have more myopic shift during quarantine is still controversial. Earlier age at onset of childhood myopia was found to be connected with faster myopic progression (Pärssinen et al., 2021). Similarly, some studies found more myopic

TABLE 2 Comparisons of behaviours by screening years.

	2019 (n=3246)	2020 (n=3224)	2021 (n=3527)	p-value
Time spent on homework (reading, writing, drawing, or playing musical instruments):				
On weekdays, n (%)				0.122
≥30 min/day	1253 (38.6%)	1261 (39.1%)	1450 (41.1%)	
<30 min/day	1965 (60.5%)	1903 (59.0%)	2056 (58.3%)	
Unknown	28 (0.9%)	60 (1.9%)	21 (0.6%)	
On weekends, n (%)				0.344
≥30 min/day	1239 (38.2%)	1201 (37.3%)	1413 (40.1%)	
<30 min/day	1972 (60.8%)	1953 (60.6%)	2088 (59.2%)	
Unknown	35 (1.1%)	70 (2.2%)	26 (0.7%)	
Time spent on screen-based devices (television, smartphones, computers, tablets or video games):				
On weekdays, n (%)				**<0.001**
≥1 h/day	1389 (42.8%)	1457 (45.2%)	1726 (48.9%)	
<1 h/day	1827 (56.3%)	1704 (52.9%)	1781 (50.5%)	
Unknown	30 (0.9%)	63 (2.0%)	20 (0.6%)	
On weekends, n (%)				**<0.001**
≥2 h/day	1145 (35.3%)	1242 (38.5%)	1515 (43.0%)	
<2 h/day	2068 (63.7%)	1918 (59.5%)	1991 (56.5%)	
Unknown	33 (1.0%)	64 (2.0%)	21 (0.6%)	
Time spent on after-school outdoor activities:				
On weekdays, n (%)				**<0.001**
≥30 min/day	1606 (49.5%)	1483 (46.0%)	1446 (41.0%)	
<30 min/day	1610 (49.6%)	1678 (52.0%)	2063 (58.5%)	
Unknown	30 (0.9%)	63 (2.0%)	18 (0.5%)	
On weekends, n (%)				**<0.001**
≥2 h/day	1352 (41.7%)	1344 (41.7%)	1199 (34.0%)	
<2 h/day	1864 (57.4%)	1814 (56.3%)	2310 (65.5%)	
Unknown	30 (0.9%)	66 (2.0%)	18 (0.5%)	

Note: p-values <0.05 are in bold type.

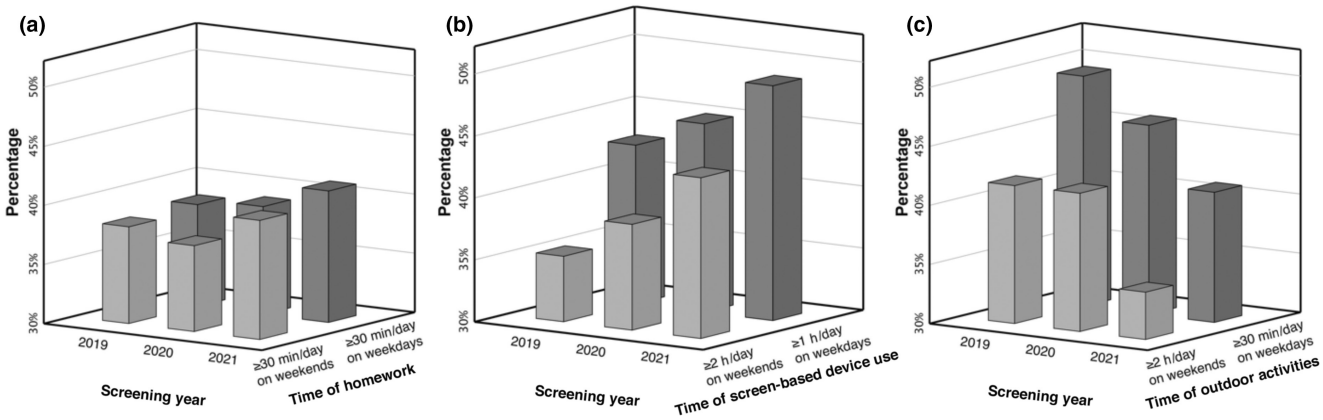

FIGURE 2 Change in the preschoolers' behaviours before (2019) and during (2020 and 2021) the COVID-19 pandemic. (a) The proportion of preschoolers spending ≥30 min/day on homework did not vary significantly. (weekdays: 38.6% in 2019, 39.1% in 2020, 41.1% in 2021; weekends: 38.2% in 2019, 37.3% in 2020, 40.1% in 2021) (b) More and more preschoolers spend time on screen-based devices under tighter social restrictions. (≥1 h/day on weekdays: 42.8% in 2019, 45.2% in 2020, 48.9% in 2021; ≥2 h/day on weekends: 35.3% in 2019, 38.5% in 2020, 43.0% in 2021). Conversely, (c) fewer and fewer preschoolers spend time outdoors under tighter social restrictions (≥30 min/day on weekdays: 49.5% in 2019, 46.0% in 2020, 41.0% in 2021; ≥2 h/day on weekends: 41.7% in 2019, 41.7% in 2020, 34.0% in 2021).

shift in younger children under the COVID-19 quarantine (Wang, Zhu, et al., 2021; Xu et al., 2021). However, Ma et al. found that variation of SE during the pandemic was significantly higher in grade 6 students than in grade 1 students (Ma, Luo, et al., 2022). Several factors may account for this finding, but the most important may be less time for online educational courses for younger children. In addition, during the time of high-level restrictions in

TABLE 3 Refractive status of participants by screening years.

	2019 (n=3246)	2020 (n=3224)	2021 (n=3527)	p value
SE (OD), mean dioptre (SD)	0.82 (1.14)	0.84 (1.07)	0.82 (1.14)	0.655
SE (OS), mean dioptre (SD)	0.81 (1.21)	0.86 (1.07)	0.85 (1.11)	0.198
SE (more myopic eye), mean dioptre (SD)	0.62 (1.16)	0.69 (1.06)	0.65 (1.15)	0.066
Refractive status, n (%)				
Non-myopia	2951 (90.9%)	2893 (89.7%)	3196 (90.6%)	0.707
Myopia	295 (9.1%)	331 (10.3%)	331 (9.4%)	

Abbreviations: SD, standard deviation; SE, spherical equivalent.

Taiwan, all preschools were closed, but most of them did not have a full curriculum of digital learning. It is possible that the refractive status of preschool children is less affected because they spend fewer hours on digital devices for both educational and leisure purposes than schoolchildren.

Another assumption is that 3 months of high-level social restrictions may not be long enough for myopic shift to develop in preschool children. In Taiwan, the alert level was only upgraded to levels 2 and 3 after a significant COVID-19 outbreak took place and worsened in May 2021. In addition, people in Taiwan did not experience actual lockdown (level-4 restrictions) during our study period. When the cities were in semi-lockdown, people could still go out as long as they wore face masks all of the time (please see Table S4 for the details of regulations). It is also possible that a lesser degree of home confinement has a lesser effect on children's refractive status, so it may take a longer time to observe the change in refractive status. Future studies with longer follow-up will be needed to investigate the effect of different levels of social restrictions on myopic progression.

In Taiwan, the strictness level of social restrictions gradually increased between 2020 and 2021, so we could observe a gradual decrease in children's outdoor time and an increase in time spent on near work. Many studies have reported similar results, but all of the populations studied have undergone some form of quarantine (Alvarez-Peregrina et al., 2021; Saxena et al., 2021; Xu et al., 2021; Zhang et al., 2022). Our study showed that lifestyle changes were found even under low-level restrictions, and the changes were more profound under high-level restrictions. In the postpandemic era, many countries still impose low-level restrictions such as social distancing and encourage online learning for school teaching. The change in near-work and outdoor behaviours may be reversible after lockdown is lifted (Shneor et al., 2021), but future large-scale studies are required to confirm whether children's behaviours could return to baseline.

Our results showed that after-school outdoor time decreased in preschoolers and screen time increased. The proportion of children spending 30 min or more per day outdoors after school decreased from 49.5% to 41.0% on weekdays, and the proportion of children spending 2 h or more per day outdoors decreased from 41.7% to 34.0% on weekends during COVID-19 pandemic restrictions. This finding is compatible with previous studies. In a study conducted by Xu et al. during the COVID-19 pandemic, they found the proportion of students with outdoor activity for more than 1 h per day decreased 1.14 times in primary school and decreased 1.71 times in high school in Wenzhou, China (Xu et al., 2021). In another cross-sectional study analysing refractive status and behaviours in 5827 children in Spain, Alvarez-Peregrina et al. also reported that the proportion of children spending more than 1.6 h every day outdoors decreased from 73% to 31% (Alvarez-Peregrina et al., 2021). The significantly decreased after-school outdoor time under social restrictions is a warning sign that parents and teachers should be aware of. If children persistently have insufficient outdoor time, they may be at a higher risk of myopic shift. On the other hand, it is important to continue school-based myopia prevention programmes to ensure that children have adequate outdoor time at school during the pandemic and in the postpandemic era (Wang et al., 2022; Wu et al., 2020; Yang, Hsu, et al., 2022).

In our study, the proportion of children who spent more than 1 h per day on screen-based devices increased from 42.8% to 48.9% on weekdays, and the proportion spending more than 2 h per day on weekends increased from 35.3% to 43.0%. It should be noted that the increased amount of screen time in our study is less profound compared to previous studies conducted on schoolchildren. Xu et al. (Xu et al., 2021) reported that the proportion of students who spent more than 2 h per day online increased 3.14 times for primary school students and 2.07 times for high school students in China. Zhang et al. (2022) also found that the mean screen time of a study population of 6- and 8-year-olds increased from 2.45 h per day to 6.89 h per day during the COVID-19 pandemic (p<0.001). Preschool children generally have less screen time than schoolchildren, and they have less dependence on smartphones, tablets and computers (Chang et al., 2018). Moreover, older children tend to have more online courses when schools are closed. Nevertheless, when examining screen time during the pandemic, it should be noted that currently, direct evidence of whether screen time increases the risk of myopia is insufficient, and further research based on reliable measures is needed (Foreman et al., 2021).

There are several strengths of this study. First, this was a population-based study with a large sample size, which made it less prone to selection bias. In addition, we provided data with serial observations before and during the COVID-19 outbreak. To our knowledge, this is the first study to report the dose-dependent relationship between strictness levels of social restrictions and children's

near-work and outdoor behaviours. This study is also the first to provide consecutive 2-year data on behaviours and refraction after the COVID-19 outbreak. Finally, the examinations were performed by trained programme staff from YMVIP and hence provided stable and reliable measurements. Several limitations should also be mentioned. First, with a short period of high-level restrictions, the causal relationship between social restrictions, the interruption of school-based eyecare programmes and refractive outcomes is not evident in our study. Second, we used questionnaires answered by key caregivers to measure preschoolers' behaviours, which may lead to recall bias. Recently, objective measurement of children's behaviours with device and application assistance has been proposed in some myopia-related studies (Shneor et al., 2021). While these methods can assess time more accurately, they come with high expenses and are difficult to apply to large-scale studies. In contrast, questionnaires are a cost-effective and valid means and are suitable for epidemiological studies with large populations (Sirard & Pate, 2001). Third, we did not include all myopia-associated risk factors in our study. Since we failed to obtain all the questionnaires directly from the participants' biological parents, we used the term 'myopic caregivers' as a substitute for 'myopic parents'. For the characteristics of near-work behaviours and educational pressure, we did not consider factors such as distance from near work, whether children had 10 min of rest after every 30 min of near work, the frequency of preschool assessments, and whether children had extra private tutoring. Finally, instead of combination with 1% cyclopentolate, we used 1% tropicamide eyedrops for cycloplegia, which may lead to overestimation of the prevalence of myopic. However, the effect of the cycloplegic regimen on refraction should be similar between groups and therefore is less likely to affect the outcome after comparison.

In conclusion, our study found that preschoolers spent more time on homework and screen-based devices during the COVID-19 pandemic, while fewer preschoolers spent time outdoors. The change in near-work and outdoor behaviours at home was more prominent under tighter social restriction measures and showed a dose–response relationship. However, the prevalence of myopia did not fluctuate significantly despite the 3-month school closure and interruption of the school-based eyecare programme. Our findings can help to raise awareness of preschool myopia control and emphasize the importance of school-based programmes that promote outdoor activity in the postpandemic era. Further longitudinal studies are warranted to investigate the long-term refractive outcome and behaviour change because the effect of a sedentary lifestyle during the COVID-19 pandemic may not be observed within a short period.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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