Clinical science

Time outdoors prevents myopia in hyperopic children, but protection is weaker in premyopic children: a post-hoc analysis of a cluster-randomised trial

Jun Chen,[1,2,3,4] Ziyi Qi ,[1,2] Ian Morgan ,[5] Kathryn Rose ,[6] Zhuoting Zhu ,[7] Xiaohu Ding,[8] Jingjing Wang ,[1,2,3,4] Bo Zhang,[1,2,3,4] Linlin Du,[1,2,3,4] Jinliuxing Yang ,[1,2,3,4] Jianfeng Zhu ,[1,2,3,4] Wei Gao,[1,2,3,4] Haidong Zou,[1,2,3,4] Mingguang He,[9] Xun Xu ,[2] Xiangui He [1,2,3,4]

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For numbered affiliations see end of article.

Correspondence to
Xiangui He; xianhezi@163.com

JC and ZQ are joint first authors.

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ABSTRACT

Aims To investigate the effect of time outdoors on myopic shift among premyopic children.

Methods Post-hoc analysis was nested in a cluster-randomised trial of the Shanghai Time Outside to Reduce Myopia (STORM) study. 6- to 9-year-old participants without myopia from the STORM study, who wore wristwatches to monitor time outdoors from 2017 to 2018, were included. Participants were all examined with cycloplegic refraction. Daily time outdoors was objectively monitored with the wearable smartwatch. Premyopia was defined as a cycloplegic spherical equivalent (SE) from −0.50 to +0.75 (inclusive) dioptres (D). Myopic shift was SE change from baseline to 1 year follow-up.

Results Among 3194 participants (1369 premyopic; mean age 8.2±0.6 years; 49.5% boys), there were no statistical differences between premyopic and hyperopic children in time outdoors (p=0.303). Hyperopes showed reduced myopic shift with increasing outdoor time (plateau at about 120 min/day). However, premyopes exhibited a J-shaped relationship between time outdoors and myopic shift. In comparison to the subgroup with daily time outdoors <60 min, the difference in SE change in the other subgroups was not statistically significant (61–90 min/d: −0.03 (95% CI −0.10 to 0.05); 91–120 min/d: −0.03 (95% CI −0.11 to 0.05)). The reduced myopic shift was only observed with time outdoors >120 min/d, although it was still not statistically significant (>120 min/d: 0.04 (95% CI −0.05 to 0.14)).

Conclusions Among premyopic children, increased time outdoors has a limited protective effect on myopic shift, suggesting longer duration of time outdoors or additional interventions to prevent or delay myopia onset in this population.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Several randomised controlled trials had been conducted to explore the relationship between time outdoors and myopia onset, showcasing the potential benefits of outdoor activities in reducing myopia incidence. Participants in these studies included hyperopic and premyopic children, but the effect of time outdoors among premyopic children was not specifically reported.

WHAT THIS STUDY ADDS

⇒ Our research, utilising objective outdoor monitoring wristwatches, investigated the influence of outdoor activities on premyopia intervention. We found that time spent outdoors had a limited protective effect on myopic shift among premyopic children, distinct from the dose-dependent protective effect observed in hyperopic children. This finding reveals the unique dynamics of myopic shift within the premyopic population, highlighting the need for more intensive interventions.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The effect of time outdoors on myopic shift was significant for hyperopic children, but limited among children with premyopia. More intensive interventions are required to delay myopic shifts and prevent myopia onset in children with premyopia.

INTRODUCTION

Myopia is a pressing public health concern due to its increasing prevalence worldwide.[1–3] While there are many interventions to slow progression in established myopes, there is growing interest in interventions aimed at preventing myopia onset, particularly in children at high risk of developing myopia. Recognising this, the International Myopia Institute (IMI) in 2019 defined a precursor stage to myopia known as ‘premyopia’.[4] This phase directs attention to the early stages of myopia development prior to the clinical diagnosis of myopia and highlights a critical window for intervention.

Premyopia, characterised by a high prevalence and a significant risk of progression to myopia, represents a crucial target for preventive efforts. In China, 62% of 6-year-old to 8-year-old children with premyopia progress to myopia within 2 years.[5] Therefore, understanding and intervening during the premyopic stage is of utmost importance. Data from major studies, such as the Collaborative Longitudinal Evaluation of Ethnicity and Refractive

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Error (CLEERE) Study,[6] the Singapore Cohort Study of the Risk Factors for Myopia (SCORM) study[7] and the Guangzhou Twin Eye Study,[8] have revealed significantly accelerated axial elongation rates in the year preceding myopia onset, underscoring premyopia as a key target for myopia prevention and control.

Randomised Controlled Trials (RCTs) have demonstrated time outdoors was effective in myopia prevention, with a relative reduction in myopia onset ranging from 11% to 52% in non-myopic children.[9–11] Furthermore, pooled data from observational studies confirms its effect in preventing myopia onset and slowing myopic shift in non-myopic children.[12] However, these trials generally included all non-myopic children, without distinguishing between those at high risk (premyopes) and low risk (hyperopes) of rapidly developing myopia. Recently, a subgroup analysis of the Recess Outside Classroom (ROC) study found that increasing outdoor time significantly reduced myopia incidence in premyopic children compared with controls (19.6 % vs 37.8 %).[13] However, the proportion of hyperopes in that cohort was small, and most were already premyopic. This gap in research leaves an important question unanswered: how effective is increased time outdoors in preventing myopia specifically among children already at high risk of developing myopia?

Therefore, based on our outdoor intervention cohort, which was a large, prospective, cluster-randomised trial, involving students aged 6–9 years in Shanghai, China,[11] this subgroup analysis aimed to investigate the potential benefits of time outdoors on children in the premyopia category. Importantly, we monitored daily time outdoors using objectively monitored smartwatches. Our goal is to provide evidence-based recommendations for myopia prevention, lowering the prevalence of myopia and thereby reducing visual impairment attributable to uncorrected myopia, as well as reducing the prevalence of potentially pathological high myopia in the longer term.

METHODS

Study design and participants

This was a post-hoc subgroup analysis nested in the Shanghai Time Outside to Reduce Myopia trial (STORM).[14] The STORM study was a prospective, school-based cluster randomised trial from October 2016 to December 2018 conducted in Shanghai, China. The detailed methods of which had been reported previously.[14] The study was approved by the Shanghai General Hospital Ethics Committee (No. 2016KY138) and conformed with the tenets of the Declaration of Helsinki. Written informed consent for each child was obtained from a parent/carer. This trial is registered with ClinicalTrials.gov, identifier: NCT02980445.

Participants were randomised into three arms: 40 min time outdoor intervention, 80 min outdoor intervention and a control arm without additional interventions. The participants in the three arms were advised to wear smartwatches every day for 1 year from December 2017 to December 2018. This study included participants in both intervention and control arms who met the following criteria: (1) wearing the smartwatch for at least 6 hours per day; (2) wearing the smartwatch for at least 90 days during the study period; (3) having complete information on variables including age, gender, spherical equivalent (SE), axial length (AL), etc.; (4) no myopia in both eyes when they started to wear the smartwatch.

Exposure

Time outdoors were objectively monitored by the 'Mumu' smartwatch developed by our research team, equipped with a global positioning system (GPS) receiver module, a light sensor and a pedometer. The light sensor collected luminance (lux) and ultraviolet intensity at 20-s intervals. Data collected from the smartwatch included time (year/month/day/00:00:00), lux, ultraviolet intensity, count of steps, weather and wearing status. The data was automatically uploaded by the smartwatch to a cloud to store the data. The accuracy of the smartwatch for differentiating time spent outdoors and indoors was 92.4%, as reported previously.[15]

The criteria for data inclusion in the analysis were set at a minimum of 90 days of recorded data. Ninety days cover the variations in time outdoors across weekends and holidays in school-aged children. Daily time outdoors was calculated as total outdoor minutes divided by the number of wearing days.

Given that we have data on the objectively monitored time outdoors from the smartwatches, participants were regrouped for this analysis based on their actual time outdoors, rather than the initial group assignments.[11] A comprehensive assessment, encompassing both statistical distribution and practical viability, guided the categorisation of daily time outdoors into four classifications: ≤60, 61–90, 91–120 and >120 min/day.

Compliance monitoring

Smartwatch compliance was rigorously monitored throughout the study. The wearing status was recorded by the built-in software of the smartwatch and automatically uploaded to the cloud-based server. Compliance data were summarised as the total days of wearing the smartwatch.

Outcome

Cycloplegic refraction was the primary measure. Cycloplegia was performed using 0.5% proparacaine hydrochloride for topical anaesthesia and 1% cyclopentolate (Cyclogyl; Alcon, Fort Worth, TX, USA) (two drops 5 min apart, plus a third if needed). A Topcon KR-8900 autorefractor was used for autorefraction, and the mean of three measurements was used to calculate SE (the sum of the sphere power plus half of the cylinder power). The IOL Master 500 (version 5.02; Carl Zeiss, Jena, Germany) was used to measure AL. Measurements were repeated three times, and if any two readings differed by >0.05 mm, additional readings were taken. All eye examinations were carried out at schools by experienced physicians who had undergone standardised training. The change of SE was calculated as the difference between the baseline SE recorded when participants wore the smartwatch and the follow-up SE 1 year later.

Covariates

Covariates included age, gender, baseline height, baseline weight, parental myopia and near work time during the follow-up. Age, gender, parental myopia and near work time were obtained through questionnaires. Near work time was derived by summing the durations of reading, indoor classes and electronic device usage during the follow-up, subsequently adjusted to a per-day basis. Height and weight were measured using standard anthropometric assessments. Sunlight intensities were objectively gauged via the smartwatch.

Statistical analysis

Normally distributed variables, such as age, height, weight, SE, AL and daily time outdoors, were presented as means and SD; skewed distributed variables like near work time and light intensity as medians and interquartile ranges (IQR) and categorical variables as frequencies (%).

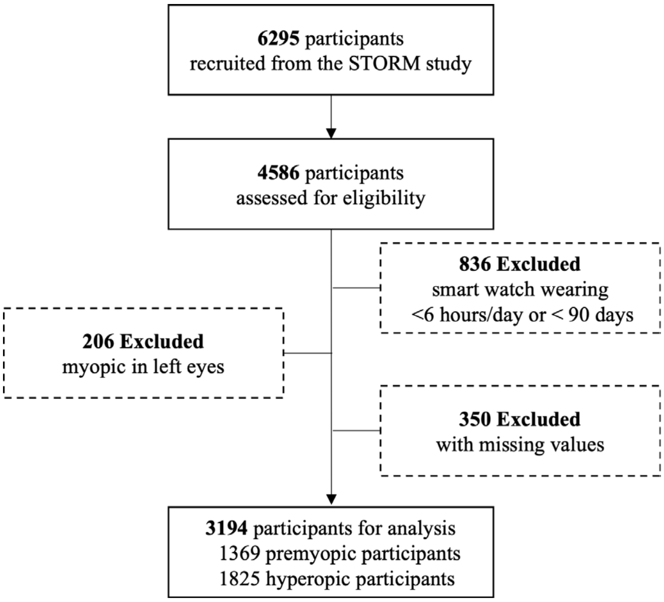


Figure 1 Flowchart for participants' assessment and enrolment in the study. STORM, Shanghai Time Outside to Reduce Myopia.

The linear association of time outdoors and light intensity with myopic shift was examined first by a restricted cubic spline regression, and a contour plot was applied to show the interaction between time outdoors and light intensity on myopic shift. Subsequently, the time outdoors was classified into four mutually exclusive groups (≤60, 61–90, 91–120 and >120 min/day), while the baseline SE was categorised into premyopia and hyperopia. Multivariable linear regressions were employed to examine the influence of various time outdoors categories on myopic shift and AL change within both the premyopia and hyperopia subgroups. This was achieved by adjusting for potential confounders including age, gender, height, weight, parental myopia, light intensity and near work time.

Sensitivity analysis was additionally conducted by removing outliers that fell below the 5th percentile or above the 95th percentile, recategorising time outdoors by quartiles, selecting participants who wore smartwatches for more than 240 days and evaluating the effect of time outdoors on myopia incidence and AL to verify the robustness and reliability of the results.

Estimated SE changes and 95% CI were presented, and statistical significance was set at a two-sided $p<0.05$. Two commercially available software packages (SAS, V. 9.4, SAS Institute, Inc., and R, V. 4.2.3) were used for data management and statistical analysis.

Patient and public involvement

Patients were not involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

Characteristics of participants

A total of 3194 participants were included in the present analysis (figure 1). There were 1369 children (42.9%) with premyopia and 1825 (57.1%) with hyperopia, respectively (table 1). The mean age of the participants was 8.2 years (SD, 0.6) and 49.5% were boys. Compared with hyperopic children, premyopic children had a lower proportion of non-myopic parents (44.9% vs 53.1%, $p<0.001$), lower baseline SE (0.40 D (SD, 0.32) vs 1.41 D (SD, 0.58), $p<0.001$) and longer baseline AL (23.20 mm (SD, 0.64) vs 22.78 mm (SD, 0.69), $p<0.001$).

Table 1 Characteristics of permyopic and hyperopic children in the study

Characteristics	Total (n=3194)	Premyopia (n=1369)	Hyperopia (n=1825)	P value
Characteristics at baseline				
Age, mean (SD), y	8.2 (0.6)	8.3 (0.6)	8.2 (0.6)	<0.001*
Height, mean (SD), cm	125.4 (6.2)	125.8 (6.2)	125.2 (6.3)	0.005*
Weight, mean (SD), kg	26.5 (5.7)	26.7 (5.7)	26.4 (5.6)	0.204*
Gender, No. (%)				0.740†
Boys	1581 (49.5)	673 (49.2)	908 (49.8)	
Girls	1613 (50.5)	696 (50.8)	917 (50.2)	
Myopia of parents, No. (%)				<0.001†
Both	496 (15.5)	254 (18.6)	242 (13.3)	
Either	1114 (34.9)	500 (36.5)	614 (33.6)	
None	1584 (49.6)	615 (44.9)	969 (53.1)	
SE, mean (SD), D	0.98 (0.70)	0.40 (0.32)	1.41 (0.58)	<0.001*
AL, mean (SD), mm	22.96 (0.70)	23.20 (0.64)	22.78 (0.69)	<0.001*
Characteristics during the follow-up				
Near work time, median (IQR), min/d	239.3 (186.4–304.3)	236.0 (186.4–300.0)	242.1 (185.7–307.6)	0.164‡
Sunlight intensity, median (IQR), lux	2294.2 (2033.1–2585.9)	2265.3 (2016.0–2550.6)	2326.3 (2055.7–2609.3)	<0.001‡
Daily time outdoors, mean (SD), min/d	91.1 (28.8)	90.5 (28.8)	91.5 (28.7)	0.303*
Categories of daily time outdoors, No.(%)				0.612†
≤60 min/d	409 (12.8)	181 (13.2)	228 (12.5)	
61–90 min/d	1296 (40.6)	568 (41.5)	728 (39.9)	
91–120 min/d	1000 (31.3)	419 (30.6)	581 (31.8)	
>120 min/d	489 (15.3)	201 (14.7)	288 (15.8)	

*Two independent samples t-test.
† Chi-square test.
‡Wilcoxon Rank-Sum Test.
AL, axial length; min/d, minutes per day; SE, spherical equivalent.

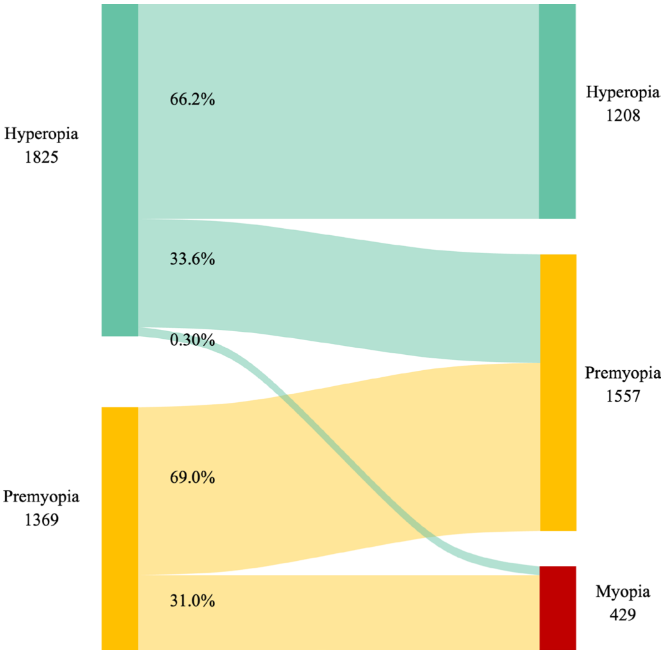


Figure 2 The incident myopia for premyopes and the incident premyopia and myopia for hyperopes.

Distribution of exposures to near work, sunlight intensity and time outdoors

Over the 1-year follow-up, 50% of participants had near work time more than 4 hours per day, 50% of participants were exposed to sunlight intensity less than 2300 lux and the average of daily time outdoors was 91.1 (SD, 28.8) min/d (table 1). Exposures to sunlight were slightly, but significantly lower for premyopic children compared with hyperopic children (premyopia vs hyperopia: 2265.3 vs 2326.3, p<0.001). No statistical differences were observed between the two groups in near work time (median 236.0 (186.4–300.0) min/d vs 242.1 (185.7–307.6) min/d, p=0.164) or time outdoors (mean: 90.5 (SD, 28.8) min/d vs 91.5 (SD, 28.7) min/d, p=0.303). The distributions of hourly time outdoors during the daytime were similar between premyopic and hyperopic children (online supplemental figure S1). There were three peaks of hourly time outdoors during the daytime including 8:00-8:59, 12:00-12:59 and 15:00-15:59.

Incident myopia and premyopia and one-year SE change

Online supplemental figure S2 displays the relationship between time outdoors and 1 year SE change. While there was some overlap in SE changes among premyopic and hyperopic children exposed to different outdoor times (online supplemental figure S2A), premyopic children exhibited more myopic shift in refraction when compared with hyperopic children within each subgroup of time outdoors (online supplemental figure S2B, P values <0.001). As time outdoors increased, the median SE change tended to shift toward a smaller negative value, with this trend being more evident in hyperopic children (online supplemental figure S2B). Figure 2 shows that among those with baseline hyperopia, within the 1 year, only 0.3% became myopic, while 33.6% moved into the premyopic range. Among those with baseline premyopia, 31.0% became myopic.

Association of time outdoors with one-year SE and AL change

Among hyperopic children, a reduced myopic shift was observed with increasing duration of time outdoors, which reached a plateau for about 120 min/d (figure 3 A2). A linear association between light intensity and myopic shift (figure 3 B2), and an interaction between time outdoors and light intensity on myopic shift (*P* for interaction=0.086, figure 3 C2) was also observed. Specifically, in comparison to the subgroup with time outdoors less than 60 min per day, the impact on myopic shift became more pronounced with increasing time outdoors (table 2). For instance, within the 61–90 min/d subgroup, the adjusted difference in SE change was 0.02D (95% CI −0.03 to 0.07; not statistically significant); within the 91–120 min/d subgroup, it was 0.05D (95% CI −0.01 to 0.10) and within the >120 min/d subgroup, it was 0.07D (95% CI 0.02 to 0.13).

Within premyopic children, there was a J-shaped relationship between time outdoors and myopic shift (figure 3 A1), and linear association between light intensity and myopic shift (figure 3 B1), with an interaction between time outdoors and light intensity on myopic shift (*P* for interaction=0.027, figure 3 C1). As shown in table 2, in comparison to the subgroup with daily time outdoors of less than 60 min, the adjusted difference in SE change in the other subgroups was not statistically significant (61–90 min/d: −0.03 (95% CI −0.10 to 0.05); 91–120 min/d: −0.03 (95% CI −0.11 to 0.05); >120 min/d: 0.04 (95% CI−0.05 to 0.14)). The reduced myopic shift was only observed with time outdoors of more than 120 min/d, although it was still not statistically significant.

Regarding AL change, we found that among premyopic children, compared with the subgroup of <60 min/day, only the subgroup with time outdoors >120 min/day was statistically associated with shorter AL change (estimate=−0.049, 95% CI −0.086 to –0.012). Among hyperopic children, compared with the subgroup of <60 min/d, axial elongation was lower in the 91–120 and >120 min/d subgroups, while the 61–90 min/d subgroup showed a smaller, non-significant difference (online supplemental table S1).

Sensitivity analysis

Four sensitivity analyses were carried out to confirm the stability of findings. First, after excluding outliers based on baseline SE and SE change, the results closely mirrored the primary findings, demonstrating the effectiveness of time outdoors on myopic shift within hyperopia, but revealing limited impact among premyopia for the subgroup of >120 min/d (difference of SE change: 0.07 (95%CI 0.00 to 0.15)) (online supplemental table S2). Second, on re-categorising time outdoors according to quartiles, the outcomes remained consistent with the primary findings (online supplemental table S3). Third, after selecting participants wearing smartwatches for more than 240 days, the results were still similar to the primary results (online supplemental table S4). Fourth, the association between time outdoors and myopia incidence was not statistically significant in the subgroup of premyopia (all p>0.05) and the myopia incidence is sparse in the subgroup of hyperopia, rendering the construction of a logistic regression model impossible (online supplemental table S5). Finally, the associations between time outdoors and AL were similar to that of SE (online supplemental tables S6–S8, figure S3).

DISCUSSION

Previous analyses focusing on preventing myopia onset and myopic shifts in non-myopic children showed a significant protective impact of increased outdoor time. Such findings align with the classical perspective of refractive development, as outlined by Josh Wallman[16] and more recently by Ian Flitcroft,[17] which

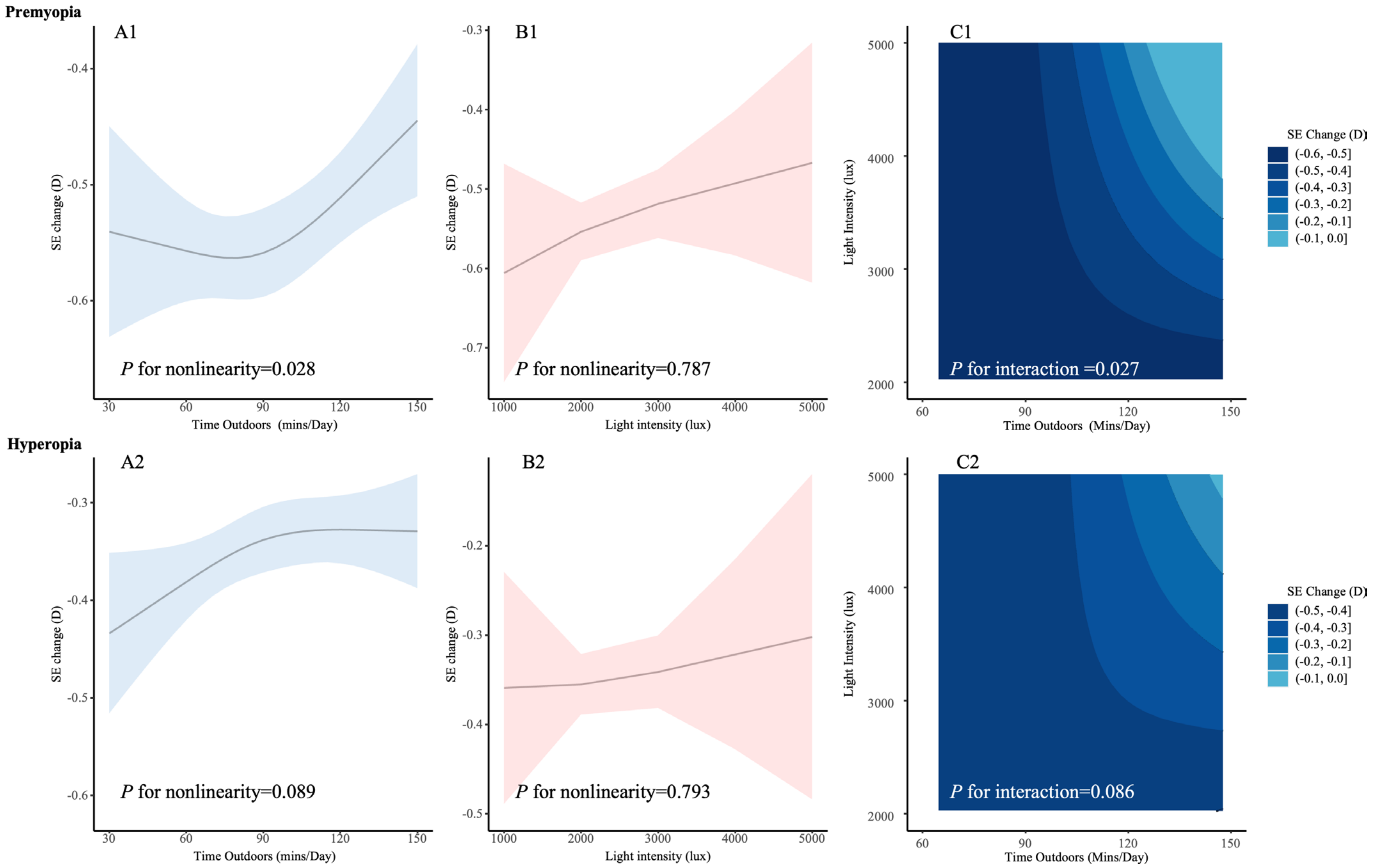


Figure 3 The effect of time outdoors and light intensity on SE change in premyopia and hyperopia. Restricted cubic spline (RCS) between time outdoors and spherical equivalent (SE) change (A1 and A2). RCS plot between light intensity and SE change (B1 and B2). Contour plot between time outdoors and light intensity on SE change (C1 and C2). The dotted grey lines represent the mean and the bands represent the 95% CI.

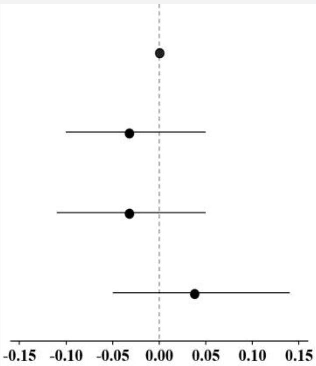
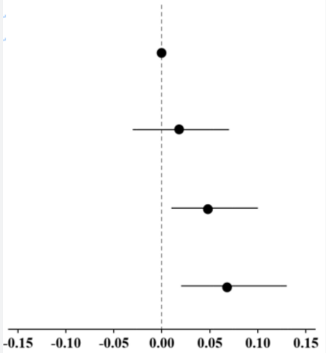
conceptualises emmetropisation as a homeostatic process aiming toward emmetropia (or 0 D) as the critical inflection point. More recently, a model of refractive development that distinguishes between hyperopic and premyopic children is beginning to be frequently used. This paper showed that contrary to the protective effect observed among hyperopic children, time outdoors offered limited benefit for premyopic children, with evidence of a protective effect only in the highest exposure group.

The present study showed a significant interaction between time outdoors and light intensity on myopic shift. Among hyperopic children, the study observed a substantial and dose-dependent protective effect of daily time outdoors on myopic shift. This finding suggests that increased time outdoors confers a tangible benefit for hyperopic individuals, which aligns with previous studies.[9–11 18 19] While the distribution of time outdoors was similar between premyopes and hyperopes (figure 2), our results highlighted a J-shaped non-linear relationship between time outdoors and myopic shift among premyopic children, suggesting limited protection. In contrast, hyperopes showed an almost linear protective effect up to 120 min per day, after which the benefit plateaued. This pattern was also observed with axial elongation. The associations between light intensity and myopic shift in children with premyopia and hyperopia at baseline were both linear. The interaction between time outdoors and light intensity highlighted that time outdoors and light intensity were both crucial for the prevention of myopic shifts[20], and it's necessary for premyopic children to increase their time outdoors when they experience moderate light intensity (eg, 3000–5000 lux) to attain a protective effect.

The ROC study in Taiwan also examined the effect of increased outdoor time on premyopic children and reported a protective impact.[13] However, their study population differed notably from ours: the majority of non-myopic participants were premyopic (intervention group: 103 (75%) premyopic and control group: 63 (57%) premyopic), and hyperopic children comprised only 5% in each arm. This distribution meant that the subgroup analysis of premyopes closely mirrored the overall trial results,[18] while the small hyperopic sample may have limited the ability to detect refractive status-specific effects. In contrast, our cohort was larger overall and included a higher proportion of hyperopic children, enabling clearer differentiation between premyopes and hyperopes.

Several potential mechanisms can explain the differences between premyopia and hyperopia. Previous studies have shown that incident myopes started to experience greater lens power reduction and more extended axial elongation 2 years before the onset of myopia.[7] Premyopic individuals are at high risk of myopia and might also be experiencing a similar trend of lens power reduction and axial elongation, wherein the lens power fails to offset the axial elongation. Swiatczak and Schaeffel have shown that during the transition to myopia, the retina appears to lose the ability to respond appropriately to defocus at red or blue wavelengths, which may explain why myopia is not self-limiting.[21] Their review suggested that a myopic retina has a diminished ability to inhibit eye growth when positive defocus is imposed compared with emmetropia, and the 'closed loop' became 'open loop' in myopic retina.[22] Ho *et al* reported that myopic children have central reduction in high contrast

Table 2 The results of multivariable regression analysis for time outdoors on myopic shift among premyopic and hyperopic children

	SE change	Difference of SE change	
Daily time outdoors in each group	**Mean (SD)**	**Estimate (95% CI)***	
Premyopia†			
≤60 min/d	−0.51 (0.49)	Ref	
61–90 min/d	−0.54 (0.49)	−0.03 (-0.10, 0.05)	
91–120 min/d	−0.53 (0.50)	−0.03 (-0.11, 0.05)	
>120 min/d	−0.44 (0.51)	0.04 (-0.05, 0.14)	
Hyperopia†			
≤60 min/d	−0.36 (0.33)	Ref	
61–90 min/d	−0.34 (0.33)	0.02 (-0.03, 0.07)	
91–120 min/d	−0.30 (0.30)	0.05 (0.01, 0.10)	
>120 min/d	−0.28 (0.32)	0.07 (0.02, 0.13)	

*Estimated difference of SE changes was adjusted for baseline spherical equivalent, age, gender, parental myopia, near work time and sunlight intensity, comparing each outdoor time category with the ≤60 min/d reference group.
†Type three test for time outdoors was applied among premyopia p=0.267, among hyperopia p=0.002.
min/d, minutes per day; SE, spherical equivalent.

multifocal ERG response.[23] These two studies indicated that premyopic retina may not fully trigger the inhibitory arm of the emmetropisation feedback loop and have the limited ability to inhibit eye growth as the myopic retina. However, the link between loss of ability to respond to positive defocus and loss of sensitivity to time outdoors and dopamine release is not clear and further research can address this issue.

In our findings, the protective effect in premyopic children was modest and reached statistical significance only at the highest exposure levels. This highlights the need for both substantially greater outdoor exposure for premyopia and earlier interventions for hyperopia. Initiating increased time outdoors regimens at younger ages, prior to premyopia, could potentially offer more significant benefits. This approach is supported by the ALSPAC study, which highlights the potential for greater protective effects against myopia development through timely preventive strategies during early childhood.[24] Although smaller in magnitude, such effects on premyopia may still accumulate over time to produce clinically relevant benefits.

The strength of this study lies in its use of smartwatches to objectively measure time outdoors, which enhances the accuracy and reliability of our findings. However, there are some limitations. First, a significant limitation of our study is that the premyopia category includes children at different stages of refractive development, those still with residual hyperopic reserve and those already showing rapid axial elongation and myopic shifts in refraction. This heterogeneity could dilute observed effects and reduce the sensitivity to detect associations. Whether decreased sensitivity to time outdoors occurs in parallel with the development of higher rates of myopic shift in refraction is not clear. Second, while the objective measurement of exposures to light is a considerable strength, the light intensity captured by the smartwatch may differ from the light intensity received by the human eye, which could underestimate the light intensity. Near work is measured by a questionnaire, and the report bias is unavoidable. This may restrict the analysis of the impact of near work on myopic shift. Third, although we adjusted for several known covariates, residual confounding remains possible. Factors such as socioeconomic status, dietary patterns and genetic risk beyond parental myopia were not fully captured in our dataset and could influence the results. Future studies with more variables may provide additional insights into the observed associations. Finally, the study duration was only 1 year, which may not be enough to capture the long-term effects of outdoor time on myopia prevention in children with premyopia. Future studies with more control over exposures and longer follow-up periods are needed to better understand these effects.

In conclusion, the study's findings hold significant implications for future myopia prevention efforts. While the protective effects of time outdoors are clear for children with hyperopia, the protective effect of time outdoors on myopic shift among children with premyopia is more limited and was only seen with longer durations of time outdoors. Nevertheless, in school-based interventions, given the other benefits of time outdoors, increased time outdoors should be provided for all children. However, additional interventions, such as low dose atropine or red-light therapy, to prevent or delay myopia onset in premyopic children may be useful.

Author affiliations
[1]Shanghai Eye Diseases Prevention &Treatment Center/ Shanghai Eye Hospital, School of Medicine, Tongji University, Shanghai, China
[2]National Clinical Research Center for Eye Diseases, Shanghai, China
[3]Shanghai Engineering Research Center of Precise Diagnosis and Treatment of Eye Diseases, Shanghai, China
[4]Eye Public Health Research Center, School of Medicine, Tongji University, Shanghai, China
[5]Research School of Biology, Australian National University, Canberra, Australian Capital Territory, Australia
[6]Discipline of Orthoptics, Graduate School of Health, University of Technology Sydney, Sydney, New South Wales, Australia
[7]Centre for Eye Research Australia Ltd, East Melbourne, Victoria, Australia
[8]State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou 510060, China, Guangzhou, China
[9]The Hong Kong Polytechnic University, Hong Kong, Hong Kong SAR, Hong Kong

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Contributors Conception and design: Xu, Xiangui He, Mingguang He, Chen, Qi. Data collection: Qi, Wang, Zhang, Du, Yang, Jianfeng Zhu, Gao, Zou. Analysis and interpretation: Chen, Qi, Morgan, Rose, Zhuoting Zhu, Ding. Obtained funding: Xu, Gao, Chen. Overall responsibility: Xiangui He is the guarantor.

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ORCID iDs
Ziyi Qi https://orcid.org/0000-0002-3611-8778
Ian Morgan https://orcid.org/0000-0002-4548-3574
Kathryn Rose https://orcid.org/0000-0003-2851-4145
Zhuoting Zhu https://orcid.org/0000-0002-9897-1192
Jingjing Wang https://orcid.org/0000-0003-2279-9514
Jinliuxing Yang https://orcid.org/0000-0002-4031-7040
Jianfeng Zhu https://orcid.org/0000-0002-4453-611X
Xun Xu https://orcid.org/0000-0002-4246-4343
Xiangui He https://orcid.org/0000-0002-8938-1879

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