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Pseudomyopia as an independent risk factor for myopia onset: a prospective cohort study among school-aged children

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ABSTRACT

Aim To investigate whether pseudomyopia is an independent risk factor for myopia onset based on a population-based cohort study.

Methods Non-myopic children were recruited from schools in rural and urban settings of Shangdong province, China. Baseline examinations started in September 2020 and all participants were invited for a 6-month follow-up. Pseudomyopia was defined as spherical equivalent (SE) ≤−0.50 diopters (D) before cycloplegia and >−0.50D after cycloplegia. Myopia was defined as cycloplegic SE ≤−0.50D.

Results A total of 2328 children (baseline age: 4–17 years) were included in the final analysis. During the 6-month follow-up, 21.1% (355/1680) pseudomyopic eyes developed myopia, and 3.8% (110/2879) non-myopic and non-pseudomyopic eyes developed myopia. After adjusting for multiple myopia risk factors, including baseline cycloplegic SE, near work and outdoor time, pseudomyopia was found to be an independent risk factor for myopia onset (relative risk=2.52, 95% CI 1.86 to 3.42). Additionally, pseudomyopic children with more myopic cycloplegic SE (p<0.001), smaller difference between cycloplegic and non-cycloplegic SE (DIFF, p<0.001), and higher binocular amplitude of accommodation (p<0.001) had higher risk of myopia development.

Conclusion This is an important longitudinal study to prove that pseudomyopia is an independent risk factor for myopia development among school-aged children.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Myopia is a major health problem leading to significant public health and economic concerns, especially in Asia.

⇒ Pseudomyopia refers to spherical equivalent (SE) ≤−0.50 diopters (D) before cycloplegia and >−0.50D after cycloplegia, and nearly 24.1% of Chinese children were found to have pseudomyopia.

⇒ Whether the presence of pseudomyopia affects the risk of myopia remains unknown.

WHAT THIS STUDY ADDS

⇒ Based on a large prospective population-based cohort study, we found that pseudomyopia was an independent risk factor for myopia development among school-aged children.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our study findings provide important evidences that children with pseudomyopia are more likely to develop myopia than those without, indicating a need to identify pseudomyopia and opening up new research questions for the underlying causes.

INTRODUCTION

Myopia is a major global health concern, with China representing one of its epicentres.[1] During home quarantine brought on by the COVID-19 pandemic, myopia progression has accelerated in Chinese children, which may be secondary to reduced time outdoors, as well as excessive near work and accommodation from online teaching during lockdowns and home isolation.[2–5] The beneficial effect of increasing outdoors on myopia control has been universally acknowledged, but existing evidence does not support a direct role of accommodation in myopia development and progression, as suggested by a recent International Myopia Institute White Paper.[4 6 7] Nevertheless, as myopic subjects demonstrated less stable accommodation responses, inaccuracies of accommodation may be related to the occurrence and development of myopia.[7–9]

Pseudomyopia is a subtype of excessive accommodation, featuring as an apparent myopic refractive error that disappears after cycloplegia in the refraction measurement.[10] Previous studies defined pseudomyopia as spherical equivalent (SE) ≤−0.50 diopters (D) before cycloplegia and >−0.50 D after cycloplegia.[11] Despite pseudomyopia being as common as 24.1% in Chinese children, clinical investigations on this issue are insufficient; for example, it remains unknown whether the presence of pesudomyopia is associated with a higher risk of developing myopia.[11] Thus, in the current study, we aimed to investigate whether pseudomyopia is an independent risk factor for myopia onset based on a population-based cohort study.

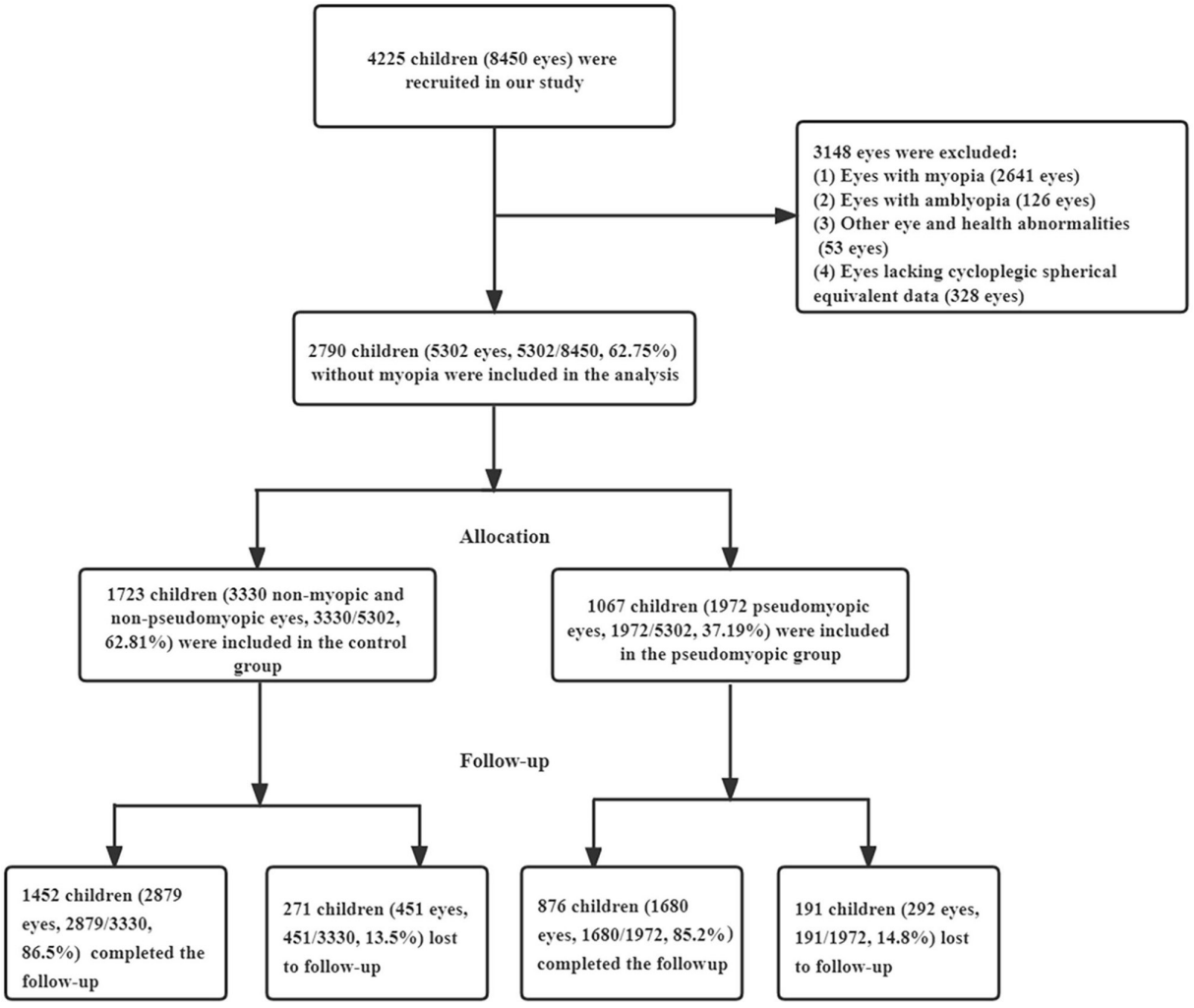

Figure 1 The study flow chart.

MATERIALS AND METHODS

Study population

This was a population-based prospective cohort study, which used a multistage stratified cluster sampling to recruit children from nine schools (two kindergartens, four primary schools, two middle schools and one high school) in Huantai City, Shandong Province, Eastern China. The local ministry of education provided a list of all schools in each urban city and rural county. The first stage involved a random selection of one urban and one rural area, respectively. In the second stage, nine schools were then chosen from the selected urban and rural areas using convenience sampling. Given that there were less than 900 children from the selected primary school in rural areas, two additional rural schools were added to the sample. In the third stage, the sampling frame was defined according to the enumeration of grades within the schools and kindergarten. For each grade,

Table 1 Distribution of baseline characteristics

	Total (n=5302*)	Pseudomyopia group (n=1972*)	Control group† (n=3330*)	P value
Axial length (mm) based on different SE (D)				<0.001
>−0.50, ≤0.00	23.52±0.71	23.53±0.71	23.48±0.69	
>0.00, ≤0.75	23.17±0.70	23.20±0.73	23.15±0.69	
>0.75	23.57±0.75	22.56±0.76	22.56±0.76	
Cycloplegic SE (D)				<0.001
>−0.50, ≤0.00	−0.17±0.14	−0.20±0.14	−0.10±0.12	
>0.00, ≤0.75	0.47±0.21	0.43±0.22	0.50±0.20	
>0.75	1.48±0.83	1.33±0.49	1.53±0.49	
Average corneal curvature (D)	43.27±1.43	43.28±1.46	43.27±1.42	0.79
Intraocular pressure (mm Hg)	16.13±2.73	16.15±2.73	16.11±2.73	0.43

*Indicates the number of eyes.
†Children with non-myopic and non-pseudomyopic eyes were included in the control group.
D, diopter; SE, spherical equivalent.

Table 2 Multiple logistic regression analysis assessing risk factors for myopia onset during the follow-up

	RR (95% CI)	P value
Pseudomyopia	2.52 (1.86 to 3.42)	<0.001
Age	0.95 (0.87 to 1.03)	0.21
Gender, female	1.41 (1.04 to 1.91)	0.03
Cycloplegic SE (D)		
>0.75	Ref.	Ref.
>0.00, ≤0.75	11.82 (6.04 to 23.14)	<0.001
>−0.50, ≤0.00	115.54 (57.79 to 231.01)	<0.001
Binocular accommodative facility (cpm)	1.02 (0.98 to 1.07)	0.27
Binocular amplitude of accommodation	1.06 (1.02 to 1.10)	<0.001

Logistic regression was performed using the GEE model, which adjusted for paternal refractive status, maternal refractive status, indoor near work time per day on weekdays (hours), indoor near work time per day on weekends (hours), outdoor activity time per day on weekends (hours), sleep duration (hours) and distance UCVA.
cpm, cycles per minute; D, diopter; GEE, generalised estimated equation; RR, relative risk; SE, spherical equivalent; UCVA, uncorrected visual acuity.

classes were selected by simple random sampling and all students in the selected classes were asked to participate in the study.

Children with myopic eyes were excluded from the study. Stratification of clusters ensured that a representative sample of non-myopic children from 4 years to 17 years was included. Baseline examinations were conducted in September 2020, and the 6-month follow-up examinations were conducted from March to April 2021. Children with amblyopia or abnormalities that may affect visual function or refractive development were excluded from the study. A parent or legal guardian provided written informed consent before participating in this study.

Data collection

Demographic data were collected by searching the school database. In addition, children included in this study underwent a series of examinations, including an interview with a standardised questionnaire similar to the one used in the Refractive Error Study in Children studies at school.

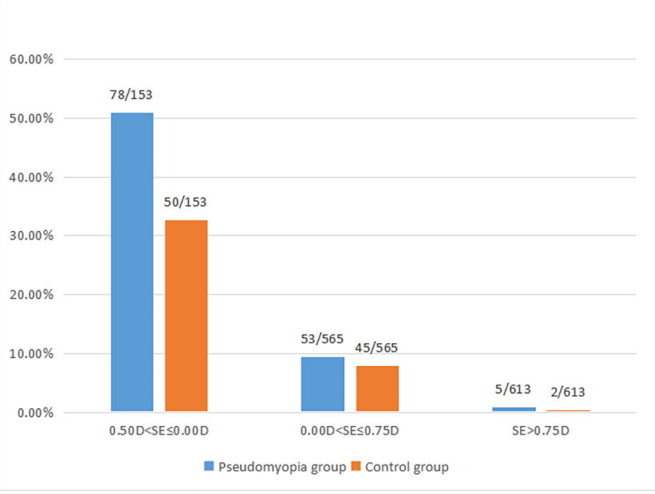

Figure 2 Incidence of myopia during the 6 month follow-up based on cycloplegic spherical equivalent. After matching by propensity score for cycloplegic SE, 1331 eyes from the pseudomyopia group and 1331 eyes from the control group were included. SE, spherical equivalent.

Two ophthalmologists performed slit-lamp ocular examinations for all children at each study visit. The other examinations were performed by trained optometrists, including uncorrected distance visual acuity (UCVA) at a standard testing distance of 3 m (#600722, Good-Lite, Elgin, IL, USA), intraocular pressure measurement using a non-contact tonometry (Topcon CT80; Topcon, Tokyo, Japan), laser interferometry-based ocular biometry (IOL-Master 500, Carl Zeiss Meditec AG, Jena, Germany), non-cycloplegic and cycloplegic autorefraction (Nidek ARK-1, Japan.), as well as binocular accommodative facility and amplitude of accommodation. According to the procedures in the manufacturer's instruction manual, the vertex distance was 12 mm and the measurement step size was 0.25 D for the assessment of the spherical power and cylindrical power. Three measurements were carried out and the mean value was recorded as the final measurement. The difference between the maximum and minimum value of the measurements of spherical refractive error and cylindrical refractive error had to be less than 0.50 D; otherwise, the measurements had to be repeated. A model eye provided by the manufacturer was used to repeatedly check the calibration of the instrument at the beginning and end of each day. Five measures of axial length were conducted on each eye prior to cycloplegia using IOL-Master. Measurements with signal-to-noise ratios of less than 10 were deleted, then the examiner would repeat the measurement. At last, the averaged value was recorded as final axial length data. Cycloplegia was achieved by using 1% cyclopentolate eye drops (Alcon, Ft Worth, TX, USA), except for eyes with contraindications.[12] Three drops of 1% cyclopentolate were instilled in intervals of 5 min. About 30 min after the last drop instillation, a repeated autorefractometry was performed. If a pupil diameter of at least 6 mm was not achieved, another drop of cyclopentolate was given and the examination was repeated 10 min later. Other detailed study methodology has been reported in previous studies.[13 14]

The accommodative function assessment was tested for children older than 7 years only. The process of accommodative function examinations was explained to the participants to ensure that the children understood the content of the test.[15] Under the subject's presenting vision, the examiner tested the cycles per minute (cpm) binocularly using ±2.00 D flip lenses and 20/30 vision card (test at 40 cm, 1 cycle=plus and minus). The optometrist repeated the test at least three times and recorded the average value. The binocular amplitude of accommodation (push-up amplitude) was tested using the accommodative rule and recorded with diopters. Subjects viewed the high contrast, black-on-white near vision card via an accommodative rule under their distant best corrected visual acuity (BCVA). They were asked to gaze optotypes in the previous line of their distant BCVA. The examiner slowly advanced the target toward the subjects at a speed of 1–2 cm/s until the target sustaining blurred, which was reported by the subjects immediately. The average of three measurements was recorded.

Definition

Spherical equivalent was defined as the sum of the spherical refractive error plus half of the cylindrical refractive error (measured as minus values). Myopia was defined as SE ≤ −0.50 D after cycloplegia. Premyopia was defined as −0.50 D<SE≤0.75 D after cycloplegia, while hyperopia was defined as SE >0.75 D after cycloplegia.[16] Pseudomyopia was defined as SE ≤ −0.50 D before cycloplegia and > −0.50 D after cycloplegia.[11] Difference between cycloplegic and non-cycloplegic refractive error (DIFF)

Table 3 Risk factors for myopia onset in children with pseudomyopia

	Univariate logistic regression		Multiple logistic regression	
	RR (95% CI)	P value	RR (95% CI)	P value
Age (years)	1.22 (1.16 to 1.27)	<0.001	1.00 (0.91 to 1.09)	0.98
Eye laterality, right eye	1.14 (0.91 to 1.45)	0.26		
Gender, female	1.22 (0.96 to 1.54)	0.10		
Paternal refractive status				
Emmetropia	Ref.	Ref.	Ref.	Ref.
Mild or moderate myopia	1.27 (0.98 to 1.65)	0.07	1.04 (0.70 to 1.54)	0.86
High myopia	1.76 (1.05 to 2.96)	0.03	1.83 (0.83 to 4.03)	0.13
Hyperopia	1.62 (0.62 to 4.25)	0.33	0.75 (0.14 to 3.95)	0.73
Maternal refractive status				
Emmetropia	Ref.	Ref.	Ref.	Ref.
Mild or moderate myopia	1.08 (0.84 to 1.40)	0.55	0.88 (0.59 to 1.32)	0.42
High myopia	1.86 (1.06 to 3.27)	0.03	1.29 (0.54 to 3.07)	0.58
Hyperopia	1.90 (0.64 to 5.66)	0.25	0.97 (0.13 to 7.52)	0.99
Indoor near work time per day on weekdays (hours)				
<4	Ref.	Ref.	Ref.	Ref.
≥4 to <8	1.29 (0.98 to 1.72)	0.07	1.26 (0.82 to 2.00)	0.28
≥8 to <12	1.21 (0.82 to 1.79)	0.33	1.04 (0.32 to 1.41)	0.29
≥12	2.30 (1.44 to 3.68)	0.00	1.56 (0.20 to 2.75)	0.66
Indoor near work time per day on weekends (hours)				
<4	Ref.	Ref.	Ref.	Ref.
≥4 to <8	1.75 (1.34 to 2.28)	<0.001	1.28 (0.82 to 2.16)	0.97
≥8 to <12	1.35 (0.88 to 2.08)	0.17	0.67 (0.32 to 4.05)	0.29
≥12	1.86 (0.84 to 4.12)	0.13	0.74 (0.20 to 2.60)	0.47
Outdoor activity time per day on weekdays (hours)				
<0.5	Ref.	Ref.		
≥0.5 to <1	0.99 (0.66 to 1.49)	0.96		
≥1 to <2	0.96 (0.65 to 1.41)	0.82		
≥2	0.71 (0.45 to 1.12)	0.14		
Outdoor activity time per day on weekends (hours)				
<0.5	Ref.	Ref.		
≥0.5 to <1	1.25 (0.70 to 2.22)	0.45		
≥1 to <2	0.90 (0.52 to 1.54)	0.69		
≥2	0.82 (0.48 to 1.40)	0.46		
Sleep duration (hours)				
<6	Ref.	Ref.		
≥6 to <8	0.95 (0.51 to 1.77)	0.86		
≥8 to <10	0.76 (0.42 to 1.36)	0.35		
≥10	0.73 (0.36 to 1.47)	0.38		
Distance UCVA				
20/20	Ref.	Ref.	Ref.	Ref.
20/25	2.27 (1.64 to 3.13)	<0.001	1.45 (0.97 to 2.16)	0.07
20/50–20/30	2.94 (2.00 to 4.31)	<0.001	2.32 (1.33 to 4.05)	<0.001
≤20/60	9.47 (2.35 to 38.13)	<0.001	0.57 (0.12 to 2.60)	0.47
Cycloplegic SE (D)				
>0.75	Ref.	Ref.	Ref.	Ref.
>−0.50, ≤0.00	192.59 (78.37 to 473.29)	<0.001	69.87 (25.07 to 194.69)	<0.001
>0.00, ≤0.75	13.03 (5.18 to 32.74)	<0.001	8.56 (3.19 to 22.95)	<0.001
Intraocular pressure (mm Hg)	1.05 (1.01 to 1.10)	0.02	1.00 (0.94 to 1.06)	0.94
DIFF	0.19 (0.15 to 0.23)	<0.001	0.68 (0.54 to 0.85)	<0.001
Binocular accommodative facility (cpm)	1.07 (1.04 to 1.10)	<0.001	1.01 (0.96 to 1.07)	0.62
Binocular amplitude of accommodation (D)	1.06 (1.04 to 1.09)	<0.001	1.06 (1.01 to 1.12)	0.02

cpm, cycles per minute; D, diopter; DIFF, difference between cycloplegic and non-cycloplegic refractive error; RR, relative risk; SE, spherical equivalent; UCVA, uncorrected visual acuity.

in diopter was defined as cycloplegic SE minus non-cycloplegic SE.

Paternal and maternal refractive status was categorised into high myopia (SE ≤−6.00 D), mild and moderate myopia (SE>−6.00 D and SE≤−0.50 D), emmetropia (−0.50 D<SE≤0.75 D) and hyperopia (SE>0.75 D).

Statistical analysis

Data from both eyes of the study participants were included in the analysis and the correlation between two eyes was adjusted using the generalised estimated equation (GEE) model. Eyes with pseudomyopia were included in the pseudomyopia group, while eyes without pseudomyopia were included in the control group. The Stata (Stata, Stata Statistical Software: Release 14; College Station, TX, USA) was used for statistical analysis. Normality and variance homogeneity of data were checked through Shapiro-Wilk and Levene tests. Parametric tests were used for data with a normal distribution. Otherwise, non-parametric tests were used. Continuous variables that conformed to a normal distribution were expressed as mean±SD, while those that did not were expressed as median (IQR). Categorical data were expressed as the number of cases/percentage (n(%)). Pearson χ^2 tests were used to examine the difference among groups for the categorical variables. Under a logistic model, we computed the RR and 95% CI using GEE to determine the association between pseudomyopia and the risk of myopia onset. Multiple confounding factors, including age, eye laterality, gender, paternal and maternal refractive status, indoor near work time, outdoor activity time, sleeping duration, distance UCVA, cycloplegic SE, intraocular pressure, binocular accommodative facility and binocular amplitude of accommodation, were adjusted in the models. Risk factors for myopia among pseudomyopic children were also determined by GEE. Propensity-matching was applied to balance the cycloplegic SE of children for correct evaluation of the primary outcomes of pseudomyopia. Children lost to follow-up were considered censored data. A bilateral p value of <0.05 was considered statistically significant.

RESULTS

There were 2790 non-myopic children who completed the baseline examinations, among whom 3330 non-myopic eyes from 1723 children (3330/5302, 62.81%) were assigned to the control group and 1972 pseudomyopic eyes from 1067 children (1972/5302, 37.19%) were assigned to the pseudomyopia group according to the inclusion and exclusion criteria (figure 1).

In March 2021, 2328 children (2328/2790, 83.44%) completed the follow-up visit (figure 1). The main reason for the loss to follow-up was that parents did not agree to perform cycloplegia again. There was no significant difference in demographics between those who completed follow-up and those who lost to follow-up (online supplemental table 1).

The baseline characteristics for children in the pseudomyopia and control group are given in table 1 and online supplemental table 2. Within 6 months, 21.1% (355/1680) pseudomyopic eyes progressed to myopia. The corresponding proportion of eyes in the control group was 3.8% (110/2879). After matching by propensity score for cycloplegic SE, 1331 eyes from the pseudomyopia group and 1331 eyes from the control group were included. In this subgroup of matched study participants, eyes in the pseudomyopia group were found to have a higher myopia incidence (10.22% vs 7.29%, figure 2), and multiple regression analysis also showed that pseudomyopia was a significant risk factor for myopia onset (RR=2.97; 95% CI 1.55 to 5.69) (online supplemental table 3). After adjusting for multiple myopia risk factors, the risk of myopia onset in pseudomyopic eyes was 2.52 times higher than that in the control group (RR=2.52; 95% CI 1.86 to 3.42) (table 2). Subgroup analysis was performed based on different refractive statuses and age groups. For premyopic eyes, pseudomyopia posed a 2.66 times higher risk of developing myopia (RR=2.66, 95% CI 1.97 to 3.59; p<0.001) (online

supplemental table 4). For children in different age groups, pseudomyopia also posed a higher risk of developing myopia, which was 3.33 times in the 8–10-year-old group (RR=3.33, 95% CI 2.13 to 5.23; p<0.001), and 4.07 times in the 11–13-year-old group (RR=4.07, 95% CI 1.85 to 8.94; p<0.001) (online supplemental table 4). The results of other univariate analyses are presented in online supplemental table 5.

We also conducted the multiple regression analysis in the pseudomyopia group to identify who were at increased risk of developing myopia within this group. Poorer distance UCVA (20/50–20/30 vs 20/20, RR=2.32 ; p<0.001), more myopic cycloplegic SE (−0.50<SE≤0.00 vs SE>0.75, RR=69.87; p<0.001; 0.00<SE≤0.75 vs SE>0.75, RR=8.56), smaller DIFF (RR=0.68; p<0.001) and higher binocular amplitude of accommodation (RR=1.06; p<0.001) were significant risk factors for pseudomyopia eyes to develop myopia (table 3).

The baseline DIFF showed a skewed distribution and we found that when stratified by cycloplegic SE and age, children with more hyperopic cycloplegic SE had larger baseline DIFF (online supplemental figures 1 and 2).

DISCUSSION

Our study demonstrated that pseudomyopia was common (1972/5302, 37.19%) among non-myopic school-aged children and was associated with a significantly higher risk of myopia onset. Despite the fact that we identify pseudomyopia as an independent risk factor for myopia onset, clinicians should envisage that the children, once they are in premyopia status, are at significantly increased risk of developing myopia, and thus all prophylactic measures should be adopted, for example, outdoor time intervention.

There have been a few studies assessing the associations between pseudomyopia and myopia.[11 17] An article investigating the association between near work-induced transient myopia (NITM) and progression of refractive error found that there was more relative myopic refractive progression for hyperopic children with more NITM.[17] The authors inferred that it might be through a mild spasm of the ciliary and increased variability of NITM decay response, which meant the hyperopic children with more NITM had inaccurate accommodative function. A previous study by Kang *et al* reported that pseudomyopia was not associated with the progression of myopia.[11] We assume that this discrepancy with the current study may be due to differences in the study objectives and methods. Kang *et al* aimed to find out whether pseudomyopic power (equivalent to the DIFF in the current study) was associated with myopic progression, whereas we aimed to investigate whether the presence of pseudomyopia was an independent risk factor for myopia onset. In addition, the prevalence of pseudomyopia is higher at 37.19% in our study.[11] This increased proportion of pseudomyopia may be due to the recently increased near work, namely, the increased use of electronic devices during homeschooling, due to COVID-19, though this hypothesis requires further testing as previous studies did not find an association between pseudomyopia and near work during normal school days.[11]

The mechanism for children with pseudomyopia, as an observed phenomenon under a specific definition in the current study, being more likely to develop myopia, is unclear. Pseudomyopia has been suggested to represent excessive accommodation or ciliary spasm, which could be persistent but not permanent.[10 18] In addition to the already-known phenomenon of NITM, the myopia onset and progression during COVID-19 lockdowns, which may be related to medium-term accommodative spasms, disappeared with time.[19] However, currently there is no clear evidence supporting that excessive accommodation directly leads to myopia, and attempts to control the development of myopia by limiting accommodation had been unsuccessful.[7] Inaccurate accommodative response in children with pseudomyopia could be another possible reason, since it may prevent the formation of clear and stable retinal images, causing blurred retinal images that may promote myopia onset and progression.[8 9] Future studies are needed to better understand the underlying reasons.

It should be noted that the definition of pseudomyopia used in the current study could not rule out instrument myopia, which in our study referred to observed myopia induced merely by the use of an autorefractor instead of by excessive accommodation. However, the instrument myopia is technically difficult to measure, and in the current study, unfortunately, we did not attempt to measure it and, therefore, were unable to disentangle the contribution of instrument myopia in the observed pseudo-myopia.[20] Despite this challenge, one way to differentiate pseudomyopia-related over-accommodation and instrument myopia is to look at uncorrected distance visual acuity (UCVA). Pseudomyopic children secondary to persistent accommodation spasm are more likely to have compromised distance UCVA, while those with instrument myopia only are more likely to have normal vision. In the current study, compromised UCVA was found to be more common in the pseudomyopia group (online supplemental table 6, p=0.013), and the observed DIFF (−1.82 [1.30]) was much larger than the amount of instrument myopia of autorefraction (−0.20 D) reported in the literature, suggesting that the observed pseudomyopia could not be merely instrument myopia.[21] However, it should be noted that the absolute difference is very small, and over 80% of the eyes in the pseudomyopia group had normal UCVA. Future studies which could directly differentiate instrument myopia from pseudomyopia are needed to better understand their separate effect on myopia risk.

To the best of our knowledge, this is an important study that reported pseudomyopia as a risk factor for myopia onset based on a longitudinal cohort study. Strengths of this study included a population-based design and the availability of multiple confounding factors adjusted in the model. The sample size was relatively large, and the subgroup analyses further supported the robustness of the study findings. The broad similarities in demographics between those followed up and those lost to follow-up suggest that the continuing participants may be considered broadly representative. Several limitations should also be noted. First, the follow-up period of 6 months is relatively short, future studies with longer follow-up time is needed. Second, the push-up test may overestimate the accommodative amplitude by about 2.00 D due to relative distance magnification, particularly in younger children, while the minus lens method may underestimate the amplitude through increasingly greater amounts of minus lenses. We choose the push-up method due to its better convenience during school-based surveys. Third, collection of outdoor activity time and near work time by self-reported questionnaires is inevitably subject to bias. Lastly, as the study was conducted in Shandong, China, the results cannot be directly applied to other populations.

In summary, we found that children with pseudomyopia were more likely to develop myopia, even after adjusting for multiple known myopia risk factor. Our research provides new considerations for myopia prevention and control in children and opens up a new window for future research to investigate the mechanisms underlying the transition from pseudomyopia to myopia.

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Contributors HB and YH designed the research. WS, MY and XH drafted the manuscript and participated in data analysis. JW and WS were responsible for the data collection and accessed and verified the data. CJ and XH were responsible for the refinement of the content and language of the manuscript. JS and WJ were involved in critically revising the manuscript. ZX, ZW and JX participated in the data collection. HB is guarantor.

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Competing interests None declared.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants. The protocols of this study were approved by the ethics committee of Affiliated Eye Hospital of Shandong University of Traditional Chinese Medicine (HEC-KS-2020016KY). Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. Direct requests for additional data to the corresponding author.

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