Clinical science

Cycloplegic autorefraction doubles diagnostic yield of myopia compared to vision testing: findings from a decade-long screening programme

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Some material of this manuscript has been presented as a poster at the Association for Research in Vision and Ophthalmology Annual Meeting, Salt Lake City, May 4–8, 2025.

Received 7 June 2025
Accepted 31 December 2025

To cite: Wang C-Y, Yang Y-C, Yang H-Y, *et al*. *Br J Ophthalmol* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/bjo-2025-328039

ABSTRACT

Background Cycloplegic autorefraction may offer higher diagnostic accuracy than uncorrected visual acuity (VA) screening. We aimed to evaluate diagnostic yield and risk factors for previously unrecognised myopia.

Methods This repeated cross-sectional study analysed data from 33 642 kindergarteners aged 5–6 years enrolled in the Yilan Myopia Prevention and Vision Improvement Program from 2014 to 2024. Participants underwent uncorrected VA testing and on-site cycloplegic autorefraction. Caregivers completed questionnaires on myopia-related behaviours. Previously unrecognised or newly detected myopia (NDM), defined as spherical equivalent ≤−0.50 dioptres without prior diagnosis. The main outcome was diagnostic yield, defined as the proportion of NDM among at-risk participants by different screening methods.

Results Among 33 642 participants (mean age, 5.23±0.41 years; 51.7% boys), 3206 (9.5%) were identified myopic, including 2303 (6.8%) who were newly detected through cycloplegic autorefraction, yielding a diagnostic rate of 7.03% (95% CI 6.76% to 7.32%). Only 47.9% children with NDM met the reduced VA referral criterion (uncorrected VA <6/7.5 in either eye), and the diagnostic yield of VA screening was 3.37% (95% CI 3.18% to 3.57%; area under the ROC curve: 0.743). NDM was significantly associated with weekend behaviours including digital screen time ≥2 hours/day (OR, 1.13; 95% CI 1.03 to 1.23) and outdoor time ≥2 hours/day (OR, 0.85; 95% CI 0.78 to 0.94). In contrast, previously detected myopia showed no association with these modifiable factors.

Conclusions Preschool myopia screening using cycloplegic autorefraction significantly improves early detection compared with VA screening. Timely diagnosis raises parental awareness and empowers children to modify myopia-related behaviours.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Visual acuity tests and non-cycloplegic refraction are commonly used for school-based myopia screening, but their accuracy is limited in preschool children due to strong accommodation.

WHAT THIS STUDY ADDS

⇒ This large-scale screening of preschool children showed cycloplegic autorefraction more than doubled the diagnostic yield compared with uncorrected visual acuity alone.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study demonstrates the feasibility of incorporating cycloplegic autorefraction in large-scale preschool screenings, supporting its use for earlier and more accurate detection in high-prevalence regions.

INTRODUCTION

High myopia and its complications may place a significant burden on healthcare.[1 2] Young children with juvenile-onset myopia are at an increased risk of rapid progression to high myopia later in life,[3–7] and early identification and timely interventions are crucial to slow its progression. Currently, visual acuity (VA) testing is the main method for large-scale school-based myopia screening in Taiwan.[8] Uncorrected VA has been reported to correlate strongly with refractive errors, including myopia, with high sensitivity (97.8%) and specificity (97.1%) for detecting myopia in 12-year olds.[9]

In Taiwan, myopia screening using VA tests for schoolchildren and preschoolers is commonly conducted by school nurses and trained kindergarten teachers as part of standard practice. This school-based approach is easy to implement and requires minimal resources.[8] Reduced VA in children aged 5–6 years is suspected if the uncorrected VA of either eye falls below 6/7.5, as measured by trained teachers using a Snellen chart at a distance of 6 m. Preschoolers with reduced VA receive referrals for ophthalmic evaluation. However, there are concerns about the accuracy of using the VA test alone to detect myopia.[10] Low myopia often causes minimal visual symptoms, allowing children to pass VA screenings. Consequently, such children may go undetected and miss the timing for early intervention.

Parents in Taiwan are encouraged to take their children for cycloplegic refraction examinations at ophthalmic clinics one to two times a year.[11] However, access to ophthalmic care is uneven

nationwide. To address this issue and facilitate early detection of myopia in young children, the Public Health Bureau of Yilan County initiated the Yilan Myopia Prevention and Vision Improvement Program (YMVIP) in 2014. This countywide preschool screening programme provides annual VA and cycloplegic autorefraction to all 5–6-year olds.[12] This study aims to analyse the results of screening examinations and questionnaires collected from 2014 to 2024 through the YMVIP, to estimate the diagnostic yield and identify factors associated with previously unrecognised myopia.

MATERIALS AND METHODS

Study design and participants

Since its launch in the 2014 school year, the YMVIP has been implemented to promote myopia prevention strategies in kindergartens across all 12 townships of the county, including 2 suburban and 10 rural areas. Details of the methodology for this preschool screening programme have been published elsewhere.[4 12] In summary, every preschool child in the final kindergarten grade, aged 5–6 years, has been invited to participate in the screening programme, which includes eye examinations and questionnaires conducted annually during the fall semester. Written informed consent was obtained from the parent of each participant. Between August 2014 and December 2024, 11 waves of screening were conducted, with a total budget of 17.17 million New Taiwan Dollars (approximately US$ 520 300), covering fees for examinations, data management and educational campaigns. The retrospective review of participant records was approved by the Institutional Review Board of National Yang Ming Chiao Tung University Hospital (approval identifiers: 2020A015 and 2023A013) and adhered to the principles outlined in the Declaration of Helsinki.

Eye examination

Qualified ophthalmologists conducted on-campus eye examinations following standardised procedures established by the YMVIP organising committee. Monocular uncorrected distant VA (UDVA) was tested by nursing staff or trained kindergarten teachers using a Snellen chart at 6 m. These personnel were masked to the refractive status of the children to prevent measurement bias.

Cycloplegia was induced using three drops of 1% tropicamide, administered at 5 min intervals. Since 2019, this regimen was replaced with a combination of 0.5% tropicamide and 0.5% phenylephrine. Approximately 30 min after the first instillation, the pupillary light reflex was evaluated. Cycloplegia was considered adequate when no pupillary constriction was observed under penlight stimulation. If a response persisted, an additional drop was administered, followed by a 10 min wait.

Cycloplegic autorefraction was then performed using an autorefractor (Topcon KR-1, Tokyo, Japan) by a trained technician who was blinded to the participants' VA results. Refractive errors for each child were calculated as the mean of three consecutive measurements.

Questionnaire survey

A caregiver-administered questionnaire designed for the YMVIP was used to collect demographic data, medical history and details about myopiogenic behaviours. One parent or primary caregiver of each participant completed the questionnaire, which comprised 17 questions organised into three sections covering caregiver details, the child's medical history and myopia-related lifestyles and behaviours.

Definition of refractive outcomes

The spherical equivalent (SE) was calculated by adding the spherical power to half of the cylindrical power. Myopia was defined as an SE refractive error of −0.5 dioptres (D) or less in either eye. Previously unrecognised or newly detected myopia (NDM), the primary outcome measure in this study, was defined as meeting the criteria for myopia without prior recognition by caregivers or detection in previous screenings. In contrast, previously detected myopia (PDM) referred to individuals who met the criteria for myopia and whose condition had been identified by caregivers or who were already receiving interventions for myopia control.

Inclusion and exclusion criteria

All children who participated in the YMVIP screening programme between 2014 and 2024 were eligible for inclusion in this study. Participants were excluded if they had missing data on cycloplegic refraction, uncorrected VA or did not provide information regarding their history of myopia. Children undergoing orthokeratology therapy were classified as having PDM; however, their refractive data were excluded from the analysis due to the known inaccuracy of autorefraction under orthokeratology treatment.

Data analysis

For this study, only refractive data from the more myopic eye of each participant were included in the analysis. Continuous variables were expressed as mean±SD, while categorical variables were presented as percentages. The diagnostic yield of myopia screening was calculated by dividing the number of newly detected myopic children by the total number of programme participants at risk for myopia development, defined as all children enrolled in the programme excluding those already confirmed to have myopia based on screening examination results and a known history of myopia (ie, PDM). Differences in continuous data across the three groups—PDM, NDM and non-myopia—were assessed using analysis of variance and Pearson's χ^2 test was used to compare categorical data. Post-hoc analysis with Bonferroni adjustment was conducted for pairwise comparisons when necessary. Variables with a p value of less than 0.1 in the univariate analyses were included in a multinomial logistic regression model using a stepwise approach. This model was utilised to identify potential risk factors for NDM and PDM. OR and their 95% CIs were calculated. The significance level was inferred at a two-sided p value <0.05. Receiver operating characteristic (ROC) curve analysis was conducted to evaluate the diagnostic accuracy of UDVA criteria in identifying the presence of myopia. The area under the ROC curve (AUC) was calculated to assess the overall diagnostic performance. Optimal cut-off points for myopia detection were determined based on the maximum sum of sensitivity and specificity. Statistical analyses were conducted using IBM SPSS Statistics V.26 (IBM, Armonk, New York).

RESULTS

Between 2014 and 2024, a total of 37 657 children in their final kindergarten grade in Yilan County were invited to participate in the YMVIP screening programme. Of these, 33 642 children (89.3%) completed the on-campus eye examination, which included VA testing and cycloplegic autorefraction, provided caregiver-administered questionnaire responses and met the eligibility criteria for analysis (figure 1). Among these eligible subjects, 3206 (9.5%) were identified as myopic, including 2303

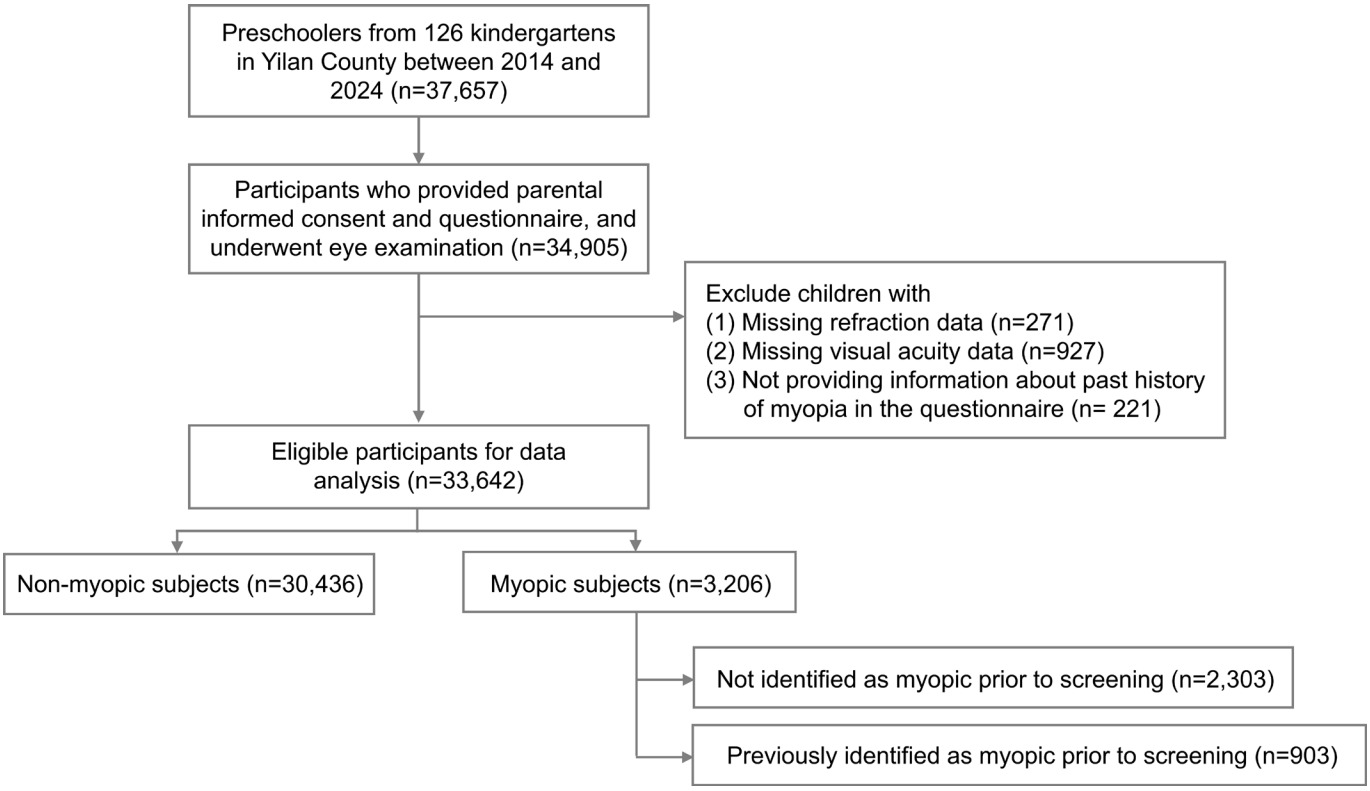

Figure 1 Flowchart showing the recruitment process for this study.

(6.9%) who had not been identified prior to the kindergarten screening. The diagnostic yield of cycloplegic autorefraction was 7.03% (95% CI 6.76% to 7.32%). In comparison, the diagnostic yield of VA screening using a cut-off of UDVA <6/7.5 in either eye was 3.37% (95% CI 3.18% to 3.57%).

Table 1 presents comparisons of characteristics and eye examination results among the non-myopic, NDM and the PDM groups. Compared with the non-myopia group, both myopic groups were more likely to have a myopic caregiver (p<0.001) and to have undergone at least one eye examination in the past year (p<0.001). The NDM group was also more likely to have a caregiver with a high school education or lower (p<0.001), and to report weekend screen time ≥2 hours/day (p=0.008), compared with the non-myopic and PDM groups. Additionally, the NDM group had the lowest proportion of children spending <1 hour/day on weekday screen time (p=0.008) and the lowest proportion spending ≥2 hours/day on weekend outdoor activities (p=0.003) among the three groups. The mean SE refractive error was 0.84±0.73 D, −1.06±0.92 D and −1.73±1.87 D in the non-myopic, NDM and PDM groups, respectively. The proportions of children with UDVA<6/7.5 in either eye were 47.9% and 81.9% in the NDM and PDM groups, respectively. Among NDM children, those with UDVA≥6/7.5 showed significantly less myopia than those with UDVA <6/7.5 (SE of the more myopic eye: −0.86±0.57 D in the UDVA ≥6/7.5 group vs −1.27±1.15 D in the UDVA <6/7.5 group; p<0.001).

Table 2 summarises the results of the stepwise logistic regression analysis identifying the associated factors for both myopic groups. Significant risk factors for NDM included male gender (OR: 1.322, 95% CI 1.208 to 1.446), caregiver myopia (OR: 1.466, 95% CI 1.321 to 1.626), spending ≥2 hours screen time on weekends (OR: 1.126, 95% CI 1.028 to 1.232) and UDVA in the worse VA eye of less than 6/7.5 (OR: 3.482, 95% CI 3.171 to 3.825). In contrast, significant protective factors against NDM were age (OR: 0.834, 95% CI 0.746 to 0.933), a caregiver with a college education or higher (OR: 0.776, 95% CI 0.706 to 0.852) and spending ≥2 hours outdoors on weekends (OR: 0.852, 95% CI 0.777 to 0.935). Meanwhile, PDM was associated with having an eye exam within the past year (OR: 57.901, 95% CI 35.712 to 93.875), caregiver myopia (OR: 2.396, 95% CI 1.968 to 2.917) and UDVA in the worse VA eye <6/7.5 (OR: 10.449, 95% CI 8.641 to 12.637) but showed no association with myopia-related behaviours.

Figure 2 illustrates the ROC curves for identifying myopia among preschoolers aged 5–6 using UDVA as a criterion. The AUC was 0.743 for the worse VA eye and 0.732 for the better VA eye. For the worse VA eye, the optimal cut-off point for detecting myopia was UDVA <6/7.5, with a sensitivity of 57.9% and a specificity of 79.5%. If the cut-off was set at UDVA<6/6, sensitivity would increase to 84.4%, but specificity would decrease to 42.9%. Additionally, 19.8% of preschoolers in the NDM group still had UDVA ≥6/6 and would pass the VA screening (table 1).

DISCUSSIONS

This study demonstrates that nearly half (52.1%) of children with NDM would not be identified by VA screening alone, highlighting the limitations of VA-based programmes in preschool settings. The diagnostic yield of cycloplegic autorefraction was more than twofold higher than that of the VA examination alone (7.03% vs 3.37%). In addition, behavioural patterns differed significantly between NDM and PDM children, suggesting that early diagnosis of myopia may influence and potentially shape visual habits and behavioural patterns in young children.

Effective myopia screening for early detection and timely intervention is critical for managing childhood myopia. At age 6, the current Taiwanese school-based screening programme uses a reduced VA referral criterion of <6/7.5 in either eye for

Table 1 Characteristics of eligible participants by refractive condition

	Non-myopia (n=30 436)	Newly detected myopia (n=2303)	Previously detected myopia (n=903)	P value
Age, mean years (SD)	5.24 (0.41)*	5.21 (0.39) *	5.23 (0.40)	**0.002**
Gender, n (%)				**<0.001**
Boy	15 615 (51.3%)*	1311 (56.9%)*	473 (52.4%)	
Girl	14 821 (48.7%)*	992 (43.1%)*	430 (47.6%)	
Area, n (%)				0.572
Rural	15 049 (49.4%)	1147 (49.8%)	462 (51.2%)	
Suburban	15 387 (50.6%)	1156 (50.2%)	441 (48.8%)	
Myopic caregiver, n (%)				**<0.001**
Yes	19 535 (64.2%)†	1593 (69.2%)†	728 (80.6%)†	
No	9856 (32.4%)†	597 (25.9%)†	149 (16.5%)†	
Unknown	1045 (3.4%)	113 (4.9%)	26 (2.9%)	
Education level of caregiver, n (%)				**<0.001**
≥ College	18 519 (60.8%)*	1253 (54.4%)*‡	571 (63.2%)‡	
≤ High school	11 636 (38.2%)*	1022 (44.4%)*‡	325 (36.0%)‡	
Unknown	281 (0.9%)	28 (1.2%)	7 (0.8%)	
Eye examination in recent 1 year, n (%)				**<0.001**
Yes	9271 (30.5%)†	862 (37.4%)†	863 (95.6%)†	
No	20 917 (68.7%)†	1412 (61.3%)†	32 (3.5%)†	
Unknown	248 (0.8%)	29 (1.3%)	8 (0.9%)	
Time spent on homework (reading, writing, drawing or playing musical instruments):				
On weekdays, n (%)				0.316
≥30 minutes/day	12 320 (40.5%)	933 (40.5%)	393 (43.5%)	
<30 minutes/day	17 954 (59.0%)	1358 (59.0%)	508 (56.3%)	
Unknown	162 (0.5%)	12 (0.5%)	2 (0.2%)	
On weekends, n(%)				**0.034**
≥30 minutes/day	11 975 (39.3%)§	914 (39.7%)	398 (44.1%)§	
<30 minutes/day	18 223 (59.9%)§	1374 (59.7%)	502 (55.6%)§	
Unknown	238 (0.8%)	15 (0.7%)	3 (0.3%)	
Time spent on screen-based devices (television, smartphones, computers, tablets or video games):				
On weekdays, n(%)				**0.008**
≥1 hour/day	14 174 (46.6%)*	1158 (50.3%)*	426 (47.2%)	
<1 hour/day	16 092 (52.9%)*	1132 (49.2) *	475 (52.6%)	
Unknown	170 (0.6%)	13 (0.6%)	2 (0.2%)	
On weekends, n(%)				**0.008**
≥2 hours/day	12 084 (39.7%)*	1000 (43.4%)*‡	350 (38.8%)‡	
<2 hours/day	18 161 (59.7%)*	1287 (55.9%)*‡	549 (60.8%)‡	
Unknown, n(%)	192 (0.6%)	16 (0.7%)	4 (0.4%)	
Time spent on after-school outdoor activities:				
On weekdays, n(%)				0.211
≥30 minutes/day	14 614 (48.0%)	1053 (45.7%)	419 (46.4%)	
<30 minutes/day	15 671 (51.5%)	1238 (53.8%)	481 (53.3%)	
Unknown	152 (0.5%)	12 (0.5%)	3 (0.3%)	
On weekends, n(%)				**0.003**
≥2 hours/day	12 441 (40.9%)*	850 (36.9%)*	367 (40.6%)	
<2 hours/day	17 835 (58.6%)*	1443 (62.7%)*	534 (59.1%)	
Unknown	160 (0.5%)	10 (0.4%)	2 (0.2%)	
SE (right eye), mean dioptre (SD)	0.98 (0.78)†	−0.77 (0.97)†	−1.45 (1.85)†	**<0.001**
SE (left eye), mean dioptre (SD)	1.00 (0.80) †	−0.73 (0.90)†	−1.40 (1.73)†	**<0.001**
SE (more myopic eye), mean dioptre (SD)	0.84 (0.73)†	−1.06 (0.92)†	−1.73 (1.87)†	**<0.001**
SE≤−1.0 Dioptre (more myopic eye), n (%)	0 (0%)	866 (37.6%)	592 (67.3%)	**<0.001**
UDVA (better VA eye), n (%)				
<6/6	13 472 (44.3%)†	1631 (70.8%)†	793 (87.8%)†	**<0.001**
<6/6.7	7570 (24.9%)†	1231 (53.5%)†	728 (80.6%)†	**<0.001**
<6/7.5	3854 (12.7%)†	824 (35.8%)†	636 (70.4%)†	**<0.001**
UDVA (worse VA eye), n (%)				
<6/6	17 394 (57.1%)†	1846 (80.2%)†	840 (93.0%)†	**<0.001**

Continued

Table 1 Continued

	Non-myopia (n=30 436)	Newly detected myopia (n=2303)	Previously detected myopia (n=903)	P value
<6/6.7	11 152 (36.6%)†	1526 (66.3%)†	796 (88.2%)†	**<0.001**
<6/7.5	6235 (20.5%)†	1104 (47.9%)†	740 (81.9%)†	**<0.001**

P<0.05 are in bold type.
*Post-hoc analysis significant with Bonferroni adjustment between newly-diagnosed myopia (NDM) and non-myopia.
†Post-hoc analysis significant with Bonferroni adjustment across NDM, PDM and non-myopia.
‡Post-hoc analysis significant with Bonferroni adjustment between NDM and PDM.
§Post-hoc analysis significant with Bonferroni adjustment between PDM and non-myopia.
PDM, previously detected myopia; SE, spherical equivalent; UDVA, uncorrected distant visual acuity; VA, visual acuity.

ophthalmic referral. Under this criterion, our study observed sensitivity and specificity of 57.9% and 79.5%, respectively. Notably, the Sydney Myopia Study demonstrated that a VA referral criterion of ≤6/9.5 could reliably detect clinically significant myopia (SE≤−1.0 D) with high sensitivity (97.8%) and specificity (97.1%) among 12-year-old adolescents.[9] Similarly, a study in Northern Ireland found that using a cut-off of UDVA <0.20 logMAR (equivalent to 6/9.5 Snellen) to detect significant refractive error, including myopia (SE≤−1.0 D), hyperopia (SE > +3.5 D) or astigmatism (cylinder >1.0 D) achieved sensitivity of 73% and specificity of 93% in 12-year to 13-year olds, but only 50% and 92%, respectively, in 6-year to 7-year olds.[13] Differences in sensitivity across age groups may relate to variations in myopia definitions, acuity development and cut-off thresholds. Before reaching school age, VA may not be fully developed in all preschoolers, and the prevalence and severity of myopia are lower compared with those in adolescents.[14] Rather than focusing solely on detecting clinically significant myopia, kindergarten screening programmes should aim to identify preschoolers with any degree of myopia, even including premyopia. However, it is important to note that children with low myopia or premyopia often do not exhibit significantly reduced VA.[15] In our study, 52.1% of NDM children are presented with VA ≥6/7.5 in both eyes and would be missed by VA screening alone. Among these children, 73.9% had an SE ≥−1.0 D in the more myopic eye and 92.7% had an SE ≥−1.50 D, suggesting that the screening ability of VA closely relates to the degree of refractive error. Our findings are consistent with previous reports demonstrating that children with low levels of refractive error may not present with measurable visual impairment.[15 16] Shea *et al* observed that among 3-year to 4-year-old children with borderline or abnormal refraction (eg, <−2.00 D myopia or ≤−1.50 D astigmatism), many maintained normal or near-normal VA under full cycloplegia, indicating that a wide range of refractive states may coexist with good distance vision.[16] Although there is no direct one-to-one correlation between refractive error and VA, this relationship may be influenced by factors such as depth of focus and the high-contrast optotypes used in vision screening. Solely relying on VA testing produces a low yield and may not effectively achieve the goal of early myopia detection in preschool-aged children.

While previous studies have examined the accuracy of UDVA alone and the combination with non-cycloplegic autorefraction in children,[9 10 13 17 18] few have focused on preschool children using cycloplegic autorefraction in large-scale screenings. Cycloplegic refraction is considered the gold standard for epidemiological studies of refraction due to its ability to eliminate the influence of accommodation during measurement.[19] The International Myopia Institute defines myopia as a condition in which the SE refractive error of an eye is ≤−0.50 D when ocular accommodation is relaxed.[20] Previous studies have shown that non-cycloplegic autorefraction tends to overestimate

Table 2 Result of multinomial logistic regression of factors associated with newly and previously detected myopia

	Newly detected myopia			Previously detected myopia		
	Adjusted OR	95% CI	P value	Adjusted OR	95% CI	P value
Age	0.834	0.746 to 0.933	**0.002**	0.967	0.806 to 1.160	0.721
Gender (ref: girl)						
Boy	1.322	1.208 to 1.446	**<0.001**	1.141	0.985 to 1.322	0.078
Myopic caregiver (ref: no)						
Yes	1.466	1.321 to 1.626	**<0.001**	2.396	1.968 to 2.917	**<0.001**
Caregiver education level (ref: ≤ high school)						
≥ College	0.776	0.706 to 0.852	**<0.001**	1.012	0.865 to 1.185	0.882
Eye examination in the past year (ref: no)						
Yes	0.997	0.906 to 1.098	0.955	57.901	35.712 to 93.875	**<0.001**
Time spent on screen-based devices on weekends (ref: <2 hours/day)						
≥ 2 hours/day	1.126	1.028 to 1.232	**0.010**	0.911	0.783 to 1.059	0.224
Time spent outdoors on weekends (ref: <2 hours/day)						
≥ 2 hours/day	0.852	0.777 to 0.935	**0.001**	0.928	0.798 to 1.078	0.326
UDVA (worse VA eye) (ref: ≥ 6.70.5)						
<6/7.5	3.482	3.171 to 3.825	**<0.001**	10.449	8.641 to 12.637	**<0.001**

P <0.05 are in bold type.
UDVA, uncorrected distant visual acuity; VA, visual acuity.

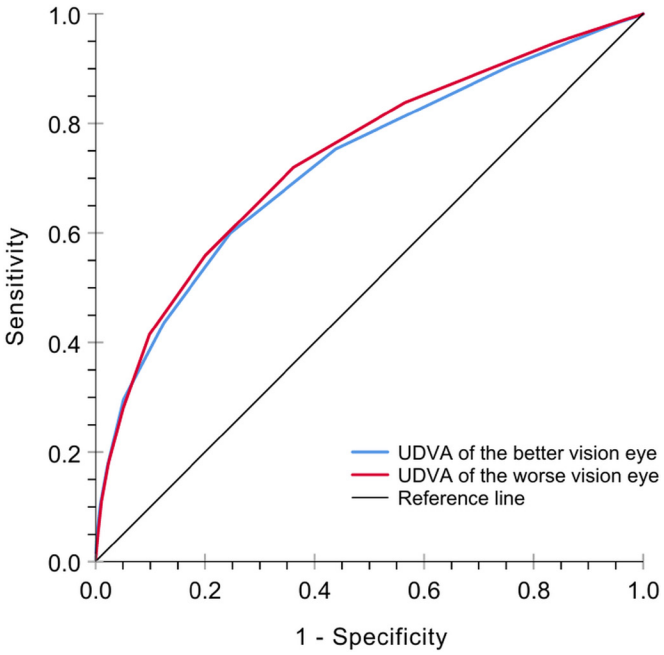

Figure 2 Receiver operating characteristic (ROC) curve for predicting myopia based on uncorrected distant visual acuity (UDVA). The area under the ROC curve (AUC) for the eye with better vision was 0.732, while the AUC for the eye with worse vision was 0.743.

myopia by 1 to 2 dioptres compared with cycloplegic autorefraction, particularly in younger children.[17 18] A cross-sectional study in Shanghai revealed that combining the uncorrected VA test (with a cut-off of 6/6) and the non-cycloplegic refraction test (with a cut-off of −0.25 D) achieved optimal accuracy (sensitivity: 94.2%; specificity: 89.5%) for detecting myopia in children aged 4–6.[10] However, 5.8% of myopic children in this age group would still remain undiagnosed using this screening method with the age-specific cut-off. Given the rapid rise in myopia prevalence following school entry and the shift in near-work behaviours,[21 22] early detection during preschool years is crucial—especially in East Asian regions with high myopia prevalence. Our study shows that cycloplegic autorefraction, although more resource-intensive, is both feasible and valuable in this age group, allowing for accurate detection of myopia.

Lifestyle and behavioural factors, such as outdoor activity and digital screen time, are associated with the prevention and progression of childhood myopia.[8 12 23–26] Studies report that myopic children spend significantly less time outdoors than their non-myopic peers.[24 25] A recent dose–response meta-analysis found that each additional hour of daily screen time was associated with a 21% higher risk of myopia.[26] In our study, children in the NDM group were more likely to use screen-based digital devices than those without myopia. Additionally, weekend screen time was significantly higher in the NDM group compared with the PDM group (43.4% vs 38.8%). Likewise, NDM children were less likely to spend ≥2 hours outdoors on weekends (36.9%) than their non-myopic (40.9%) and PDM (40.6%) peers. Children with PDM exhibited similar behavioural patterns to those without myopia, in contrast to children with NDM.

Preschoolers' behaviours are shaped by their caregivers' knowledge and attitudes towards myopia. Caregivers of children in the PDM group may have received prior guidance to reduce myopiogenic behaviours. In contrast, caregivers of children in the NDM group—likely unaware of their children's refractive status—may have overlooked such factors or lacked sufficient knowledge. Screening programmes can enhance awareness and enable timely behaviour modification.

Cycloplegic autorefraction has not been widely adopted in large-scale childhood myopia screening programmes because it is more resource-intensive and requires specialised equipment with cycloplegic eyedrops. In the YMVIP, the average cost was approximately US$15 per child. This cost is justified compared with long-term myopia-related burdens. For example, individuals with myopic choroidal neovascularisation incur additional direct medical costs of €1629 (US$1743) compared with those without the condition.[27] Moreover, uncorrected myopia and myopic macular degeneration are estimated to result in global productivity losses of US$244 billion and US$6 billion, respectively.[2] Given the rising global prevalence and economic burden of high myopia, implementing screening programmes with higher diagnostic yield and accuracy in young children—alongside timely intervention—represents a sound public health investment.

There are several limitations to this study. First, cycloplegic retinoscopy or subjective refraction was not used in the screening. Although considered the historic gold standard for paediatric refraction, this method is time-consuming and requires child cooperation.[17] In contrast, refraction can be quickly measured using an autorefractor without a highly trained technician. Evidence suggests that cycloplegic autorefraction is appropriate for population-based studies in children without ocular pathology, aside from refractive errors.[17] Second, lifestyle data were collected via caregiver-administered questionnaires. Whether children were previously recognised as myopic by caregivers was also based on questionnaire-reported medical history. Although such data are subjected to recall bias, most questions focused on routine behaviours, making self-report bias less likely. In addition, intraocular pressure was not assessed in this screening programme because the primary goal was to detect refractive and VA abnormalities. However, optic disc evaluation by direct ophthalmoscopy was performed to exclude obvious optic nerve pathology. Finally, temporary side effects of cycloplegia, such as blurred near vision and photophobia, may discourage participation in cycloplegic autorefraction. To address this, comprehensive instructions were given to caregivers and kindergarten teachers before screening. As a result, YMVIP achieved a participation rate of 92.7%, with no significant adverse effects reported since the programme's launch.

In conclusion, kindergarten screening programmes using cycloplegic autorefraction offer two times the diagnostic yield of VA screening at a reasonable cost, effectively identifying many myopic children at a preclinical stage who would otherwise pass VA tests. Kindergarten-based examinations can expand access to cycloplegic autorefraction screening during the preschool years. NDM was associated with excessive screen time and insufficient outdoor time on weekends, whereas PDM showed no association with these myopia-related behaviours. Our findings support the use of cycloplegic autorefraction as a preschool screening tool for the early detection of myopic children—particularly those without visual symptoms—enabling timely referral, enhancing caregiver awareness and increasing the likelihood of behaviour improvement. Further studies should evaluate the optimal timing and cost-effectiveness of such programmes.

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Acknowledgements The authors thank the contributors and members in the Yilan Myopia Prevention and Vision Improvement Program Committee, including Luke Long-Kuang Lin, Chien-Ting Liu, Yiing-Mei Liou, Yi-Min Lin, Mei-Zhi Chen, Ren Fang, Gang Hou, Chia-Feng Yang, Hsiu-Ying Peng, Sheng-Xiong You, Heng-Yi Liao, Ying-Xi Chen, Cheng-Xun Lin, Jin-Qi Chen, Shao-Chun Hong, Shu-Juan Guo, Li-Chun Chang, Ying-Hua Chen, Cheng-Hsiu Wu, Shun-An Wu, Qi Lin, Hui-Mei Huang for their full support for the YMVIP.

Contributors All authors contributed to the study design, data interpretation and manuscript preparation. D-CT and N-WH conceived the study and supervised the project. D-CT, Y-CY, H-YY, M-PS, C-WL, P-WH and Y-LC contributed to data collection and curation. Y-CY and S-YF performed the statistical analysis. C-YW drafted the initial manuscript and coordinated revisions. All authors reviewed and approved the final version of the manuscript. D-CT is the guarantor and takes responsibility for the overall content. During the preparation of this work, the authors used ChatGPT (OpenAI) to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the final version of the manuscript.

Funding This study was supported by grants from National Yang Ming Chiao Tung University Hospital (RD2021-010, RD2023-006). The funder had no role in the study outcomes, despite authors' institutional affiliations.

Disclaimer During the preparation of this work, the authors used ChatGPT (OpenAI) to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the manuscript.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the Institutional Review Board of National Yang-Ming University Hospital (approval identifiers: 2020A015 and 2023A013). This is a retrospective study analysing anonymised data collected from a population-based screening programme. According to the Institutional Review Board of National Yang-Ming University Hospital (approval numbers: 2020A015 and 2023A013), individual patient consent was not required. No identifiable personal or medical information is included in the manuscript.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The dataset involves paediatric participants under the age of 18 and is protected under institutional and IRB regulations. Deidentified data may be made available from the corresponding author upon reasonable request, subject to review and approval by the institution.

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