BMJ Open

Developmental characteristics and control effects of myopia and eye diseases in children and adolescents: a school-based retrospective cohort study in Southwest China

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To cite: Tang W, Tan T, Lin J, *et al*. Developmental characteristics and control effects of myopia and eye diseases in children and adolescents: a school-based retrospective cohort study in Southwest China. *BMJ Open* 2024;**14**:e083051. doi:10.1136/bmjopen-2023-083051

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2023-083051).

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Received 11 December 2023
Accepted 06 September 2024

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ABSTRACT

Objectives To characterise the prevalence of myopia and eye diseases among school adolescents and children in Southwest China, and to evaluate the effectiveness of myopia control tools.

Design Retrospective cohort study.

Setting Across 95 basic education institutions in Southwest China.

Participants 96 146 children aged 3–17 years from a school-based survey conducted between 2019 and 2021.

Primary outcome measures The data of vision assessment and eye disease examination of school students were analysed, including a total of four surveys once per semester. The prevalence of myopia categorised as low (−0.5D to −3.0D), moderate (−3.0D to −6.0D) and high (≥−6.0D), along with the prevalence of significant ocular diseases, was assessed. Stratified analyses were conducted to investigate the impact of correction time on visual acuity (VA) and biological parameters. Subsequently, the subjects across the groups were matched using the nearest neighbour method, followed by multidimensional statistical analysis.

Results The prevalence of myopia among the surveyed students was 38.39%. After controlling for confounding variables, the statistical analysis revealed a 0.1 increase in mean VA within the orthokeratology group and a 0.1 decrease in VA within the spectacle group ($p<0.001$), with statistically significant differences in corneal radius, corneal curvature and equivalent spherical lens ($p<0.05$). Multivariate analysis indicated a statistically significant reduction in VA in the ophthalmopathy group compared with the control group ($p=0.031$). Furthermore, it was demonstrated that the risk of eye disease during vision correction was greater among older students than their younger counterparts (OR>1), and that female students exhibited a higher risk than male students (OR=1.5).

Conclusions The current high prevalence of myopia and eye diseases among Southwest China's school youths demands public health attention. Minors wearing orthokeratology lenses at night, especially in primary school, exhibit significantly improved naked-eye vision. However, vigilant eye healthcare during the correction period is crucial, especially for girls.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Evaluated the effectiveness of myopia control tools through a longitudinal study design, with one follow-up visit per semester for a total of four assessments.
⇒ Included a large cohort of students aged 3–17 years, encompassing comprehensive ocular biometric parameters, optical measures and distribution of eye diseases.
⇒ Controlled for confounding bias using propensity score matching to mitigate the impact of non-random grouping inherent in observational studies.
⇒ Did not account for potential genetic, environmental or socioeconomic factors that may influence the development and progression of myopia.
⇒ Limited to schools in one city in Southwest China, potentially affecting the generalisability of the findings to the entire country.

BACKGROUND

Axial myopia is irreversible can only be corrected with glasses or surgery, and is not curable.[1–3] High myopia can lead to serious eye issues like retinal detachment, retinal fissures and permanent damage to photoreceptor cells, which may worsen with age and potentially lead to conditions like cataracts or even blindness in severe cases.[3–5]

Globally, the prevalence of myopia was estimated to affect 2.5 billion people in 2022, with projections indicating an increase to 4.949 billion by 2050.[6] The highest prevalence of myopia among school-age children (6–19 years) is in Asia (60%; including East Asia (73%)).[7] In Korea, 65.4%[8] of children aged 12–18 have myopia, while in Hong Kong,[9 10] myopia rates range from 30% in 6–7-year-olds to 74% in 16–17-year-olds.[11] In contrast, the prevalence among Finnish children is around 2%–3%. In China, the overall myopia rate among children and adolescents

was 52.7% in 2020; specifically, rates were 14.3% among 6-year-olds, 35.6% among primary school students, 71.1% among junior high school students, and 80.5% among high school students.[12]

Since 2016, China has implemented various policies and plans to combat the rising prevalence of myopia among children and adolescents.[13–16] These initiatives include the 'Guidance on Strengthening Prevention and Control of Myopia among Children and Adolescents' and the 'National Eye Health Plan for the 14th Five-Year Plan (2021–2025)'.[17] These efforts include large-scale surveys on the eye health of school-age children.

In this study, we collected data from an eye health survey of primary and secondary school students in Southwest China to objectively assess the prevalence of myopia and eye diseases among adolescents and children, as well as the effectiveness of different myopia preventive measures, recommendations for improving the implementation of myopia preventive strategies in schools.

METHODS

Patient and public involvement

None.

Study population

This cohort study included students and preschoolers from 95 primary schools, secondary schools and kindergartens in Chengdu, Sichuan Province, China. Starting from September 2019, ocular optometry and eye disease examinations were conducted every 6 months, resulting in four surveys by June 2021. Participants with vision-related infections, lesions, trauma or complications (eg, keratitis, leukoplakia, corneal opacity, cataracts) were excluded from the baseline data. To ensure objective analysis, the baseline data were processed as follows:

Group criteria:

1. Participants were categorised into the orthokeratology (OK) lenses group and the framed spectacle group based on the form of correction, while those who never received any form of correction were categorised as 'uncorrected'.
2. Participants who changed their correction type during follow-up were categorised according to new correction type and treated as new patients at baseline.

Exclusion criteria:

1. Participants wore spectacles with continuous correction for less than 12 months at the end of follow-up.
2. Participants wore OK lenses for less than 12 months and switched to frames.

Data collection

The data for this study were obtained from the National Youth Myopia Prevention and Control Programme, which monitors minors in schools through qualified institutions. Optometry indicators, such as visual acuity (VA) and spherical equivalent (SE) lens, were assessed by experienced senior optometrists using a Topcon KR800 instrument. Ocular biometric parameters, including axial length (AL), keratometric power (KP) and corneal radius of curvature (CR), were measured with a LENSTAR LS900 instrument. Only data from the right eye[18] were analysed due to strong inter-eye correlation.

Definition

Myopia was defined as spherical equivalent refraction (SER) ≤−0.50 diopters (D)+uncorrected visual acuity (UCVA) >3.3 logMAR in children of different age groups[18] with non-cycloplegic refraction. Myopia severity was classified as follows: low myopia (−3.00 D≤SER≤−0.50 D), moderate myopia (−6.00 D<SER<−3.00 D) and high myopia (SER ≤−6.00 D). Uncorrected myopia was diagnosed if a child was myopic without corrective lenses, while fully corrected myopia required glasses and normal VA.

Propensity score matching (PSM)

To investigate the impact of myopia prevention and control measures on eye health, we selected individuals aged 3–17 years with SER ≤−0.5, without eye disease, who had not received corneal intervention before enrolment. Who voluntarily chose different interventions after the baseline survey and completed the follow-up visit on schedule. Information on VA, changes in ocular appearance, fundus and ocular inflammation or pathology were collected using the method of correction (lens-free, framed spectacles and nocturnal keratoprosthesis) as the grouping condition. To control for confounders, propensity scores were matched for gender, grade and whether or not they wore frames before entering the cohort.

PSM was employed to reduce bias and confounding variables, ensuring balanced and comparable groups for analysis. High-quality matching was considered when the balance showed an absolute standardised mean difference (SMD) of less than 0.1 (<10%).[19 20] Matching was considered to be of high quality when the balance showed an SMD of less than 0.1. SMD between 0.1 and 0.2: this range indicates that the balance is poor and there is still some mixing influence, but it may still be acceptable in some cases. SMD >0.2: this indicates a poorer quality of matching, a greater difference in the distribution of covariates between the groups and a more severe imbalance, which may affect the credibility of the results of the study. Logistic regression modelled propensity scores, considering gender, grade, bare-eye VA, prior frame usage and full correction. The nearest neighbour matching with a caliper of 0.25*SD(ps) and 1:1 or 1:4 pairing ratios was applied.

Statistical analyses

Descriptive statistics were used for baseline data, stratified analysis for repeated measures and trend testing for correction duration's impact on ocular parameters. Statistical significance was determined using χ^2 or Wilcoxon tests ($p<0.05$). All analyses were performed in R V.4.2.2.

Table 1 Distribution of general and visual indicators in the baseline data

Characteristics	Total (N=96 146)	High (n=2549)	Moderate (n=10 753)	Low (n=23 612)	No (n=59 232)	P
General situation						
Gender						
Girl	46 535 (48.4%)	1345 (52.8%)	5482 (51.0%)	12 093 (51.2%)	27 615 (46.6%)	<0.001
Boy	49 611 (51.6%)	1204 (47.2%)	5271 (49.0%)	11 519 (48.8%)	31 617 (53.4%)	
Grade level						
High	6437 (6.7%)	992 (38.9%)	2436 (22.7%)	1903 (8.1%)	1106 (1.9%)	<0.001
Junior	16 403 (17.1%)	1160 (45.5%)	4918 (45.7%)	5934 (25.1%)	4391 (7.4%)	
Upper primary	23 827 (24.8%)	321 (12.6%)	2901 (27.0%)	8869 (37.6%)	11 736 (19.8%)	
Lower primary	41 013 (42.7%)	67 (2.6%)	489 (4.5%)	6718 (28.5%)	33 739 (57.0%)	
Preschool	8466 (8.8%)	9 (0.4%)	9 (0.1%)	188 (0.8%)	8260 (13.9%)	
Age						<0.001
Mean (SD)	9.62 (3.33)	14.4 (2.34)	13.3 (2.40)	11.0 (2.81)	8.20 (2.72)	
Median (IQR)	9.1 (7.0, 12.1)	14.6 (13.0, 16.0)	13.3 (11.7, 15.0)	11.0 (8.8, 12.9)	7.6 (6.6, 9.7)	
Part that involves ocular disease						<0.001
Normal	83 390 (86.7%)	2398 (94.1%)	9850 (91.6%)	20 564 (87.1%)	50 578 (85.4%)	
Double	437 (0.5%)	13 (0.5%)	47 (0.4%)	74 (0.3%)	303 (0.5%)	
Left	218 (0.2%)	5 (0.2%)	22 (0.2%)	50 (0.2%)	141 (0.2%)	
Right	341 (0.4%)	8 (0.3%)	22 (0.2%)	73 (0.3%)	238 (0.4%)	<0.001
Follow	11 760 (12.2%)	125 (4.9%)	812 (7.6%)	2851 (12.1%)	7972 (13.5%)	
Ophthalmopathy						
Normal	85 552 (86.8%)	2398 (94.1%)	9850 (91.6%)	20 564 (87.1%)	50 578 (85.4%)	
Congestion/inflammation	86 (0.1%)	1 (0.0%)	4 (0.0%)	23 (0.1%)	57 (0.1%)	
Lens opacity	17 (0.0%)	2 (0.1%)	1 (0.0%)	4 (0.0%)	9 (0.0%)	
Strabismus	156 (0.2%)	8 (0.3%)	32 (0.3%)	41 (0.3%)	70 (0.1%)	
Trichiasis	532 (0.5%)	5 (0.2%)	25 (0.3%)	82 (0.3%)	409 (0.7%)	
Keratoderma	25 (0.0%)	0 (0%)	3 (0.0%)	6 (0.0%)	15 (0.0%)	
Lithiasis	17 (0.0%)	1 (0.0%)	2 (0.0%)	6 (0.0%)	7 (0.0%)	
Ptosis	55 (0.1%)	4 (0.2%)	5 (0.0%)	10 (0.0%)	35 (0.1%)	
Talantropia	16 (0.0%)	2 (0.1%)	3 (0.0%)	5 (0.0%)	3 (0.0%)	
Cular prosthesis	2 (0.0%)	0 (0%)	0 (0%)	0 (0%)	2 (0.0%)	
Else	132 (0.2%)	3 (0.1%)	16 (0.2%)	22 (0.1%)	79 (0.1%)	
Missing	11 955 (12.1%)	125 (4.9%)	812 (7.6%)	2850 (12.1%)	7968 (13.5%)	

Continued

Table 1 Continued

Characteristics	Total (N=96 146)	High (n=2549)	Moderate (n=10 753)	Low (n=23 612)	No (n=59 232)	P
Glasses type						<0.001
No	75 020 (78.0%)	120 (4.7%)	1637 (15.2%)	15 991 (67.7%)	57 272 (96.7%)	
Frame	21 105 (22.0%)	2429 (95.3%)	9116 (84.8%)	7621 (32.3%)	1939 (3.3%)	
OK	21 (0.0%)	0 (0%)	0 (0%)	0 (0%)	21 (0.0%)	
Visual indicators						<0.001
SE						
>−0.5	49 263 (51.2%)	2549 (100%)	10 753 (100%)	23 612 (100%)	12 349 (20.8%)	
≤−0.5	46 883 (48.8%)	0 (0%)	0 (0%)	0 (0%)	46 883 (79.2%)	
Myopia						<0.001
Yes	36 914 (38.4%)	2549 (100%)	10 753 (100%)	23 612 (100%)	0 (0%)	
No	59 232 (61.6%)	0 (0%)	0 (0%)	0 (0%)	59 232 (100%)	
UCVA						<0.001
Mean (SD)	4.82 (0.290)	4.40 (0.324)	4.37 (0.275)	4.65 (0.229)	4.98 (0.124)	
Median (IQR)	4.90 (4.70, 5.00)	4.30 (4.10, 4.80)	4.30 (4.20, 4.60)	4.70 (4.50, 4.80)	5.00 (4.90, 5.00)	
Missing	59 (0.1%)	0 (0%)	0 (0%)	0 (0%)	59 (0.1%)	
VA						<0.001
Mean (SD)	4.91 (0.129)	4.87 (0.140)	4.90 (0.130)	4.93 (0.119)	4.93 (0.135)	
Median (IQR)	4.90 (4.80, 5.00)	4.90 (4.80, 5.00)	4.90 (4.80, 5.00)	5.00 (4.90, 5.00)	5.00 (4.90, 5.00)	
Complete correction						<0.001
Yes	9714 (10.1%)	773 (30.3%)	3823 (35.6%)	3957 (16.8%)	1161 (2.0%)	
No	11 412 (11.9%)	1656 (65.0%)	5293 (49.2%)	3664 (15.5%)	799 (1.3%)	
Uncorrected	17 748 (18.5%)	120 (4.7%)	1637 (15.2%)	15 991 (67.7%)	0 (0%)	
AL						<0.001
Mean (SD)	23.5 (1.29)	26.2 (1.10)	25.2 (0.917)	24.0 (0.961)	22.9 (0.912)	
Median (IQR)	23.36 (22.62, 24.29)	26.23 (25.59, 26.89)	25.19 (24.61, 25.76)	24.05 (23.42, 24.65)	22.89 (22.32, 23.46)	
Missing	1723 (1.8%)	86 (3.4%)	310 (2.9%)	543 (2.3%)	784 (1.3%)	
KP						<0.001
Mean (SD)	43.1 (1.52)	43.4 (1.67)	43.2 (1.47)	43.1 (1.50)	43.0 (1.53)	
Median (IQR)	43.12 (42.12, 44.00)	43.38 (42.50, 44.49)	43.25 (42.25, 44.12)	43.12 (42.12, 44.00)	43.00 (42.00, 44.00)	
Missing	341 (0.4%)	11 (0.4%)	26 (0.2%)	61 (0.3%)	243 (0.4%)	
CR						<0.001
Mean (SD)	7.84 (0.308)	7.77 (0.366)	7.81 (0.279)	7.83 (0.300)	7.85 (0.313)	

Continued

Table 1 Continued

Characteristics	Total (N=96 146)	High (n=2549)	Moderate (n=10 753)	Low (n=23 612)	No (n=59 232)	P
Median (IQR)	7.82 (7.66, 8.00)	7.77 (7.57, 7.93)	7.79 (7.64, 7.98)	7.82 (7.66, 8.00)	7.84 (7.66, 8.02)	
Missing	341 (0.4%)	11 (0.4%)	26 (0.2%)	61 (0.3%)	243 (0.4%)	
AL/CR						<0.001
Mean (SD)	3.00 (0.158)	3.38 (0.134)	3.23 (0.0955)	3.07 (0.105)	2.92 (0.101)	
Median (IQR)	2.98 (2.90, 3.09)	3.38 (3.32, 3.44)	3.23 (3.18, 3.28)	3.08 (3.01, 3.13)	2.92 (2.87, 2.98)	
Missing	1973 (2.1%)	92 (3.6%)	322 (3.0%)	577 (2.4%)	982 (1.7%)	

AL, axial length; CR, corneal radius of curvature; KP, keratometric power; SE, spherical equivalent; UCVA, uncorrected visual acuity; VA, visual acuity.

RESULTS

Baseline statistics

The baseline survey encompassed a total of 96 146 school students and preschool children. Among them, 38.39% were identified as myopic, with further breakdowns revealing 6.91% having high myopia, 29.13% with moderate myopia and 63.96% with low myopia. In terms of grade, the myopia rate of high school students was 82.82% (5331/6437), accounting for 18.61% high myopia, 44.54% moderate myopia and 34.41% low myopia; the myopia rate of junior high school students was 73.23% (12012/16403), with 9.66% high myopia, 40.94% moderate myopia and 49.40% low myopia. The myopia rate of upper primary school students was 50.74% (12091/23827), with 2.65% high myopia, 13.99% moderate myopia and 73.35% low myopia. The myopia rate of lower primary school students was 17.74% (7274/41013), consisting of 0.92% high myopia, 6.72% moderate myopia and 86.31% low myopia; lastly, the myopia rate among preschool children was 2.43% (206/8466), of which 91.26% were low myopia.

Online supplemental figure S1 illustrates the distribution of myopia across school age groups, indicating that the proportion of myopic students surpasses that of non-myopic students from upper primary grades onwards. There is a clear tendency for the severity of myopia to increase with age.

Among the students surveyed, 21 105 (21.95%) wore spectacles, with 45.98% being fully corrected, 54.02% incompletely corrected and a minimal 0.02% using OK lenses at night. A total of 996 (1.04%) individuals were diagnosed with eye diseases, which included 437 (0.45%) cases of binocular disease, 341 (0.35%) cases affecting the right eye and 218 (0.23%) cases impacting the left eye. These cases encompassed various conditions such as trichiasis, strabismus, congestion or inflammations, lens opacity, cataracts, prosthetic eyes and glaucoma, with details available in table 1 and online supplemental table S1.

Effects of glasses wearing on vision in different school-age groups

A total of 64 096 participants completed four follow-up visits from September 2019 to June 2021, representing a follow-up rate of 66.7%. A sensitivity analysis comparing these 64 096 participants with the original baseline survey data of 94 146 participants was conducted to construct online supplemental table S2. Of these, 22 446 had myopic vision in the right eye at the first follow-up, divided between those who wore glasses (17 278) and those who did not (5,168). We compared the difference between their last follow-up data and the baseline data (online supplemental tables S3 and S4).

Over time, more myopic individuals opted for glasses, especially among junior and high school students. At the end of the study, subjects exhibited lower AL and AL/CR than at the outset. High school students wearing glasses increased from 3.2% to 17.2%, and junior high school students increased from 17.7% to 42.6%. Conversely, the

Table 2 Trends of optometric and ocular biological parameters in spectacle wearers of different school ages

School age	d_UCVA Mean (SD)	d_SE Mean (SD)	d_AL Mean (SD)	d_KP Mean (SD)	d_CR Mean (SD)	d_AL/CR Mean (SD)
Preschool						
First visit (n=6)	0.0500 (0.207)	−0.478 (0.997)	0.735 (0.166)	0.207 (0.204)	−0.0350 (0.0356)	0.00667 (0.00516)
Second visit (n=6)	−0.167 (0.294)	−0.810 (1.27)	0.465 (0.261)	0.148 (0.225)	−0.0240 (0.0391)	0.0133 (0.00516)
Third visit (n=3)	0.367 (0.0577)	0.0867 (0.381)	0.527 (0.370)	0.0400 (0.259)	−0.00667 (0.0513)	0.00667 (0.00577)
Fourth visit (n=18)	0.0667 (0.197)	−0.0861 (1.06)	0.695 (0.322)	0.0218 (0.125)	−0.00353 (0.0203)	0.0111 (0.00758)
p*	**0.006**	**0.6**	**0.200**	**0.3**	**0.2**	**0.8**
p for trend†	**0.352**	**0.22**	**0.017**	**0.437**	**0.021**	**0.407**
Lower primary						
First visit (n=820)	−0.232 (0.288)	−1.28 (1.19)	0.603 (0.716)	−0.0108 (0.572)	0.00258 (0.106)	0.0198 (0.0211)
Second visit (n=854)	−0.257 (0.327)	−1.51 (0.981)	0.645 (0.597)	0.0107 (0.756)	−0.00435 (0.209)	0.0193 (0.0245)
Third visit (n=693)	−0.145 (0.297)	−1.35 (0.993)	0.644 (0.367)	0.00270 (1.01)	−0.00695 (0.325)	0.0193 (0.0328)
Fourth visit (n=817)	−0.0670 (0.262)	−1.21 (0.898)	0.617 (0.451)	−0.00620 (0.943)	−0.00271 (0.265)	0.0147 (0.0124)
p	**<0.001**	**<0.001**	**0.2**	**0.8**	**0.7**	**<0.001**
p for trend	**<0.001**	**0.018**	**0.645**	**0.134**	**0.08**	**<0.001**
Upper primary						
First visit (n=996)	−0.159 (0.283)	−1.05 (0.970)	0.487 (0.397)	−0.0179 (0.518)	0.00390 (0.0951)	0.0140 (0.0239)
Second visit (n=1082)	−0.170 (0.300)	−1.07 (0.988)	0.493 (0.386)	−0.00677 (0.880)	−0.000945 (0.222)	0.0128 (0.0143)
Third visit (n=1360)	−0.113 (0.286)	−1.10 (0.858)	0.474 (0.581)	0.00434 (0.802)	−0.00270 (0.211)	0.0114 (0.0212)
Fourth visit (n=2827)	−0.0232 (0.259)	−1.05 (0.644)	0.475 (0.775)	0.0209 (0.734)	−0.00573 (0.198)	0.0110 (0.0286)
p	**<0.001**	**<0.001**	**0.018**	**0.3**	**0.2**	**<0.001**
p for trend	**<0.001**	**0.65**	**0.471**	**0.131**	**0.182**	**0.001**
Junior school						
First visit (n=407)	−0.103 (0.308)	−0.617 (1.20)	0.369 (0.362)	0.0177 (0.633)	−0.00335 (0.110)	0.00986 (0.0180)
Second visit (n=494)	−0.131 (0.311)	−0.805 (0.991)	0.389 (0.464)	−0.0174 (0.640)	0.00231 (0.108)	0.00952 (0.0182)
Third visit (n=963)	−0.0766 (0.295)	−0.815 (0.959)	0.352 (0.511)	0.0260 (0.902)	−0.00765 (0.243)	0.00833 (0.0309)
Fourth visit (n=3891)	−0.00214 (0.269)	−0.799 (0.814)	0.363 (0.388)	0.0196 (0.807)	−0.00585 (0.214)	0.00753 (0.0309)
p	**<0.001**	**<0.001**	**0.12**	**0.7**	**0.7**	**<0.001**
p for trend	**<0.001**	**0.01**	**0.487**	**0.645**	**0.608**	**0.054**
High school						
First visit (n=74)	−0.0472 (0.416)	0.0267 (1.74)	0.208 (0.241)	−0.0911 (0.605)	0.0177 (0.113)	0.00371 (0.0211)
Second visit (n=97)	−0.0484 (0.290)	−0.231 (1.01)	0.259 (0.321)	0.00753 (0.700)	0.000412 (0.129)	0.00348 (0.0127)

Continued

Table 2 Continued

School age	d_UCVA	d_SE	d_AL	d_KP	d_CR	d_AL/CR
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Third visit (n=297)	−0.0171 (0.292)	−0.124 (1.26)	0.256 (0.255)	0.0638 (0.341)	−0.0116 (0.0628)	0.00481 (0.0155)
Fourth visit (n=1573)	−0.00976 (0.216)	−0.409 (0.786)	0.240 (0.390)	0.0396 (0.709)	−0.00846 (0.174)	0.00250 (0.0155)
p	**0.007**	**0.006**	**0.2**	**0.039**	**0.028**	**0.6**
p for trend	**0.066**	**<0.001**	**0.975**	**0.24**	**0.262**	**0.112**
p for interaction‡	**<0.001**	**<0.001**	**0.951**	**0.981**	**0.999**	**0.639**

d_ is the difference (follow-up value – baseline).
*Kruskal-Wallis rank sum test with no glasses as a reference.
†Number of follow-up visits with lenses from 1 to 4, a generalised linear model for trend test for the duration of corrective eyewear.
‡Interaction effect of the grade level of the study subject with each ocular biological parameter.
AL, axial length; CR, corneal radius; KP, keratometric power; SE, spherical equivalent; UCVA, uncorrected visual acuity.

proportion of primary school students wearing glasses decreased. Preschoolers showed no significant change. Those wearing glasses experienced improved UCVA, with an increase in high myopia from 3.6% to 7.1% and moderate myopia from 24.2% to 35.1%. Across the four follow-up visits, various vision indices in the right eye changed significantly. AL and AL/CR decreased significantly, while pupil size (P) and CR remained largely unchanged.

The duration of spectacle wear correlated with changes in measured parameters. Longer spectacle wear was associated with smaller changes in AL and CR for preschoolers and smaller deteriorations in UCVA, SE, CR and AL/CR for primary school children. There was an interaction between naked-eye VA, SE and school age. Long-term spectacle wear in primary school led to significant improvements in naked-eye VA, while long-term wear in upper primary and lower secondary school improved equivalent spherical VA. More details can be found in table 2 and online supplemental table S5.

In terms of gender, more girls chose OK for orthodontic treatment. By the end of the 2-year follow-up, the percentage of people with fully corrected myopia increased in the spectacle-wearing group (from 2.5% to 3.1%), those wearing OK lenses at night (from 0% to 12.5%) and those using both (from 0% to 15.7%). Students wearing OK lenses also saw significant improvements in high myopia, eye axis, and corneal curvature.

Analysis of differences in VA indicators after PSM

As shown in online supplemental figure S2, there was an overlapping support area to perform PSM prior to PSM, and participants were matched primarily within the common area. After PSM, the SMD was almost always less than 0.1 as shown in figure 1. Detailed SMD results are shown in online supplemental tables S6–S11, and the mirror histograms before and after matching are shown in online supplemental figure S3. As shown in online supplemental tables S6–S11, after PSM to exclude the confounding effects of gender, grade, whether or not they wore frame glasses before enrolment and whether or not they were fully corrected, the results showed that compared with minors who wore frames at night, minors who wore OK lenses had significantly better naked-eye VAs (mean increase in naked-eye VA of the OK group was 0.1, and mean decrease in naked-eye VA of the frames group was 0.1, $p<0.001$) . The difference between the two groups was not statistically significant for AL and AL/CR, whereas the difference in P, CR and SE was statistically significant ($p<0.05$). Compared with wearing framed spectacles, wearing OK lenses is more effective in reducing corneal curvature and preventing the increase of equivalent spherical lenses (online supplemental tables S6 and S7). Compared with adolescents without OK lenses, people who wore OK glasses had better indicators such as UCVA, SE, KP and CR, especially in controlling the deterioration of CR and corneal curvature (online supplemental tables S8 and S9). Besides, comparing the

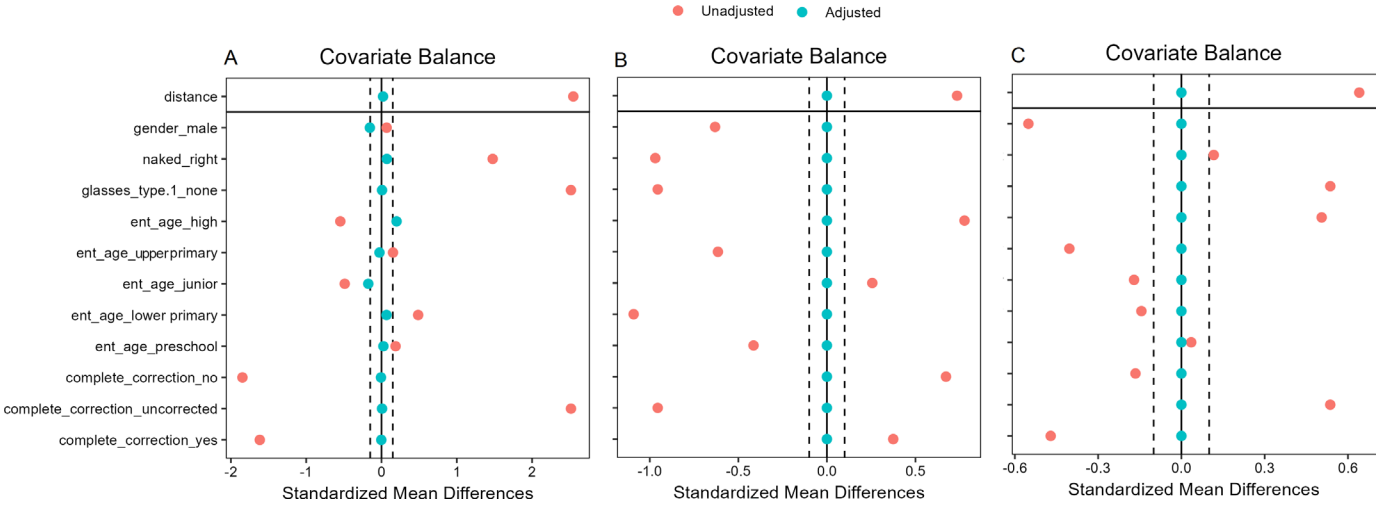

Figure 1 Dot plot of absolute standardised mean differences for all variables before and after matching. (A) Frame spectacles versus no spectacles; (B) orthokeratology lens versus no spectacles; (C) frame spectacles versus orthokeratology lens).

survey data with and without spectacles, there were significant differences in all metrics, suggesting that spectacle wear has a favourable effect on ocular biological changes (online supplemental tables S10 and S11).

Statistical analysis of the occurrence of eye diseases

Univariate and multivariate analyses were performed using the presence of ocular disease within 6 months of follow-up as the outcome measure, and the results are shown in table 3. The prevalence of eye disease was 0.28% (119/42335), of which 39.5% for boys and 60.5% for girls (p=0.03), with an OR=1.5. The naked-eye VA of the diseased group was lower than that of the normal group (p=0.031). The incidence of eye disease in the group wearing OK lenses and spectacles was higher than that in the group without glasses, where the risk of the glasses group increased by 43% and the risk in the OK group increased by 13.67 times. What is clear is that the incidence of eye disease is similar among students of different ages.

Using no eye diseases as the reference, an unordered multicategorical regression analysis was performed with the distribution of eye disease types as the dependent variable, gender, grade level, baseline naked-eye VA, whether or not fully corrected and type of lens wear as independent variables. The results showed no significant difference in the distribution of eye disease types between boys and girls. Taking the upper primary group as a reference, the incidence of all eye disease types was much lower in preschool children and much higher in middle school students. Among junior and high school students, the proportion of inflammatory lesions increased by 64% and 30%, the proportion of nystagmus increased by 65% and 11%, the proportion of strabismus increased by 85% and 12%, respectively, and other eye diseases increased by 162% and 49%, respectively. Specifically, the risk of trichiasis in high school students increased by 3.22 times, and the risk of nystagmus and strabismus increased by 2.83-fold and 2.09-fold in the lower primary grades, respectively (table 4). (The distribution of various types of eye diseases is shown in online supplemental table S12). The proportion of patients with various eye diseases increases with school age, and the incidence is higher in students who wear glasses.

DISCUSSION

China's development is highly imbalanced between the East and West, and this imbalance has resulted in much less investment in healthcare, especially eye health, in the Southwest region. Based on extensive in-school follow-up data from tens of thousands of individuals, this study aims to shed light on the prevalence and management of myopia among adolescents in Southwest China, in addition to focusing on eye diseases presenting in different school-age groups.

The overall myopia rate among high school students in Southwest China was 82.8%, far exceeding that of Japan (63.2%), as well as the USA and Europe (less than 30%). This may be related to a more severe academic burden, fewer outdoor activities and even insufficient education on eye health habits. It is noteworthy that myopia even affects children in the early grades of primary school and preschool, with the youngest case being as young as 3 years old. Adolescent eye diseases are often overlooked by parents and policymakers.[21 22] Our survey reveals a lower prevalence of strabismus (0.16%) and childhood cataracts (0.03%) compared with global averages, but cases of lens clouding or pathology were detected, and the prevalence of cataracts and glaucoma was nevertheless high, which highlights the potential risk to children's eye health. The above evidence suggests that the focus of enhanced prevention and control policies in Southwest China should be on controlling the progression of moderate to high myopia and addressing serious eye diseases.

Table 3 Distribution of ophthalmopathy in the cohort

	Univariate analysis				Multivariate analysis		
Characteristics	**Total (N=42335)**	**Abnormal (n=119)**	**Normal (n=39328)**	**P value**	**Estimate**	**P value**	**OR (95%CI)**
Gender				0.030			
Boy	20940 (49.5%)	47 (39.5%)	19440 (49.4%)		ref.		
Girl	21395 (50.5%)	72 (60.5%)	19888 (50.6%)		0.4	0.032	1.5 (1.04, 2.18)
UCVA				0.031	−0.63	0.022	0.53 (0.31, 0.92)
Mean (SD)	4.67 (0.324)	4.61 (0.333)	4.67 (0.323)				
Median (IQR)	4.80 (4.40, 4.90)	4.70 (4.25, 4.90)	4.80 (4.40, 4.90)				
Glasses type				<0.001			
No	25181 (59.5%)	57 (47.9%)	23077 (58.7%)		ref.		
Frame spectacles	17008 (40.2%)	57 (47.9%)	16113 (41.0%)		0.36	0.055	1.43 (0.99, 2.07)
OK lens	146 (0.3%)	5 (4.2%)	138 (0.4%)		2.69	<0.001	14.67 (5.06, 33.77)
School age				0.001			
Preschool	1101 (2.6%)	6 (5.0%)	1080 (2.7%)		ref.		
Lower primary	9809 (23.2%)	27 (22.7%)	9284 (23.6%)		−0.65	0.153	0.52 (0.23, 1.41)
Upper primary	13488 (31.9%)	20 (16.8%)	12363 (31.4%)		−1.23	0.008	0.29 (0.12, 0.8)
Junior	12814 (30.3%)	45 (37.8%)	12071 (30.7%)		−0.4	0.36	0.67 (0.31, 1.76)
High	5123 (12.1%)	21 (17.6%)	4530 (11.5%)		−0.18	0.697	0.83 (0.36, 2.28)
Complete correction				>0.9			
No	9537 (22.5%)	35 (29.4%)	9064 (23.0%)		ref.		
Yes	7605 (18.0%)	27 (22.7%)	7176 (18.2%)		−0.03	0.919	0.97 (0.58, 1.61)
Missing	25193 (59.5%)	57 (47.9%)	23088 (58.7%)				

OK, orthokeratology; UCVA, uncorrected visual acuity.

Table 4 Disordered logistic regression for the influencing factors of ophthalmopathy

	Ophthalmopathy				
	Inflammatory lesion	**Nystagmus**	**Strabismus**	**Trichiasis**	**Other**
Gender					
Boy	ref.	ref.	ref.	ref.	ref.
Girl	−0.01	0.64	0.55	0.57	−0.12
OR (95% CI)	0.99 (0.26, 3.75)	1.9 (0.57, 6.35)	1.73 (0.64, 4.66)	1.77 (0.61, 5.12)	0.89 (0.18, 4.41)
School age					
Preschool	−9.52	−8.65	−10	−10.07	−7.93
OR (95% CI)	0 (0, 0)***	0 (0, 0)***	0 (0, 0)***	0 (0, 0)***	inf
Lower primary	−13.34	1.34	1.13	−0.11	−12.88
OR (95% CI)	0 (0, 0)***	3.83 (0.53, 27.9)	3.09 (0.61, 15.54)	0.9 (0.09, 8.72)	0 (0, 0)***
Upper primary	ref.	ref.	ref.	ref.	ref.
Junior	0.5	0.5	0.63	−0.08	0.96
OR (95% CI)	1.64 (0.32, 8.51)	1.65 (0.33, 8.23)	1.87 (0.5, 6.96)	0.92 (0.21, 4.13)	2.62 (0.29, 23.56)
High	0.27	0.1	0.11	1.44	0.4
OR (95% CI)	1.3 (0.18, 9.69)	1.11 (0.15, 8)	1.12 (0.22, 5.77)	4.22 (1.12, 15.99)***	1.49 (0.09, 24.1)
UCVA	0.13	−1.78	−0.7	0.4	0.64
OR (95% CI)	1.13 (0.12, 10.73)	0.17 (0.02, 1.58)	0.5 (0.09, 2.66)	1.49 (0.3, 7.32)	1.89 (0.11, 31.4)
Complete correction					
No	ref.	ref.	ref.	ref.	ref.
Yes	−0.54	1.05	−0.18	−1.08	0.13
OR (95% CI)	0.58 (0.14, 2.34)	2.85 (0.84, 9.64)	0.83 (0.32, 2.17)	0.34 (0.11, 1.05)	1.14 (0.23, 5.71)
Glasses type					
No	ref.	ref.	ref.	ref.	ref.
Frame spectacles	−3.59	4.01	−2.4	−3.78	4.53
OR (95% CI)	0.03 (0, 0.82)*	55.25 (0.4, 7595.75)	0.09 (0.01, 1.12)	0.02 (0, 0.26)*	92.54 (0.15, 56018.36)
OK lens	−0.96	−8.79	0.27	−1.62	−20.32
OR (95% CI)	0.38 (0.01, 16.38)	0 (0, 0)***	1.3 (0.08, 20.12)	0.2 (0.01, 2.84)	0 (0, 0)***

***p<0.001; *p<0.05.
OK, orthokeratology; UCVA, uncorrected visual acuity.

In the baseline survey, myopia rates were higher among girls than boys, consistent with previous research,[23 24] and may be related to less outdoor activity among girls. The overall myopia rate of 38.39% aligns with some studies but is lower than that of Europe (49.2%)[25] and higher than certain developed nations like Spain (20.1%)[26] and France (32.6%).[24] Notably, the myopia rate in Southwest China rises significantly among high school (82.82%) and junior high school (73.23%) students, surpassing the national averages (80.5% and 71.1%).[12] The myopia rate in the upper primary group is slightly higher than that in Shenyang (49.83%),[27] and the rate in the primary to the junior group is higher than that in Chongqing (33.9%).[28] Under the criteria of SER ≤−0.50 D or SER ≤−1.0 D, the results of this study for each age group are almost all higher than those in the eastern, southern and northeastern regions, such as Shanghai,[29] Zhejiang,[30] Guangdong,[31] Shandong,[32] Taiwan[33] and Hong Kong.[34] However, the rates are lower compared with those in central Shanxi.[35] The age-specific myopia rates under different criteria are shown in online supplemental table S13.

In terms of vision correction, the OK lens, although economically more costly, is superior to spectacles in preventing myopia progression. Wearing glasses, particularly over 6 months, leads to an average increase in AL of 0.12 mm, which is associated with various eye complications.[36–39] Conversely, OK lenses improve naked-eye vision by 0.1 without affecting AL.

Despite the higher risk of eye diseases associated with wearing lenses, it can be mitigated through proper hygiene and regular eye exercises. WHO recommends good eye habits for students, such as maintaining an appropriate sitting position while reading and writing, taking breaks every 40 min of close work, and increasing outdoor activities.

CONCLUSIONS

This study sheds light on the current state of eye health among adolescent students in Southwest China, especially filling the gap in data on lens opacity or lesion prevalence. Through statistical evidence, we observed the different effects of wearing glasses and OK lenses on correcting myopia, exposed the risk factors associated with myopia and eye diseases, demonstrated the value of myopia prevention and control measures in Southwest Chinese cities and made recommendations for family and social policies to optimise for adolescent eye health. In the future, further reducing the cost of OK lenses and improving the use process to reduce the risk of infection are potential directions to increase the benefits of adolescent vision.

This study provides valuable insights into the eye health status of middle and high school students in Southwest China, addressing the issue of adolescent myopia comprehensively. By comparing the application practices of glasses and OK lenses in Eastern China and internationally, significant differences in the effectiveness of these correction tools for myopia treatment and prevention have been identified. These empirical findings are consistent with global research outcomes, offering crucial insights for enhancing eye health policies and practices in Southwest China.

Currently, the adoption rate and effectiveness of OK lenses in Southwest China, particularly at the high school level, are suboptimal. We recommend enhancing public education to increase awareness and acceptance of OK lenses among parents and students. Moreover, there is a need to intensify training programmes for eye care professionals to improve their skills and knowledge in the correct usage of these lenses. Government and school collaborations should focus on developing targeted eye health policies, including financial support to reduce the cost of correction tools and improve the accessibility and quality of eye care services.

Future research should further explore the long-term effects and cost-effectiveness of different correction tools, as well as their impact on the long-term development of adolescent eye health. Through continuous improvement and innovation, we aim to effectively reduce the prevalence of myopia, thereby enhancing the quality of life and academic performance among adolescents.

Limitations

This study did not investigate the influence of genetic and environmental factors on myopia, nor did it explore the impact of other systemic diseases on VA. Additionally, it only estimated the degree of eye use based on different grades, without quantifying specific indicators like the amount of time spent on intensive near-eye activities or outdoor activities. Furthermore, the study did not differentiate between the types of materials used for OK lenses. Future research is needed to identify any potential eye diseases associated with wearing glasses. Moreover, socioeconomic factors were not included in the survey due to limitations in available resources.

In addition, this study was based on a national public health programme, the Free Service Scheme for Prevention and Control of Myopia in Children and Adolescents, and the data were obtained from a whole cohort sample of 95 primary and secondary schools in the first pilot units in Southwest China. Data from these pilot units were fully included in the study. However, because this study only included data from 95 primary and secondary schools in one city in Southwest China, it may not be representative of the entire of China.

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Acknowledgements We are especially grateful to the Chengdu Qingyang District Education Bureau for providing high-quality adolescent myopia screening data, all of which are desensitised and do not involve the privacy of participants.

Contributors LZ designed the study; JL and XW collected the data; WT, TT, XW, BY, LZ, DZ and LL prepared the figures and tables; WT and LYZ made the draft manuscript. All authors (WT, TT, JL, XW, BY, LZ, DZ, LL, and LZ) collectively contributed to the final version. Each author played a comprehensive role in the project and assumed public responsibility for relevant portions of the content.

Funding This work was supported by the Natural Science Foundation of Chongqing (Grant No. CSTB2023NSCQ-MSX0237), the Scientific and Technological Research Program of Chongqing Municipal Education Commission (Grant No. KJZD-K202300101) and Youth Research Program of Chongqing Municipal Education Commission (Grant No. KJQN202400120).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Approval for this retrospective observational study was obtained from the Ethics Committee of Chongqing University Central Hospital, and the need to obtain informed consent was waived.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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