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CLINICAL TRIAL REPORT

Interventional Study on the Effectiveness of Eye Exercises Based on Composite Feedback Model in School-Age Children

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Objective: This study aims to explore the effects of eye exercises on the accommodative ability of Chinese school-aged children.
Methods: This study used a convenience cluster sampling and selected 149 students from grades 2–5 in a Wenzhou primary school to participate in the intervention in June 2022. This study involved a one-month intervention teaching eye exercises using a composite feedback model. Assessments were made at 3 and 9 months post-intervention. Data collection occurred thrice, including a baseline and two follow-ups, measuring monocular and binocular accommodative facility, monocular and binocular accommodative amplitude, CISS scale, spherical equivalent refraction, and uncorrected visual acuity. Analysis used chi-square tests and generalized estimating equations to evaluate the exercises' effectiveness, with a significance threshold of $P < 0.05$.
Results: 134 students completed the follow-up, including 61 females (45.52%). After teaching intervention, students showed significant improvements in the accuracy of manipulation, rhythm, acupoint location, strength effectiveness and rhythm of acupressure eye exercises (all $P < 0.05$), with increases of 10.37%, 13.03%, 16.96%, and 25.17%, respectively. Follow-up assessments revealed both monocular and binocular accommodative amplitude at T3 were significantly higher than at T1 and T2. Moreover, the binocular accommodative amplitude in the high-quality eye exercise group remained significantly higher than that in the low-quality group even (B=1.39,1.46, $P < 0.01$). Eye exercises could improve monocular and binocular accommodative amplitude in the short term($P < 0.05$). High-quality eye exercises could alleviate visual fatigue (B=−2.00–3.49, both $P < 0.05$). However, eye exercises did not demonstrate any advantages in affecting spherical equivalent refraction or uncorrected visual acuity ($P > 0.05$).
Conclusion: Eye exercises can alleviate myopia-related symptoms in Chinese children aged 7 to 11 years. However, this study did not find that eye exercises effectively reduce the degree of myopia in children.
Trial Registration: The original trial (Registration site: https://www.chictr.org.cn/ Registration number: ChiCTR2300070903) was retrospectively registered on 26/04/2023.
Keywords: Eye exercises, myopia, accommodative facility, accommodative amplitude, visual fatigue

Introduction

The prevalence of myopia is increasing globally, with an estimated half of the world's population projected to be myopic by 2050, including 10% being highly myopic.[1,2] In China, the myopia rate among young people is alarmingly high at 52.7%, significantly exceeding the global average.[3] The occurrence of myopia is not only related to genetic factors but also associated with prolonged near-work activities, poor visual habits (such as excessive use of electronic devices, lack of outdoor activities, incorrect reading and writing postures, etc).[4,5] Myopia not only affects vision but also increases the risk of eye-related diseases, especially in cases of high myopia and pathological myopia, which can lead to irreversible

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vision impairment, even blindness. Severe eye diseases include glaucoma, retinal detachment, and macular degeneration.[6] Therefore, it is imperative to rigorously evaluate all methods aimed at preventing or slowing the progression of myopia to determine their effectiveness.

Eye exercises are rooted in the principles of traditional Chinese medicine meridian acupoint massage, aiming to combat myopia by promoting blood circulation, enhancing metabolism, relaxing eye muscles, and relieving eye fatigue.[7] In 1972, China's State Education Commission stipulated that primary school students should do eye exercises twice a day during breaks. In 2008, the Ministry of Education released the "Work Plan for the Prevention and Control of Myopia among Primary and Secondary School Students", which requires that eye exercises be included in the class timetable twice a day, and that students be organized to complete the exercises conscientiously. It also clarified the responsibilities of school doctors, class teachers, and subject teachers in implementing the system.[8] Nevertheless, the prevalence of myopia and myopia-related visual impairments in China continues to rise.[9] A randomized, double-blind controlled trial showed that the degree of myopia progression was significantly higher in the standard eye exercise group (−0.10D) compared to the sham eye exercise group (−0.03D) and the closed-eye group (0.07D) ($P = 0.04$), considering the high near-work load among Chinese children, the long-term efficacy of eye exercises in preventing myopia progression may be insufficient.[10] Lin[11] summarized 11 studies for systematic review, suggesting limited or ineffective effectiveness of eye exercises in preventing or controlling myopia progression. However, another study indicated that eye exercises had a protective effect on adolescent myopia (OR, 95% CI: 0.605, 0.475–0.770).[12] It has also been reported that having a "serious attitude" towards eye exercises can improve the vision of primary school students.[13] A meta-analysis by Yang[14] showed that performing eye exercises seriously and regularly twice or more a day can effectively prevent myopia in children and adolescents.

According to statistics, there are 154,300 primary schools and 52,900 junior high schools in China, with a total of 158 million students.[15] If each student performs eye exercises twice a day for a total of 10 minutes, then the total time spent by primary and secondary school students nationwide is nearly 1.58 billion minutes per day, equivalent to 1.097 million days. Internationally, outdoor activities are considered the primary means to address vision health issues in children and adolescents.[16] In this context, it is necessary to deeply consider and demonstrate the possibility of converting the indoor eye exercise time specified in school policies to outdoor physical activity time. Whether to continue the current policy or make necessary revisions, empirical research is urgently needed to verify and publicize the actual effects of eye exercises on the protection of vision in children and adolescents. Alarmingly, reports show that about 90% of children do not meet the prescribed standards for these eye exercises.[17] Many children have difficulty determining the precise locations of acupoints, applying pressure, and techniques. Research shows that only 60.10% of primary school students correctly perform eye exercises.[18]

Therefore, the main purpose of this study is to investigate factors affecting the effectiveness of eye exercises, particularly examining whether the quality of exercise execution or the exercises themselves affect myopia prevention. Although the mechanisms behind myopia development are still not fully elucidated, the regulation theory suggests that weakened accommodative ability and inadequate accommodation reserves in myopic eyes can challenge accurate adjustment of retinal images.[19,20] This inaccuracy can lead to blurred vision and trigger elongation of the eyeball, resulting in the progression of myopia. Studies have shown that eye exercises can significantly alleviate accommodative lag, enhance accommodation amplitude (AMP), especially in adolescents.[10,21] Most existing studies include longitudinal follow-up, but the quality of eye exercises is often not assessed.[22,23] Therefore, it is crucial to determine the true value of eye exercises and consider short-term outcomes such as AMP and accommodation facility (AF) as evaluation indicators of eye exercises to assess their efficacy in inhibiting myopia and relieving eye fatigue in Chinese children.

Although randomized controlled trials are the gold standard for assessing the effectiveness of eye exercises, practical limitations may prevent parents in China from discontinuing these habitual practices. Additionally, the ethical review process may pose challenges to establishing control groups in China. So far, the most compelling evidence comes from a pre-post self-controlled study that effectively controlled potential confounding variables and examined the relationship between Chinese eye exercises and myopia.[24] This research approach provides empirical data to confirm or refute the scientific validity and effectiveness of Chinese eye exercises.

This study aims to explore the effects of eye exercises on the accommodative ability of Chinese school-aged children. We envisage that by providing standardized and effective training, we can correct children's existing irregular and inadequate practices, thereby promoting these exercises as effective means for preventing myopia progression and relieving eye fatigue.

Materials and Methods

Study Design

This study is a self-controlled before-after study combined with a cohort study. The primary outcomes were AF and AMP, and the secondary outcomes were CISS scores, Uncorrected visual acuity (UCVA), and spherical equivalent refraction (SER), in order to understand the effects of standardized eye exercises on eye accommodation function. The study was conducted in the following three phases from 2022 to 2023:

1) Baseline Phase (T1): Complete the standard Chinese Eye Exercises assessment form at baseline.
2) Intervention Phase: Three eye exercises teaching interventions were completed within one month. After the third intervention, a questionnaire survey was conducted, including the Eye Health-related Behaviors Questionnaire, the Standard Chinese Eye Exercises Assessment Form, Convergence Insufficiency Symptom Survey (CISS) and eye parameter measurements.
3) Post-Intervention Phase: Follow-up was conducted over 9-months with the same group of pre-adolescents. Data were collected at 3-months (T2) and 9-months (T3). During these follow-up phases, CISS, and eye parameter measurements were once again completed.

Population and Sample

In June 2022, students from grades 2 to 5 of a primary school in Lucheng District, Wenzhou City were selected as research subjects using the convenience cluster sampling method. This study selected students from grades 2 to 5 based on factors such as the quality of questionnaire collection, students' cooperation in eye examinations, and a high sample loss rate due to further studies.

Inclusion criteria (1) School-age children in grades 2 to 5; (2) Possessing basic language communication and comprehension skills. (3) Best-corrected visual acuity (BCVA) ≤ 0.1 (minimum angle of resolution, LogMAR) or better; (4) Participating in after-school services at school; (5) Willing to cooperate and make regular follow-up visits. Exclusion criteria (1) Excluding students with obvious strabismus and amblyopia, and dyslexia or attention deficit disorder; (2) Those who use other methods such as functional frame glasses, contact lenses, orthokeratology, acupuncture, massage, eye drops or auricular acupuncture to correct vision in addition to wearing frame glasses; (3) Those with mental, psychological, cardiovascular or other systemic diseases; (4) Children with facial trauma or skin diseases; (5) Those who have participated in other eye health research and experimental studies.

We used a quasi-experimental before-after design to measure the subjects' AF as the primary outcome. Based on relevant studies,[25] we estimated the mean pre-intervention AF at 5.03 cycles per minute (cpm). We projected an expected post-intervention increase of 2.97 cpm, with a standard deviation of 5.54 cpm for the difference. We computed the sample size using the formula: $N = \left[\left(t_{\frac{\alpha}{2}} + t_{\beta}\right)S/d\right]^2$ with a significance level of α=0.05 and a power of 90%. The study required at least 36 subjects. We added a 10% dropout rate for possible loss to follow-up or refusals, which increased the final sample size to 40 subjects. We conducted a baseline survey with 166 students. We screened out 5 individuals using other myopia control methods and 12 individuals with uncorrected visual impairments. We enrolled 149 eligible individuals who met the inclusion criteria in the intervention study (Figure 1), which matched the calculated sample size.

This study followed ethical principles, regulations, and the Declaration of Helsinki and was approved by the Ethics Committee of a tertiary hospital in Wenzhou (approval number 2022–117-K-89-01). Before conducting the study, the research team informed the school of the purpose and significance of the study, the details of the ophthalmological examination, and the completion process of the questionnaire. The researchers obtained informed consent from the school, parents, and students.

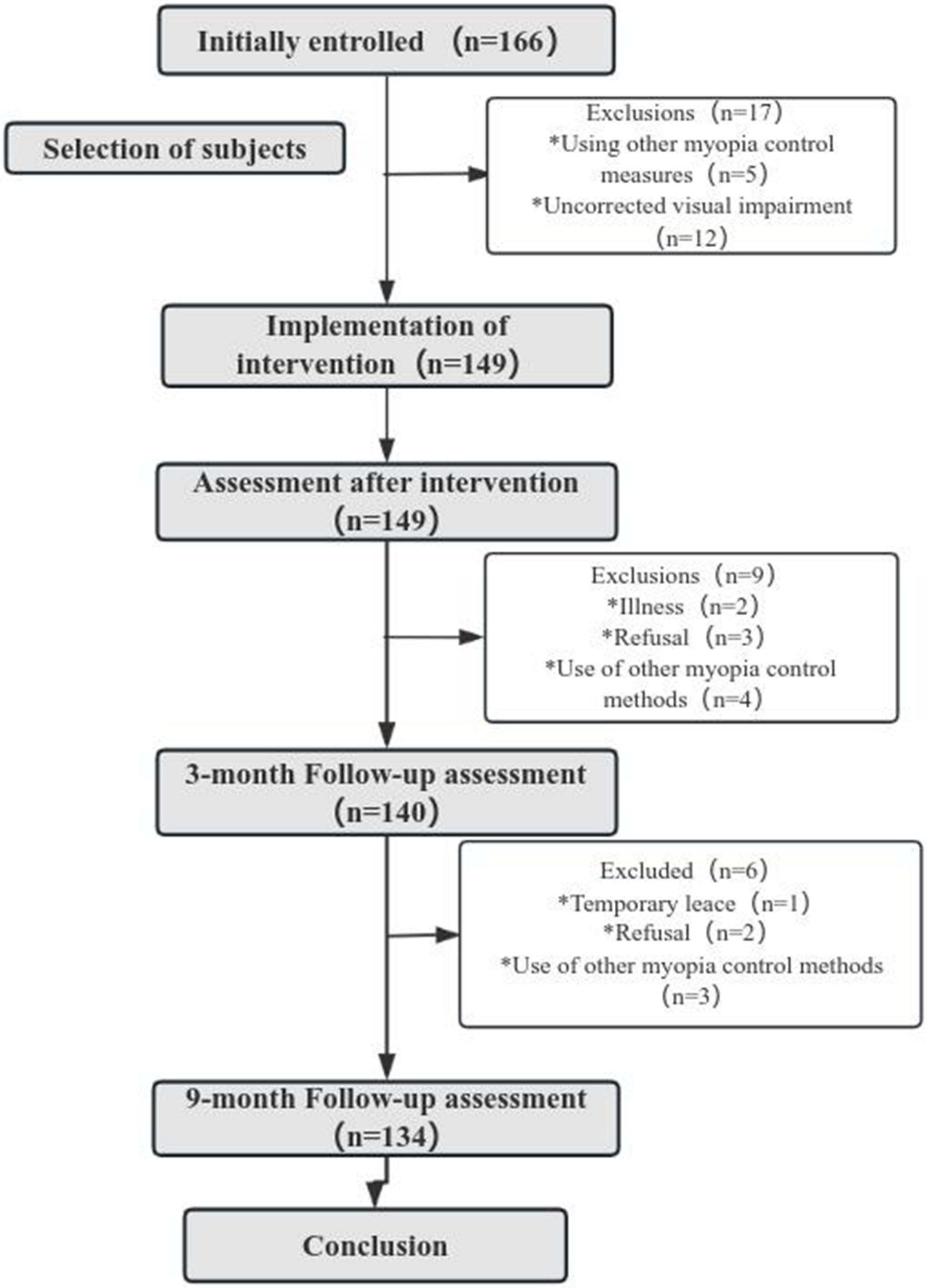

Figure 1 Study Flowchart.

Questionnaire

The Eye Health-related Behaviors Questionnaire This questionnaire[26] included students' demographic characteristics, eye-related behaviors (such as reading/writing distance, continuous working hours, etc), eye time, and outdoor activity time. Eye time includes time spent on homework, extracurricular reading, using mobile phones, computers, and television. Questions about eye time and outdoor activity time involved continuity and accumulation. The average time spent on eye time and outdoor activities per day was calculated using the following formula: [(hours spent on weekdays) × 5 + (hours spent on weekends) × 2] / 7. The content validity index of the questionnaire was 0.89, and the Cronbach' s α coefficient was 0.82. The Cronbach' s α coefficient for this study was 0.71.

Figure 2 Schematic diagram of the acupressure point locations for eye exercises.

The Standard Chinese Eye Exercises Assessment Form[24] It consists of 4 exercises, including pressing and kneading cuanzhu, pressing and nipping Jingming, pressing and kneading Sibai, and pressing and kneading Taiyang, scrape orbit (Figure 2). There are 18 questions on the manipulation dimension, 5 questions on the rhythm dimension, 10 questions on the acupoint location, and 5 questions on the strength effectiveness. Among them, 1 point is awarded for correct answers and 0 points for errors. There are 38 items in total, with a total score of 38 points. The higher the score, the more standard the operation. A score of ≥30 points is considered high-quality eye exercises, and a score of <30 points is considered low-quality eye exercises. The correct rate = correct score/(number of people × number of questions). The inter-rater reliability of this study was 0.845. (Supplementary Tables 1 and 2)

The CISS The CISS is a reliable instrument used for child surveys.[27] In their study, Junghans et al[28] employed the CISS scale to assess visual fatigue prevalence in school-age children. This survey contains 15 items addressing symptoms related to visual fatigue. Respondents rate the frequency of these symptoms using the following categories: never (0 points), occasionally (1 point), sometimes (2 points), often (3 points), or always (4 points). A higher sum of 15 question scores indicates more severe symptoms, with a total score of 60 and a cronbach' s α coefficient of 0.77.[29] The Cronbach' s α coefficient in this study was 0.86.

Eye Parameter Measurements

AF Monocular and binocular AF was measured by calculating the speed of alternating viewing of +2.00 diopters (D) and −2.00 D lenses. Lenses immediately switched between +2.00 D and −2.00 D when the participant reported the letters to be clear for a 20/30 size vertical letter column at 40 cm. The number of cpm was calculated. One cycle involved the ability to clear the positive lens and the negative lens.

AMP To measure the monocular and binocular AMP using the push-up method, a movable card containing a 20/30 size letter column was attached to the Gulden near point rule (Gulden Ophthalmics, Elkins Park, PA). After distance vision was fully corrected, the subject fixated on the optotype with the smallest letter size located at 40 cm. The optotype was gradually moved closer at a rate of 1 cm per second until it became blurred. Then, the subject was asked to refocus. The distance from the eye to the point where the participant first reported the letters to be continuously blurred was recorded to the nearest half centimeter and then converted to diopters.

UCVA The standard visual acuity chart lightbox was positioned 5 meters away. During the examination, the students were seated, looked straight ahead with both eyes, and covered the opposite eye with an occluder. The uncorrected and corrected visual acuity values for both the left and right eyes were recorded.

SER Considering that the number of students recruited under cycloplegic refraction is limited, and secondly, if ciliary muscle paralysis optometry is used, it will affect students' normal classes and violate students' right to learn. Therefore, noncycloplegic refraction is adopted. An ophthalmic nurse uses a fully automatic computer ophthalmometer (TOPCON-RM800) to measure the refractive state of students' eyes in the noncycloplegic refraction. Before measurement, students are asked to take off their glasses, adjust the height of the seat and the instrument, place their chin on the chin rest, put their forehead close to the forehead rest, and adjust the adjustment knob of the chin rest so that the students' outer canthus angle is consistent with the forehead rest height mark. Ask students to look at the sight mark in the ophthalmometer, keep their heads and eyes still, measure each eye of the students three times in a row, and calculate the arithmetic average of the three valid measurement values. If the spherical lens or cylindrical lens difference in the three computer optometry results exceeds 0.50D, the computer optometry test needs to be repeated.

Intervention Measures

The Composite Feedback Model is a teaching model applicable to motor skill learning. It integrates traditional feedback models, observational learning, and self-regulation theory, proposing a new feedback method called composite feedback.[30] In motor skill learning, the concept of composite feedback suggests that learners, under the guidance of teachers, utilize observational learning and self-regulation feedback appropriately at the right time according to the nature, complexity, and practice stage of the task.[31] Learners selectively receive external feedback to further consolidate and strengthen relevant information in internal feedback. This organic combination of external and internal feedback facilitates skill learning. The learning process involves four steps: observation guidance, imitation practice, self-monitoring, and self-adjustment.

We designed a teaching program based on the composite feedback method and the baseline survey results, combined with literature review, expert group Discussion and preliminary experiments. The program, grounded in Traditional Chinese Medicine principles and the Chinese Traditional Medicine Appropriate Technology Guidelines,[32] spanned 4 weeks with 45-minute group sessions in the 1st, 2nd, and 4th weeks, aimed at enhancing students' eye movement skills through instructional videos. Groups were organized by class, each containing 15–20 students.The specific measures are shown in Table 1.

Students will do eye exercises twice a day (five minutes each), one after the third get out of class in the morning and one after the second get out of class in the afternoon, following the eye exercises music played by the school. There will be guidance and follow-up from teachers each time they do the exercises, and the project team members will also visit the school every week to follow up on the corresponding progress.

Table 1 Intervention Program Content

Practice Teaching Stage	Teaching Objectives	Teaching Content	Intervention Format and Time
Guided Observation Stage	To enable students to recognize the importance of eye exercises for ocular health and comprehend fundamental eye relaxation and exercise movements.	• Introduction to the significance of eye relaxation and exercise. • Demonstration of basic eye exercise movements, emphasizing correct posture and techniques. • Explanation of the impact of each movement on ocular health, fostering a deeper understanding among students.	Face-to-face (Week 1/ Week 2, 20 minutes/ 10 minutes)
Imitation Practice Stage	Students learn eye exercises through imitation of demonstrated movements.	• Students follow the teacher's demonstration of eye exercise movements. • Inviting 2–3 students to showcase based on observation to aid better learning through observation. • Group practice enabling students to observe, imitate, and correct each other.	Face-to-face, one-on-one (Week 1, 25 minutes)
Self-Monitoring and Guiding Stage	Developing students' self-observation and self-assessment abilities to comprehend the strengths and weaknesses of their own eye exercise movements.	• Students compare their practice of eye exercises with standard action videos. • Guiding students in self-evaluation, identifying strengths and areas needing improvement in their movements. • Establishing a WeChat group, encouraging parents to watch standard action videos and assist students in self-monitoring and gradual improvement.	Face-to-face, one-on-one (Week 2/Week 4, 20 minutes/20 minutes)
Self-Adjustment Stage	Students adjust eye exercise movements based on self-observation and monitoring to enhance adaptability and flexibility in movements.	• Students compare their practice of eye exercises with standard action videos.- Teachers provide feedback and one-on-one corrections, guiding adjustments to eye exercise movements according to students' proficiency levels. • Encouraging students to adjust their movements based on feedback during practice.	Face-to-face, one-on-one (Week 2/Week 4, 15 minutes/25 minutes)

Data Collection Methods

Before the survey begins, explain the purpose, content, process and significance of the study to school teachers, parents and students, and obtain their consent and support. All investigators were professional ophthalmic nurses who had received uniform training and mastered the eye examination methods and questionnaire requirements. Data collection was carried out in collaboration with the class teacher. The questionnaire was completed uniformly during the morning break, and the eye examination time was uniformly arranged during the school lunch break. During the questionnaire collection process, we used a unified instruction and answered the respondents' questions in a timely manner. After filling out the questionnaire, we immediately collected the questionnaire to ensure timely data collection and checked it. If there were blanks, omissions or obvious errors, they were filled in and corrected on the spot. Before the eye examination, the instruments were checked and calibrated.

The standard Chinese eye exercises assessment form was independently evaluated by two qualified ophthalmic professionals with relevant knowledge of traditional Chinese medicine. Only one student was evaluated at a time (only one eight-beat exercise was performed in each session). After each session, the student was asked whether he felt soreness or swelling. The total score difference must be less than 5 points, and the scoring results were averaged.

Team members were uniformly trained before the intervention, and the intervention process was carried out during the school's after-school service time.

Statistical Analysis

Data processing was carried out using SPSS 26.0 software, converting decimal visual acuity into the LogMAR visual acuity. We analyzed only the right eye data of each student because of the high correlation between the right and left eyes in AF, AMP, SER, and UCVA (Spearman' s correlation coefficients: 0.82, 0.83, 0.621, 0.814; all $P < 0.001$).

For non-normally distributed data, descriptive analysis was conducted using the median (interquartile range). The Chi-square test was used to compare differences in the correct rate of eye exercise before and after intervention. The Mann–Whitney *U*-test and Chi-square test were employed to compare differences in baseline covariates under different qualities of eye exercise. Subgroup analysis was performed for the high-quality group (eye exercise score ≥ 30 points) and low-quality group (eye exercise score < 30 points).[24] For the two-sample non-parametric rank-sum test, the Mann–Whitney *U*-test was used. For the multiple-sample rank-sum test, the Kruskal–Wallis *H*-test was used, and multiple comparisons were adjusted using the Bonferroni correction method. The significance level was adjusted to compare differences between the high-quality group and low-quality group in AF, AMP, CISS score, SER, and UCVA at 3-months and 9-months follow-up periods.

We also used the Generalized Estimating Equation (GEE) analysis to measure the intervention effects of eye exercises on AF, AMP, CISS score, SER, and UCVA. Model 1 did not control for any covariates, while Model 2 controlled for student myopia, gender, age, parental education level, parental myopia count, outdoor activity time, average eye time, continuous eye use time, and uninterrupted outdoor activity time. We set a significance level of $P < 0.05$ for all analyses.

Results

In the initial phase of this study, an initial cohort of 166 students was enrolled, with 149 completing the program post-intervention, accounting for 89.76% of the initial cohort. Subsequently, after the educational intervention in the participating schools, 134 students successfully underwent the follow-up post-intervention, representing 89.93% of the pre-intervention sample and 80.72% of the initial sample. Reasons for attrition included illness, temporary leave, refusal to participate, and the utilization of alternative methods for myopia control, as indicated in Figure 1. Consequently, the final analysis involved 134 participants. No significant health-related issues or severe adverse events were reported following the eye exercise intervention.

The median age of the participants in this study was 10 years old, comprising 61 females (45.52%) and 73 males (54.48%). The average eye time was 4.18 hours, outdoor activity duration was 1.79 hours, the duration of eye use was 0.50 hours, and uninterrupted outdoor activity sessions lasted approximately 1.25 hours each. Statistical analysis revealed no significant differences between the two groups concerning age, gender, student myopia, parental education level, parental myopia count, average eye time, outdoor activity time, continuous eye use time, and uninterrupted outdoor activity time. Both groups demonstrated balanced and comparable baseline characteristics. Detailed demographic statistics are presented in Table 2.

Table 3 shows that after the intervention, the students' accuracy in the manipulation, acupoint location, strength effectiveness and rhythm of acupressure eye exercises improved significantly (all $P < 0.05$), with increases of 10.37%, 13.03%, 16.96% and 25.17%, respectively.

Table 4 and Figure 3 show that at T3, the high-quality eye exercise group had higher monocular and binocular AF than the low-quality group (P=0.018, P=0.026). The high-quality group also had higher monocular AF at T3 than at T1, but lower at T2 than at T1 (both $P < 0.05$). The high-quality and low-quality groups differed significantly in monocular AMP at T1 ($P = 0.016$). The high-quality group had lower monocular AMP at T3 than at T2, but higher at T2 than at T1 (both $P < 0.05$). The high-quality group also had lower binocular AMP at T3 than at T2 ($P = 0.030$).

Table 4 and Figure 4 show that the high-quality group had lower CISS scores than the low-quality group at both T3 (all $P = 0.003$). There were no significant differences in SER between groups at any time point ($P = 0.232$, $P = 0.498$, $P = 0.289$). SER were consistent across time for both groups ($P = 0.167$, $P = 0.231$). SER and UCVA did not change significantly across the three time points for either group.

The Results from the GEE analysis indicated that both monocular and binocular AF at T3 were significantly higher than at T1 and T2. Moreover, the binocular AF in the high-quality eye exercise group remained significantly higher than that in the low-quality group even after controlling for other factors ($B = 1.46$, $P < 0.01$), as shown in Table 5. There was no statistically significant main effect of eye exercises on monocular and binocular AMP in terms of group and time ($B = 0.082$–0.847, all $P > 0.05$), as shown in Table 6. As shown in Table 7, in both Model 1 and Model 2, significant changes in CISS scores were observed for the high-quality eye exercise group at different time points ($B = -2.00$–3.49, both $P < 0.05$), however, the low-quality group did not exhibit significant changes over time ($B = -0.21$–0.22, $P > 0.05$). No significant effect of eye exercise quality and duration on UCVA ($P > 0.05$). On SER, the difference between groups was not significant ($P > 0.05$), but within groups was influenced by time ($P < 0.05$) (Supplementary Tables 1 and 2).

Table 2 Differences in Baseline Covariates Between the Low-Quality and High-Quality Eye Exercise Groups

Parameter		Total	Low-Quality Group (n=56) Median (IQR) /n (%)	High-Quality Group (n=78) Median (IQR) /n (%)	χ^2 / Z Value	P value
Age(yrs)		10.00 (9.00,11.00)	10.00 (9.00,11.00)	10.00 (9.00,11.00)	−0.823	0.410
Gender	Female	65 (48.51)	26 (46.43)	39 (50.00)	0.166	0.683
	Male	69 (51.49)	30 (53.57)	39 (50.00)		
Parental Education Level	≤ Middle School	61 (45.52)	23 (31.07)	38 (48.72)	0.769	0.381
	High School	73 (54.48)	33 (58.93)	40 (51.28)		
	≥ College	19 (14.18)	10 (17.86)	9 (11.54)	3.054	0.217
Parental myopia count	0	34 (25.37)	17 (30.36)	17 (21.79)		
	1	81 (60.45)	29 (51.78)	52 (66.67)		
	2	32 (23.88)	14 (25.00)	18 (23.08)	3.739	0.154
Student myopia	No	54 (40.30)	27 (48.21)	27 (34.61)		
	Yes	48 (38.82)	15 (26.79)	33 (42.31)		
Average eye time, (h/d)		4.18 (3.27,5.23)	4.29 (3.00,5.71)	3.93 (3.29,5.04)	−0.801	0.423
Outdoor activity time(h/d)		1.79 (1.07,2.50)	1.79 (1.07,2.50)	1.50 (1.07,2.50)	−0.270	0.787
Continuous eye use time(h/d)		0.50 (0.33,0.75)	0.58 (0.42,0.83)	0.42 (0.33,0.75)	−1.650	0.099
Uninterrupted outdoor activity time(h/d)		1.25 (0.75,1.75)	1.25 (0.75,1.75)	1.25 (0.75,1.25)	−0.934	0.350

Notes: χ^2 represents the result of the chi-square test. Z values represent the results of the Mann–Whitney U-test.
Abbreviation: IQR, interquartile range.

Table 3 Comparison of Differences in Eye Exercise Accuracy Before and After Intervention (Correct Rate,%)

	Number (n = 149)	Press and Nead Cuanzhu	Press and nip Jingming	Press and Knead Sibai	Press and Knead Taiyang, scrape Orbit	Overall
Manipulation	Baseline	80.74	79.26	73.88	73.46	76.46
	Postintervention	91.30	86.85	85.56	84.69	86.83
	χ^2 Value	6.003	2.620	5.926	5.004	4.811
	P value	**0.014**	0.106	**0.015**	**0.025**	**0.028**
Rhythm	Baseline	83.70	84.44	80.74	61.85	74.52
	Postintervention	96.30	95.55	95.55	75.19	87.55
	χ^2 Value	11.893	9.259	14.181	6.198	6.986
	P value	**0.001**	**0.002**	**<0.001**	**0.013**	**0.008**
Acupoint Location	Baseline	35.71	35.14	25.14	60.37	49.04
	Postintervention	65.19	71.48	52.96	70.19	66.00
	χ^2 Value	23.705	37.202	22.428	2.772	8.013
	P value	**<0.001**	**<0.001**	**<0.001**	0.096	**0.005**
Strength Effectiveness	Baseline	28.89	26.66	33.33	30.00	31.11
	Postintervention	54.80	63.70	53.33	54.81	56.30
	χ^2 Value	18.643	37.384	10.995	16.495	17.402
	P value	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**
Overall	Baseline	66.01	64.91	59.35	61.85	63.02
	Postintervention	80.83	81.20	74.63	74.92	77.43
	χ^2 Value	7.576	9.167	7.392	4.962	7.105
	P value	**0.006**	**0.002**	**0.007**	**0.026**	**0.008**

Notes: χ^2 represents the result of the chi-square test. Bold indicates statistical significance.

Table 4 Differences in Outcome Measures at Baseline, the 3-Month Follow-Up, and the 9-Month Follow-Up Between the Different Eye Exercise Quality Groups

Measurement		Low-Quality Group (n = 56)	High-Quality Group (n = 78)	*Z* Value	*P* value
Monocular AF (cpm)	T1	7.50 (4.00,9.88)	8.00 (6.00,9.00)[a]	−0.45	0.649
	T2	7.00 (4.62,10.00)	7.50 (5.00,10.75)	−0.92	0.360
	T3	8.00 (6.00,11.00)	10.00 (6.50,13.00)	−2.32	**0.018**
	H Value	2.35	13.36		
	P value	0.313	**0.001**		
Binocular AF (cpm)	T1	8.00 (6.00,10.00)	8.50 (6.50,11.50)	−1.55	0.122
	T2	7.75 (6.00,9.00)[b]	9.00 (6.75,11.25)	−2.73	**0.006**
	T3	9.00 (7.00,11.00)	10.25 (8.00,13.00)	−2.22	**0.026**
	H Value	7.90	5.49		
	P value	**0.019**	0.064		
Monocular AMP (D)	T1	16.03 (13.33,20.00)	14.29 (10.00,16.67)	−2.42	**0.016**
	T2	14.29 (12.50,16.67)	16.67 (12.50,20.00)[c]	−1.85	0.065
	T3	14.29 (12.50,16.67)	14.29 (11.11,16.67)	−0.92	0.359
	H Value	4.98	13.68		
	P value	0.083	**0.001**		
Binocular AMP (D)	T1	20.00 (16.67,25.00)	20.00 (16.67,25.00)	−0.78	0.430
	T2	25.00 (20.00,32.14)	25.00 (20.00,33.33)[d]	−0.42	0.678
	T3	20.00 (16.67,25.00)	20.00 (15.38,25.00)	−0.29	0.776
	H Value	3.03	7.45		
	P value	0.221	**0.024**		

(*Continued*)

Table 4 (Continued).

Measurement		Low-Quality Group (n = 56)	High-Quality Group (n = 78)	*Z* Value	*P* value
CISS Score	T1	7.00 (4.00,13.00)	6.00 (3.00,12.50)[e]	−0.52	0.603
	T2	8.00 (3.25,13.00)	6.00 (3.00,10.00)	−1.68	0.091
	T3	8.50 (4.75,12.00)	4.00 (1.00,9.00)	−2.94	**0.003**
	H Value	0.04	6.23		
	P value	0.978	**0.042**		
UCVA (LogMAR)	T1	0.10 (0.00,0.30)	0.05 (−0.10,0.43)	−0.18	0.856
	T2	0.10 (0.00,0.30)	0.05 (−0.10,0.50)	−0.37	0.723
	T3	0.10 (0.00,0.40)	0.05 (−0.10,0.50)	−0.29	0.770
	H Value	0.15	0.071		
	P value	0.925	0.962		
SER (D)	T1	−0.25 (−1.13,0.25)	−0.38 (−1.75,0.00)	−1.20	0.232
	T2	−0.50 (−1.13,0.13)	−0.63 (−2.31,0.13)	−0.68	0.498
	T3	−0.50 (−1.88,0.00)	−0.63 (−2.38,0.00)	−1.06	0.289
	H Value	3.00	3.53		
	P value	0.231	0.167		

Notes: T1 = baseline phase, T2 = the 3-month follow-up, T3 = the 9-month follow-up; a Compared to T2, *P* = 0.003; Compared to T3, *P* = 0.008. b Compared to T3, *P* = 0.019. c Compared to T1, *P* = 0.005; Compared to T3, *P* = 0.003. d Compared to T3, *P* = 0.030. e Compared to T3, *P* = 0.039. *Z* values represent the results of the Mann–Whitney *U*-test. *H* Value represents the result of Kruskal–Wallis *H*-test. Bold indicates statistical significance.
Abbreviations: AF, accommodation facility; AMP, accommodation amplitude; CISS, Convergence Insufficiency Symptom Survey; UCVA, uncorrected visual acuity; SER, spherical equivalent refraction; D, diopters; cpm, cycles per minute; LogMAR, logarithm of the minimum angle of resolution.

Discussion

Based on the results of the baseline survey, it is clear that children exhibit lower accuracy in selecting acupressure points and applying the correct pressure, which aligns with the findings of An Shuhui and her research team.[18] This underscores

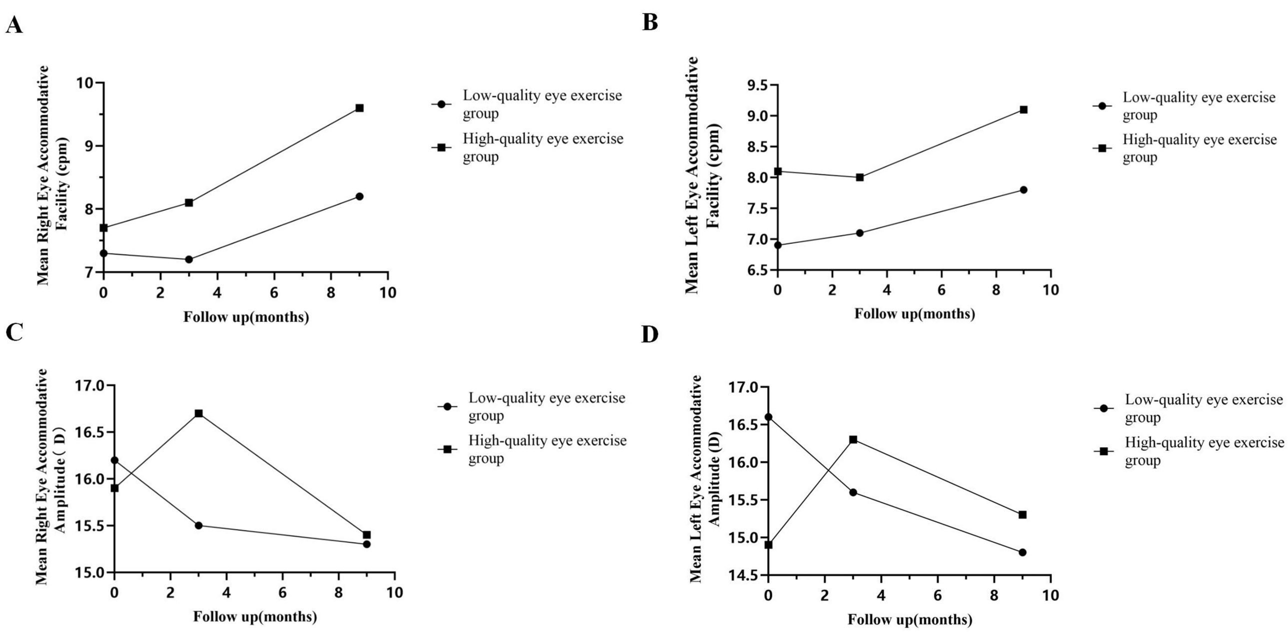

Figure 3 Changes in accommodation facility (**A-B**) and accommodation amplitude (**C-D**) with different eye exercise qualities during the 9-month follow-up period.
Abbreviations: D, diopters; cpm, cycles per minute.

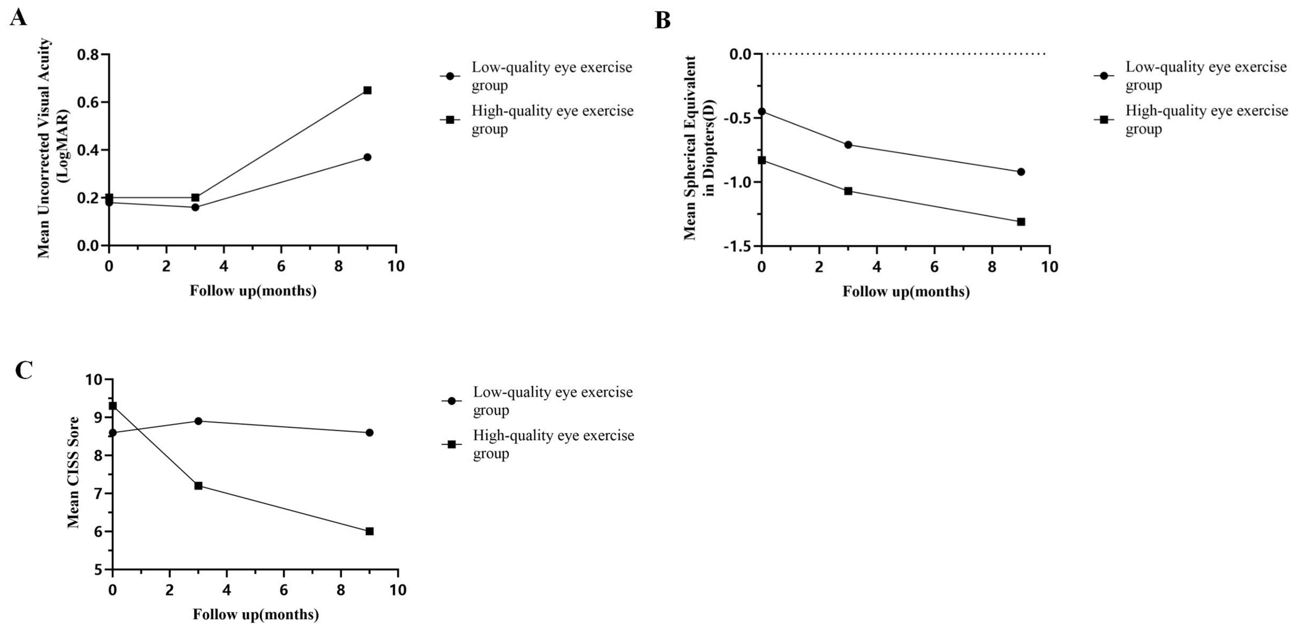

Figure 4 Changes in uncorrected visual acuity (**A**), spherical equivalent refraction (**B**) and CISS score (**C**) with different eye exercise qualities during the 9-month follow-up period.

Abbreviation: D, diopters; LogMAR, logarithm of the minimum angle of resolution.

the persistent inadequacy in children's understanding and proficiency in performing eye exercises over the past two decades, emphasizing the crucial need for professional guidance and training.

This study is the first to apply the composite feedback teaching method to eye exercise instruction, which consists of four steps: observation guidance, imitation practice, self-monitoring, and self-regulation.Teachers employed various

Table 5 Parameter Estimation of Accommodation Facility

Variable	Group	Monocular AF				Binocular AF			
		Model 1		Model 2		Model 1		Model 2	
		B (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value
Eye Exercise Quality	High-Quality	0.90 (−0.14,1.94)	0.090	0.97 (−0.07,2.01)	0.067	1.39 (0.45,2.33)	**<0.01#**	1.46 (0.52,2.39)	**<0.01#**
Time	T3	1.44 (0.69,2.19)	**<0.001***	1.45 (0.70,2.20)	**<0.001***	1.10 (0.32,1.87)	**<0.01***	1.12 (0.34,1.90)	**<0.01***
	T2	0.16 (−0.46,0.78)	0.614	0.14 (−0.49,0.77)	0.655	−0.07 (−7.76,0.63)	0.849	−0.03 (−0.73,0.66)	0.924

Notes: T1 = baseline phase, T2 = the 3-month follow-up, T3 = the 9-month follow-up; Model 1: Unadjusted. Model 2: Adjusted for factors including student myopia, age, gender, parental education level, parental myopia count, average eye time, outdoor activity time, continuous eye use time, and uninterrupted outdoor activity time. Low-quality eye exercises and T1, are used as references; *Statistically significant differences compared to T1; statistically significant differences compared to T2. # Statistically significant differences compared to the low-quality group. AF = accommodation facility. Bold indicates statistical significance.

Table 6 Parameter Estimation of Accommodation Amplitude

Variable	Group	Monocular AMP				Binocular AMP			
		Model 1		Model 2		Model 1		Model 2	
		B (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value
Eye Exercise Quality	High-Quality	−0.04 (−1.49,1.41)	0.959	−0.15 (−1.59,1.29)	0.840	−0.10 (−2.43,2.24)	0.934	−0.05 (−2.40,2.31)	0.967
Time	T3	−0.02 (−1.28,1.23)	0.970	−0.10 (−1.36,1.16)	0.874	−0.74 (−2.69,1.21)	0.459	−0.78 (−2.75,1.18)*	0.436
	T2	0.79 (−0.52,2.11)	0.236	0.76 (−0.56,2.08)	0.260	1.69 (−0.11,3.49)	0.065	1.60 (−0.20,3.41)	0.082

Notes: T1 = baseline phase, T2 = the 3-month follow-up, T3 = the 9-month follow-up; Model 1: Unadjusted. Model 2: Adjusted for factors including student myopia, age, gender, parental education level, parental myopia count, average eye time, outdoor activity time, continuous eye use time, and uninterrupted outdoor activity time. Low-quality eye exercises and T1 are used as references; *Statistically significant differences compared to T2. AMP = accommodation amplitude.

Table 7 Parameter Estimation of CISS Score

Variable	Group	CISS Score			
		Model 1		Model 2	
		B (95% *CI*)	*P* value	*B* (95% *CI*)	*P* value
Low-Quality	T3	−0.22 (−1.79,1.35)	0.782	−0.21 (−1.80,1.39)	0.800
	T2	0.23 (−1.08,1.55)	0.729	0.22 (−1.12,1.56)	0.749
High-Quality	T3	−3.49 (−5.24,-1.74)	**<0.001*#**	−3.49 (−5.24,-1.75)	**<0.001*#**
	T2	−2.00 (−3.67,-0.33)	**0.019***	−2.00 (−3.67,-0.33)	**0.019***

Notes: T1 = baseline phase, T2 = the 3-month follow-up, T3 = the 9-month follow-up; Model 1: Unadjusted. Model 2: Adjusted for factors including student myopia, age, gender, parental education level, parental myopia count, average eye time, outdoor activity time, continuous eye use time, and uninterrupted outdoor activity time Low-quality eye exercises and T1 are used as references; *Statistically significant differences compared to T2; statistically significant differences compared to T1. #Statistically significant differences compared to T1. CISS = Convergence Insufficiency Symptom Survey. Bold indicates statistical significance.

methods such as live demonstrations, video instruction, one-on-one corrections, feedback from parents and peers, among others, to utilize student feedback effectively. Compared with the traditional eye exercises teaching method of roving guidance and error correction and passive reception of centralized feedback,[33] they promptly communicated this feedback to students to ensure optimal control of the teaching process, thereby achieving the best possible teaching outcomes. After a 4-week intervention period, there was a notable enhancement in the quality of the children's eye exercises, resulting in improved effectiveness.[34] This emphasizes the significance of reinforcing supervision and providing feedback to students during interventions to boost the precision and efficacy of their eye exercises.

This study conducted follow-ups on different eye exercise quality groups and found that high-quality eye exercises significantly improved AF, which is consistent with the findings of Fu W's research.[35] However, this study found a short-term downward trend in AF, which may be related to the subjective nature of AF measurement and the lack of stability.[36] AF is considered to be a sensitive indicator of myopia onset and progression.[37,38] Following this study, Pandian et al believed that AF may not be able to predict the onset of myopia, mainly due to the subjective nature of its assessment, but may help identify high-risk eyes. However, the proportion of myopic subjects (20) involved was smaller than the emmetropic subjects (977) studied by Pandian et al.[39] A study involving 62 children with myopic patients found that enhancing children's AF through training can effectively reduce myopia progression[37] Han et al compared three groups of 240 children wearing single-vision glasses (90 subjects), orthokeratology lenses (90 subjects), and multifocal lenses (60 subjects) and found a significant reduction in the accommodative lag and increase in the AF after 1 year of treatment, which was more pronounced in the orthokeratology group.[40] Improvement in AF is thought to play a positive role in delaying the progression of myopia in pre-adolescents.[38] Nevertheless, a recent study by Chen et al investigated the accommodative response of 144 myopic school-age children and reported no association between a AF and lag with myopia progression.[41]

In this study, we found that eye exercises can improve monocular and binocular AMP in the short term, but have no significant effect on monocular and binocular AMP in the long term. These findings support the previous findings of Li SM et al and Li FF et al, who indicated that eye exercises can enhance AMP and reduce accommodation lag.[10,21] This may indicate a short-term increase in myopic defocus during near work activities, which in turn delays the long-term progression of myopia in children. While orthokeratology (Ortho-K) has demonstrated efficacy in controlling myopia, its different findings regarding AMP, either reporting no change or improvement in this accommodation parameter, indicate that there is conflicting evidence regarding the effect of AMP on myopia prevention and control.[42–44] In addition, Chinese children usually perform eye exercises twice a day. This frequency may not be effective in interrupting hyperopic defocus caused by prolonged near work, and further and long-term studies are needed.

This study also discovered that high-quality eye exercises can alleviate visual fatigue. Research has shown that the peak systolic velocity of the central retinal artery and ophthalmic artery can be increased, as observed through color Doppler imaging,[45] thereby enhancing periorbital blood circulation. Furthermore, simply taking a break from close-up work to perform eye exercises provides a brief period of rest, reducing visual fatigue effects in and of itself.[46] Visual fatigue is a significant factor in the onset and development of myopia. Therefore, eye exercises not only enhance visual quality but also contribute significantly to myopia prevention and control.[47] However, this study found that the quality of eye exercises did not significantly affect SER or UCVA. This might be attributed to the excessive near work demands on children and the relatively brief duration of eye exercises. Students engaged in eye exercises twice per day, with each session lasting 5 minutes. When factoring in weekends and holidays, the average daily time dedicated to eye exercises was less than 6 minutes, which may not be sufficient to address the behavioral factors associated with myopia.[11,48] Additionally, the follow-up period in this study was relatively short, and further observation is warranted.

The innovation of this study is the first time to combine the composite feedback model with the eye exercise teaching intervention to develop an intervention program, and to assess the real effect of eye exercises in terms of AF, AMP, visual fatigue, and other aspects of eye exercises.This study has some limitations, particularly the relatively small sample size and short follow-up period. In addition, the objective eye parameters are missing. These factors constrained the ability to conduct a thorough evaluation of the long-term effects of eye exercises on myopia prevention and control in pre-adolescents. Consequently, further research is necessary, focusing on adopting a combination of subjective and objective indicators for more extensive and long-term studies to investigate the true effectiveness of eye exercise in the management of myopia.

Conclusion

The study revealed that the high-quality eye exercise group exhibited superior performance in terms of monocular/binocular AF and CISS scores when compared to the low-quality group. This indicates that eye exercises may offer a certain level of relief for myopia symptoms in Chinese urban children aged 7 to 11 years. However, in relation to SER and UCVA, no significant differences were observed between the high-quality and low-quality eye exercise groups. Overall, while eye exercises contribute to enhancing accommodative ability and alleviating visual fatigue in the management of childhood myopia, they did not effectively reduce the degree of myopia in children.

Institutional Review Board Statement

This study adhered to ethical principles, regulations, and the Helsinki Declaration, with approval (Approval number 2022-117-K-89-01) from the Ethics Committee of the Ophthalmology Hospital at Wenzhou Medical University. Written informed consent for participation was obtained from the children's parents/guardians.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Informed Consent Statement

Written informed consent was obtained from the children's parents/guardians.

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Author Contributions

All authors have made substantial contributions to the work reported, either in conception, study design, execution, acquisition of data, analysis and interpretation, or all of these areas; participated in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article will be submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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