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• Original Article •

Refractive shifts induced by cycloplegia and their correlation with visual fatigue scores in patients with asthenopia

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HIGHLIGHTS

• Previous studies have demonstrated that cycloplegic refraction allows for more precise refractive assessments of refractive errors. However, its clinical significance for adults suffering from asthenopia has not been thoroughly investigated.

• This study enhances our current understanding by examining the refractive differences between cycloplegic and non-cycloplegic measurements in adults with asthenopia, uncovering a notable correlation between the severity of visual fatigue and refractive discrepancies.

• These findings offer evidence that underscores the clinical importance of cycloplegic refraction in managing adult asthenopia, highlighting its crucial role in ensuring accurate refractive evaluations.

Abstract: **Objective**: Asthenopia, also known as visual fatigue, is common condition among individuals who engage in prolonged near-vision tasks, with global prevalence rate of 40% to 70%. Cycloplegic refraction, which eliminates the interference of accommodation, is essential for accurate refractive assessments. However, its roles in adults with asthenopia remains underexplored. This study aimed to evaluate refractive shifts induced by cycloplegia and their association with the severity of visual fatigue. **Methods**: This cross-sectional study recruited 53 adults aged 18–40 years who were clinically diagnosed with asthenopia at Zhongshan Ophthalmic Center, Sun Yat-sen University.

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Full Text

Participants underwent both cycloplegic and non-cycloplegic subjective refraction assessments. Visual fatigue was evaluated using the Convergence Insufficiency Symptom Survey (CISS). We analyzed refractive differences in spherical equivalent (SE), spherical, and cylindrical components and evaluated their associations with fatigue scores and accommodative parameters using Spearman correlation analysis. **Results**: Non-cycloplegic measurements showed significantly more myopic values than cycloplegic measurements in terms of SE and spherical values ($P< 0.05$), while no significant differences were observed in cylinder values. Fatigue scores were positively correlated with differences in SE (r=0.35, P=0.01) and differences in spherical differences (r=0.34, P= 0.01), but not with cylindrical differences in cylindrical values. Bland-Altman analysis confirmed good agreement between cycloplegic and non-cycloplegic measurements, revealing minor hyperopic shifts induced by cycloplegia. **Conclusions**: Cycloplegic refraction provides more accurate refractive assessments in adults with asthenopia by effectively reducing accommodative interference. Higher fatigue scores are associated with larger refractive shifts following cycloplegia, highlighting the importance of incorporating fatigue evaluations into clinical refractive assessments.

Keywords: asthenopia; cycloplegic refraction; adult; refractive shifts

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INTRODUCTION

Asthenopia, commonly known as visual fatigue, affects 40% to 70% of the global population and is manifested by symptoms such as blurred vision, eye strain, headaches, and diplopia.[1–4] Its prevalence has significantly increased due to the widespread use of digital screens, particularly among office workers and university students, thereby substantially affecting work productivity and quality of life.[5–7]

Refractive error is closely associated with asthenopia. Hyperopic individuals are particularly vulnerable due to higher accommodative demands, while myopic individuals may experience symptoms related to accommodative lag, the method of refractive correction, or inappropriate corrective prescriptions.[7–10] Under-correction or over-correction of refractive errors can intensify visual discomfort and compromise the accuracy of refractive evaluations.[11-12]

Subjective refraction (SR) is notably affected by the individual's accommodative status, which may lead to measurement inaccuracies in individuals with asthenopia.[13] Cycloplegic refraction (CR) is considered the gold standard method for eliminating accommodative interference and is particularly advantageous for populations with high accommodative demands, including hyperopes, adolescents, and those frequently engaged in prolonged near tasks.[14-15] The difference in refractive error before and after cycloplegia, known as hyperopic shift, reflects latent accommodative tone. Studies involving pediatric and adolescent populations have reported a hyperopic shift of approximately 0.50D to 1.00D following cycloplegia, with more pronounced shifts observed in individuals with hyperopic and low myopic.[10,15-16] Refractive error, axial length, and accommodative function have been identified as primary factors influencing the magnitude of hyperopic shift.[9,17]

Despite its well-established role in pediatric and adolescent populations, the use of CR in adults—particularly those with asthenopia—remains a subject of ongoing debate. Some studies support its use, highlighting its ability to provide a more accurate assessment of refractive error by eliminating accommodative influences.[16-17] Conversely, other research raises concerns about its limited utility in adults, especially those with lower accommodative demands or reduced accommodative power.[18] Furthermore, the relatively small hyperopic shifts observed in adults compared to younger populations have led to questions regarding the clinical significance of CR in this group. These conflicting viewpoints underscore the need for further investigation into the role of CR in adults with asthenopia, particularly to determine its potential to enhance diagnostic accuracy and optimize refractive correction.

This study aims to investigate the changes in subjective refraction induced by cycloplegia in adults with asthenopia, identify associated influencing factors, and assess the correlation between these refractive shift and visual fatigue severity scores. The findings will provide clinical insights to optimize refraction strategies and personalized refractive correction, thereby improving patient management outcomes.

METHODS

Participants

This cross-sectional study was carried out at Zhongshan Ophthalmic Center, Sun Yat-sen University, spanning from January 2023 to January 2025. We recruited patients aged between 18 to 40 years who visited to the ophthalmology outpatient clinic with a primary complaint of asthenopia. Asthenopia was characterized by the presence of at least one of the following symptoms during near-vision tasks: dry eye, ocular pain, diplopia, eyelid swelling, a sensation of a foreign body in the eye, blurred vision, difficulty maintaining focus, reduced visual acuity, photophobia, and excessive tearing. We excluded individuals with systemic diseases such as dry eye, thyroid disorders, hypertension, diabetes, osteoporosis, arthritis, chronic headaches or migraines, as well as those with ocular conditions including retinal nerve defects, amblyopia, anisometropia, cataracts, conjunctivitis, or glaucoma. This study complied with the principles outlined in the Declaration of Helsinki. Approval was obtained from the Institutional Review Board of Zhongshan Ophthalmic Center, Sun Yat-sen University (2025KYPJ134). Written informed consent was obtained from all patients prior to participation. Before the study commenced, patients were provided with detailed written instructions on the use of cycloplegia medications.

We collected information on health status (including ocular and medical history), environmental factors (such as physical activities and reading habits), and sociodemographic characteristics (age and sex) using a structured consent form. For the purpose of analysis, age was divided into two groups: 18-25 years and 26-40 years.

Examinations

The following procedures were conducted at Zhongshan Ophthalmic Center, Sun Yat-sen University by experienced optometrists and ophthalmologists.

Refraction measurement: Subjective refraction was evaluated separately before and after cycloplegia using a phoropter. An ophthalmologist performed a slit-lamp examination to screen participants for the risk of angle-closure glaucoma. Cycloplegic medication was administered only after confirming the absence of risk for mydriasis. All participants underwent cycloplegic subjective refraction in both eyes using a phoropter, following the instillation of 1% tropicamide eye drops three times at 10-minute intervals. Refractive error was quantified using spherical equivalent (SE), which is defined as the spherical power plus half of the cylindrical power. Refractive differences were calculated by subtracting non-cycloplegic values from cycloplegic values for SE and cylinder. A positive SE difference indicated a more myopic measurement under non-cycloplegic conditions, while a negative cylindrical difference suggested increased astigmatism in non-cycloplegic refraction.

Refractive errors were classified based on the cycloplegic refraction measurements obtained with a phoropter. Myopia was defined as SE ≤ -0.50 D and was categorized into mild (-0.50 to -2.99 D), moderate (-3.00 to -5.99 D), and high (≥ -6.00 D).

Hyperopia was similarly defined as SE ≥ +0.50 D and was classified as mild (+0.50 to +1.99 D), moderate (+2.00 to +4.99 D), and high (≥+5.00 D). Astigmatism, defined as cylinder power ≥ 1.00 D, was categorized as low (1.00 to 2.99 D) or high (≥ 3.00 D). Emmetropia was defined as SE ranging from −0.5 D to +0.5 D.

Best corrected visual acuities (BCVA): Monocular BCVA was assessed at a distance of 6 meters using the Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity chart under non-cycloplegic condition.

Phoria measurement: The magnitude of both near and distance phoria was measured using the alternate cover test combined with a prism bar, and the results were recorded in prism diopters (PD). For analytical purpose, the angle of phoria was categorized into two groups: ≤10 PD and >10 PD.

Amplitude of accommodation (AA): AA was measured monocularly by gradually moving a 20/30 target closer until sustained blur was reported. The amplitude, expressed in diopters (D), was calculated as 100 divided by the distance in centimeters (D). AA was classified into three groups: <5 D, 5-10 D, and >10 D.

Accommodative facility (AF): AF was measured at 40 cm by counting the number of complete cycles per minute (cpm) of clear vision through ±2.00D flipping lenses while the participant viewed a 20/30 target. For analysis, AF was categorized into two groups for analysis: ≤7 cpm and >7 cpm.

Accommodative convergence/ accommodation (AC/A) ratio: The AC/A ratio was calculated by measuring phoria at 40 cm under habitual viewing conditions and again after introducing lenses of −1.00D or −2.00D. The AC/A ratio was determined as the change in phoria (PD) divided by the change in accommodation (PD). The AC/A ratio results were grouped into three categories: <3, 3-5, and >5.

Asthenopia questionnaires

The Convergence Insufficiency Symptom Survey (CISS) questionnaire comprises 15 items aimed at evaluating visual discomfort and fatigue associated with reading and near- work activities.[17,19] Each item was rated on a five-point Likert scale ranging from 0 ("never") to 4 ("always"). Scores below 16 suggest mild asthenopia, scores from 16 to 28 represent moderate asthenopia, and scores exceeding 28 are classified as severe asthenopia, reflecting a significant degree of visual discomfort and functional impairment. The complete questionnaire is presented in Supplementary data.

Statistical analysis

The normality of the data was evaluated using the Shapiro–Wilk test. Continuous variables were presented as means ± SD or median (interquartile range, IQR) depending on their normality. Categorical variables were summarized using frequencies and percentages. Paired *t*-tests were performed to compare differences in SE and cylinder values before and after cycloplegia across different demographics, accommodative parameters, and refractive groups. One-way ANOVA was applied to assess differences among multiple groups. Spearman correlation analysis was employed to explore relationships between refractive differences and related parameters. Given the high interocular correlation (≥90%) within the same individual, only data from the right eye data were included in the analysis. Statistical significance was set at $P<0.05$ (two-sided).

RESULTS

Study population and general characteristics

This study recruited 53 adults with asthenopia (mean age: 26.04 ± 5.70 years), of whom 29 (54.7%) were male. Among participants, 44 (83.02%) had severe asthenopia, and 8 (15.09%) had moderate asthenopia (Table 1). The study population mainly consisted of myopic patients, with moderate myopia being the most common (39.6%), followed by mild myopia (24.5%) and high myopia (17.0%). A substantial proportion of participants exhibited accommodative anomalies, including reduced AA (<5D, 9.4%; 5-10 D, 35.8%), diminished AF (≤7 cpm, 84.9%), and abnormal AC/A ratios (<3, 41.5%; >5, 22.6%). Furthermore, 52.8% of participants had near phoria angles exceeding 10 PD, while distance phoria

Table 1 Demographic and based visual information

Varibles	Values
Age, years (Mean±SD)	26.04 ± 5.70
Sex, *n* (%)	
Female	24(45.3)
Male	29(54.7)
BCVA, LogMAR (Mean±SD)	
Right eye	0.03 ± 0.08
Fatigue score, *n* (%)	
Mild (<16 points)	1(1.89)
Moderate (16 to 28 points)	8(15.09)
High (>28 points)	44(83.02)
Accommodation amplitude of right eye (D), Mean±SD	10.54 ± 3.94
Accommodative facility of right eye (cpm), Mean±SD	2.25 ± 4.05
AC/A, Mean±SD	3.88 ± 2.88
Angle of phoria at near (PD), Median (IQR)	−11.7 (9.50)
Angle of phoria at distance (PD), Median (IQR)	−5.68 (8.07)

was predominantly ≤10 PD. (Table 2)

Comparison of cycloplegic and noncycloplegic refraction

Before cycloplegia, the mean spherical, cylindrical, and SE values were −3.19 ± 2.68 D, −0.65 ± 0.70 D, and −3.51 ± 2.78 D, respectively. After cycloplegia, these values changed to −2.98 ± 2.66 D, −0.73 ± 0.69 D, and −3.34 ± 2.77 D, respectively. Significant differences were found between non-cycloplegic and cycloplegic measurements for SE (P=0.03) and sphere (P=0.01) (Figure 1), whereas the differences for cylinder was not statistically significant. Figure 2 illustrates the agreement between cycloplegic and non-cycloplegic refraction measurements for all participants. The Bland–Altman plot showed mean differences of −0.21 ± 0.59 D for sphere (95% limits of agreement [LOA]: −1.27 to 0.94 D), 0.08 ± 0.20 D for cylinder (95% LOA: −0.31 to 0.47 D), and −0.17 ± 0.57 D for

Table 2 Factors influencing SE difference between noncycloplegic and cycloplegic refraction in the right eye

Influencing factors	Total	SE，D (Mean ± SD)			Cylinder, D (Mean ± SD)		
	n (%)	Noncycloplegic	Cycloplegic	*P*	Noncycloplegic	Cycloplegic	*P*
Overall	53(100)	−3.51 ± 2.78	−3.34 ± 2.77	0.03	−0.65 ± 0.70	−0.73 ± 0.69	0.05
Age group							
18 to 25 years	26(49.1)	−3.97 ± 3.21	−3.88 ± 3.14	0.83	−0.69 ± 0.78	−0.83 ± 0.78	0.39
26 to 40 years	27(50.9)	−3.07 ± 2.26	−2.81 ± 2.3	0.63	−0.60 ± 0.63	−0.63 ± 0.59	0.82
Sex							
Female	24(45.3)	−3.51 ± 2.48	−3.31 ± 2.43	0.66	−0.73 ± 0.75	−0.79 ± 0.71	0.68
Male	29(54.7)	−3.51 ± 3.15	−3.38 ± 3.19	0.81	−0.54 ± 0.64	−0.65 ± 0.68	0.51
Cycloplegic SE refraction of right eye							
High myopia	9(17)	−7.60 ± 1.78	−7.53 ± 1.75	0.76	−1.08 ± 1.05	−1.22 ± 1.09	0.65
Moderate myopia	21(39.6)	−4.53 ± 1.23	−4.35 ± 0.75	0.27	−0.57 ± 0.47	−0.68 ± 0.45	0.44
Mild myopia	13(24.5)	−1.71 ± 0.87	−1.65 ± 0.76	0.9	−0.77 ± 0.81	−0.73 ± 0.79	0.79
Emmetropia	6(11.3)	−0.23 ± 0.28	−0.02 ± 0.23	0.32	−0.12 ± 0.21	−0.38 ± 0.21	0.08
Mild hyperopia	4(7.5)	0.28 ± 0.26	0.94 ± 0.22	0.03	−0.44 ± 0.43	−0.38 ± 0.32	1
Accommodation amplitude of right eye							
<5 D	5(9.4)	−2.25 ± 2.18	−2.00 ± 1.94	0.92	−0.80 ± 0.99	−0.9 ± 0.96	0.83
5 to 10 D	19(35.8)	−2.87 ± 2.95	−2.65 ± 3.02	0.54	−0.58 ± 0.82	−0.64 ± 0.78	0.48
>10 D	29(54.7)	−4.15 ± 2.66	−4.02 ± 2.59	0.83	−0.66 ± 0.58	−0.75 ± 0.60	0.67
Accommodative facility of right eye							
≤7 cpm	45(84.9)	−3.38 ± 2.47	−3.18 ± 2.47	0.68	−0.62 ± 0.61	−0.72 ± 0.59	0.39
>7 cpm	8(15.1)	−4.23 ± 4.27	−4.22 ± 4.19	0.75	−0.78 ± 1.15	−0.75 ± 1.17	0.87
AC/A							
<3	22(41.5)	−3.11 ± 2.99	−2.80 ± 3.08	0.56	−0.73 ± 0.84	−0.77 ± 0.80	0.76
3 to 5	19(35.8)	−4.20 ± 2.75	−4.22 ± 2.58	1	−0.55 ± 0.5	−0.66 ± 0.58	0.66
>5	12(22.6)	−3.16 ± 2.41	−2.94 ± 2.25	0.75	−0.65 ± 0.75	−0.75 ± 0.70	0.60
Angle of phoria at near							
≤10 PD	25(47.2)	−3.37 ± 2.62	−3.23 ± 2.55	0.7	−0.65 ± 0.63	−0.75 ± 0.66	0.61
>10 PD	28(52.8)	−3.64 ± 2.96	−3.43 ± 2.99	0.77	−0.64 ± 0.77	−0.71 ± 0.73	0.59
Angle of phoria at distance							
≤10 PD	42(79.2)	−3.54 ± 2.7	−3.4 ± 2.64	0.7	−0.61 ± 0.63	−0.71 ± 0.63	0.39
>10 PD	11(20.8)	−3.4 ± 3.22	−3.1 ± 3.34	0.67	−0.8 ± 0.95	−0.8 ± 0.93	0.97

SE (95% LOA: −1.28 to 0.94 D), all of which were distinct from zero.

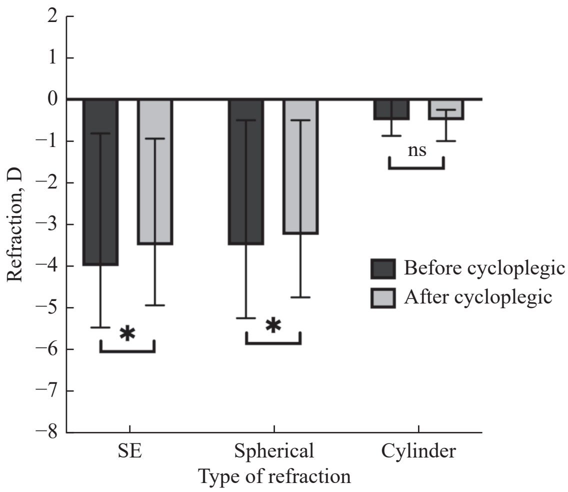

Figure 1 Refraction errors before and after cycloplegic in adult patients with asthenopia

Factors associated with significant differences by cycloplegia

The differences between cycloplegic and non-cycloplegic refractive measurements, stratified by age, sex, cycloplegic SE, AA, AF, AC/A ratio, and phoria angle, are summarized in Table 2. Non-cycloplegic measurements generally exhibited a more myopic (less positive) trend compared with cycloplegic refraction across all analyzed subgroups. A significant refractive difference between cycloplegic and non-cycloplegic measurements was observed exclusively only in patients with mild hyperopia (P=0.03), indicating a higher susceptibility to accommodative-induced myopic shifts under non-cycloplegic conditions. However, no significant refractive differences were detected among individuals with moderate to high myopia or emmetropia (*all* P>0.05). Moreover, these differences did not reach statistical significance with respect to demographic factors or accommodative parameters.

Fatigue scores were positively correlated with difference in SE (r_s=0.35, P=0.01). Similarly, a statistically significant positive correlation was observed between fatigue scores and the difference in spherical values (r_s=0.34, P=0.01). No significant correlation was found between fatigue scores and the cylindrical difference (r_s=0.01, P=0.93) (Figure 3).

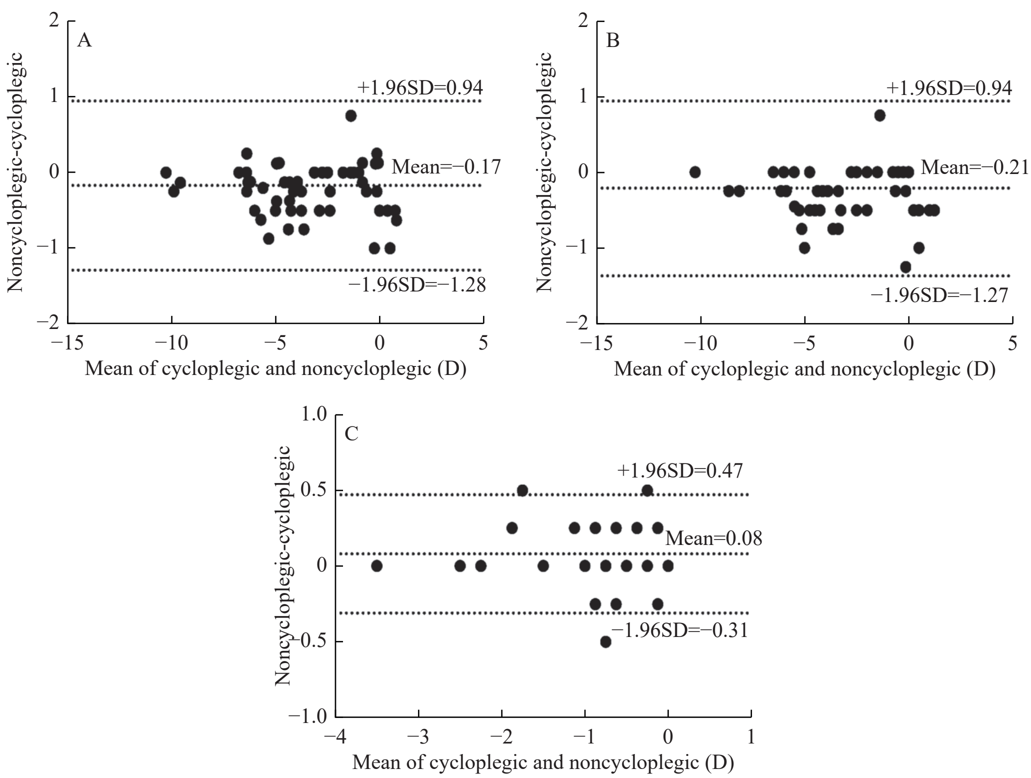

Figure 2 Comparison of cycloplegic and noncycloplegic measurements of spherical equivalent (A), sphere (B), and cylindrical values (C)

DISCUSSION

This study is the first to investigate cycloplegia-induced refractive changes in adults with asthenopia and their relationship with visual fatigue. The cycloplegic measurements of SE and spherical power were more accurate, demonstrating a mild hyperopic shift. Visual fatigue scores showed a positively correlation with SE and spherical differences, indicating that the severity of fatigue influences refractive outcomes, particularly spherical power.

In this study, most patients with asthenopia had myopia, with moderate myopia being the most common. This suggests a potential link between myopic refractive errors and visual fatigue.[7–10] Moreover, accommodative dysfunction—including reduced AA, AF, and abnormal AC/A ratios — was widespread among participants, highlighting the critical role accommodative anomalies might play in asthenopia.[9,20]

In adult patients with visual fatigue, cycloplegic refraction exhibited a hyperopic shift, which is consistent with previous findings in children and adolescents.[15-16] This phenomenon is often attributed to the relaxation of the ciliary muscle under cycloplegia, which reveals latent hyperopia that was previously compensated for by accommodation.[10,18,21] Cycloplegic agents, such as atropine, temporarily inhibit accommodation, enabling a more precise assessment of the true refractive status.[22] However, compared to children and adolescents, adults generally have reduced accommodative power, resulting in smaller hyperopic shifts.[9,20] This distinction has led to less emphasis on cycloplegic refraction in adults; yet, our findings underscore its critical importance in adults with visual fatigue. Given the prevalence of accommodative anomalies in adults with visual fatigue, cycloplegic assessment is necessary to

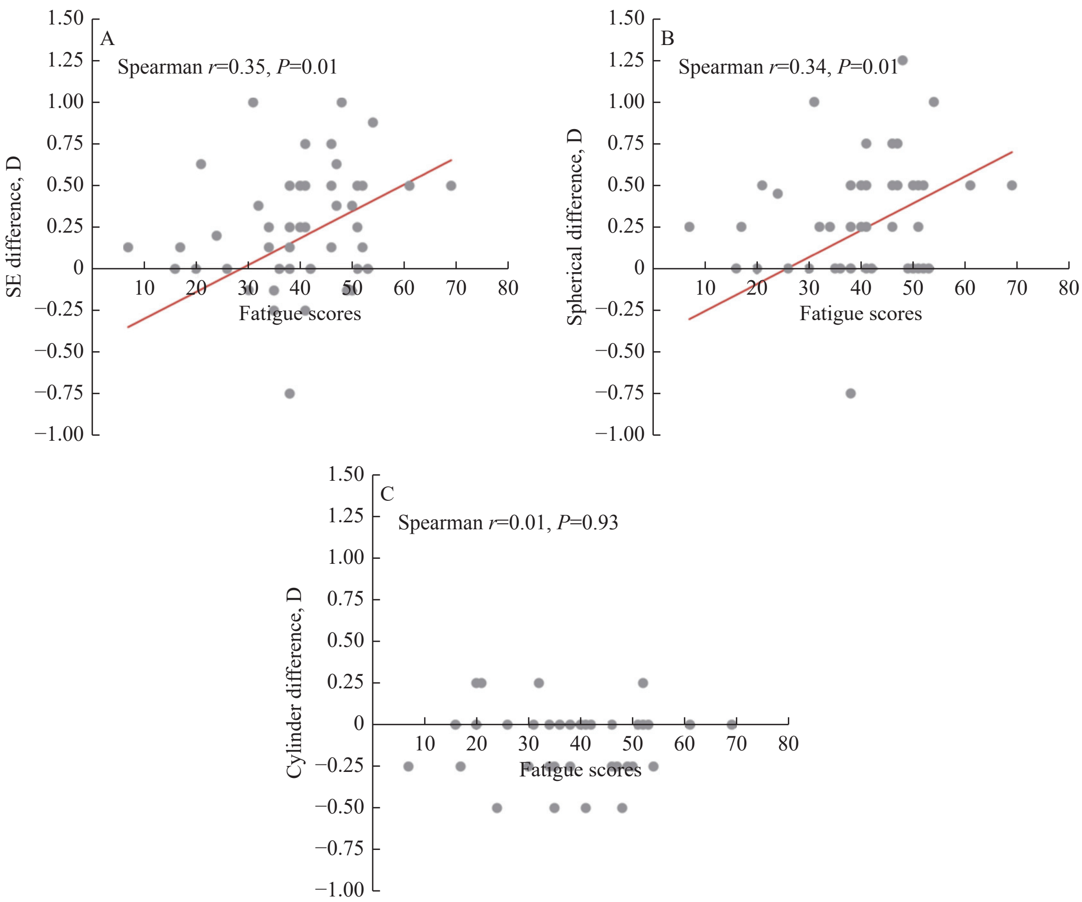

Figure 3 Spearman correlation between visual fatigue scores and differences in cycloplegic and noncycloplegic measurements of spherical equivalent (A), sphere (B), and cylindrical values (C)

improve diagnostic accuracy and optimize refractive correction.

Significant refractive discrepancies between cycloplegic and non-cycloplegic measurements were mainly observed in patients with mild hyperopia, indicating an increased susceptibility to accommodative-induced myopic shifts under non-cycloplegic conditions. In contrast, no significant associations were found with age, sex, AA, AF, AC/A ratio, or phoria angles. This is likely because the high prevalence of accommodative anomalies in this cohort minimized inter-individual variability and limited statistical detectability. Sample size limitations and compensatory accommodative mechanisms may have further influenced these results. Although statistical significance was not achieved, the consistent trend of non-cycloplegic refraction being more myopic than cycloplegic refraction underscores the impact of accommodation on refractive assessments. Further studies with larger sample sizes and objective accommodative measurements are needed to validate these findings and clarify their clinical implications.

This study revealed a significant correlation between visual fatigue scores and changes in SE and spherical power, but no such association was found with cylindrical power. This discrepancy may be due to the differential impacts of accommodation on spherical and cylindrical components. Accommodative lag primarily influences spherical refraction as it affects the ciliary muscle's ability to adjust the focal length for near vision, leading to spherical shifts. In contrast, cylindrical refractive errors are more closely related to structural factors, such as corneal curvature and internal astigmatism, which are less sensitive to accommodative changes.[23] This difference in how accommodation affects refractive components may explain why fatigue scores correlate with spherical power changes but not with cylindrical power. Notably, individuals with higher visual fatigue scores exhibited greater discrepancies in SE and spherical power before and after cycloplegia, suggesting a connection between accommodative anomalies and asthenopia symptoms. These findings are in line with previous reports indicating that accommodative lag, which is frequently observed in patients with asthenopia, may result in non-cycloplegic refraction skewed toward myopia.[24-25]

These findings emphasize the importance of cycloplegic refraction in accurately assessing refractive errors in patients with visual fatigue, particularly in severe cases. By eliminating accommodative interference, cycloplegia reduces the risk of mis-correction and enhances visual comfort.[7,15] Visual fatigue scores may serve as indicators of refractive instability, suggesting the need for cycloplegic assessment in patients with high fatigue levels. Additionally, the link between accommodative lag and asthenopia symptoms suggests that interventions such as vision therapy or optimized optical correction may help alleviate fatigue and improve accommodative function.

This study has several limitations. The small sample size (53 participants) may limit generalizability of the results, and the cross-sectional design prevents causal inferences from being made between visual fatigue and refractive changes. Moreover, unaccounted factors such as dry eye, near-work duration, and lighting conditions may influence both outcomes. Future research should include larger, more diverse cohorts and longitudinal designs to evaluate the long-term impact of cycloplegia on refractive progression and visual fatigue.

CONCLUSION

This study revealed significant differences between cycloplegic and non-cycloplegic refraction in adults with visual fatigue, which are closely related to fatigue severity. Cycloplegic refraction is crucial for accurate assessment in asthenopia, highlighting the need to integrate fatigue evaluation into clinical refractive analysis.

Correction notice

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Authors contribution

(Ⅰ) Conception and design: Yan Yang, Jing Lin

(Ⅱ) Administrative support: Yan Yang

(Ⅲ) Provision of study materials or patients: Xinping Yu
(Ⅳ) Collection and assembly of data: Jing Lin
(Ⅴ) Data analysis and interpretation: Yan Yang, Xinping Yu, Jing Lin
(Ⅵ) Manuscript writing: All authors
(Ⅶ) Final approval of manuscript: All authors

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Conflict of interests

None of the authors has any conflicts of interest to disclose. All authors have declared in the completed the ICMJE uniform disclosure form.

Patient consent for publication

Written informed consent was obtained from all participants.

Ethical statement

This study adhered to the principles of the Helsinki declaration. Ethics' committee approval was obtained from the Institutional Review Board of Zhongshan Ophthalmic Center (2025KYPJ134).

Provenance and peer review

This article was standard submission to our journal. The article has undergone peer review with our anonymous review system.

Data sharing statement

None

Suppplementary data

Please visit https://journal.gzzoc.org.cn/article/5898 for detailed information.

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