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# Accommodative and binocular characteristics in myopes with age-related accommodation deficiency

Ruiyu Zhang[1,2], Yifei Yuan[1,2], Yu Zhang[1,2] and Yueguo Chen[1,2*]

## Abstract

**Background** To investigate accommodative and binocular characteristics in myopic patients with age-related accommodation deficiency, and to investigate the relationship of accommodation amplitude (AA) with other accommodative and binocular parameters.

**Methods** Myopic patients between 40 and 50 years old to undergo refractive surgery were enrolled. Accommodative function, including AA, positive and negative relative accommodation (PRA and NRA), accommodative response (binocular cross cylinder, BCC), and binocular accommodative facility (BAF) were examined. Binocular vision measurements including simultaneous perception, fusional vergence, and stereovision assessed with a synoptophore. Near point of convergence (NPC) and the gradient accommodative convergence/accommodation (AC/A) ratio were also measured. A questionnaire was used to assess subjective visual discomfort experienced after prolonged near work.

**Results** A total of 145 subjects were evaluated, with a mean age of 42.59 ± 2.89 (SD) years. In the full data set, 96(66.21%) of patients had PRA (>-1.50 D), 21(14.48%) of patients had NRA (< 1.50 D), and 113(77.93%) of patients had BCC (< 0.25 D). Out of 97 patients, 17(17.53%) had AC/A (< 2), 54(55.67%) had NPC (> 7.5 cm), 51(52.58%) had BAF (< 5 cpm). As for the simultaneous perception, 59(60.82%) had values greater than 0 prism dioptres. Adjusting for associated factors, participants with lower AA were more likely to be older (odds ratio [OR], 2.080; 95% confidence interval [CI], 1.523–2.841) and with milder myopia (OR, 1.280; 95% CI, 1.029–1.594). Lower BAF (OR, 4.990; 95% CI, 1.731–14.386) was more likely to be found in individuals with lower AA. The three most commonly reported visual discomforts were eye strain or soreness, ocular pain or headache, and blurred text.

**Conclusion** For myopes at the early stage of presbyopia, the continuous tension in the vergence system was also worthy of our attention, in addition to the well-known AA insufficiency. Comprehensive assessment of the binocular status and appropriate management is recommended before and after corneal refractive surgery.

**Keywords** Accommodative function, Binocular vision, Age-related accommodation deficiency, Refractive surgery, Monovision

*Correspondence:
Yueguo Chen
chenyueguo@263.net
[1]Department of Ophthalmology, Peking University Third Hospital, No 49 Huayuan North Road, Haidian District, Beijing 100191, China
[2]Beijing key laboratory of restoration of damaged ocular nerve, Peking University Institute of Laser Medicine, Beijing, China

## Background

Presbyopia, which usually occurs in people aged 40 or older, is well-recognized with varying degrees of age-related accommodation deficiency [1, 2]. As elderly persons are becoming more active and request high visual requirements, especially those in the early stage of presbyopia with a high "prosperity" of social work" and family life, demands for surgical refractive correction are increasing [3]. For those with the lens, still relatively clear and accommodative function partially exists, corneal refractive surgery with monovision or optimized monocular vision protocol, where the dominant eye is corrected to emmetropia for distance vision, whereas the non-dominant eye retains a certain degree of spherical diopter for intermediate or near vision, continues to be the regular and effective methods.

However, refractive surgery is a procedure that can suddenly break the balanced state of binocular vision [4–6]. Elderly patients with age-related reduced binocular function may have a high risk of having accommodative and binocular dysfunctions after the sudden change in refractive status, not to mention unbalanced monovision correction with a certain degree of anisometropia introduced. Besides, if an underlying binocular vision anomaly exists, the pre-existing anomalies may easily decompensate and become strabismic, resulting in loss of binocular function and stereopsis, or become symptomatic, causing numerous vision-related symptoms during near and distance visual activities and impairing quality of life by interfering with daily visual activities [7–9]. Consequently, in presbyopes to undergo refractive surgery, it would be critical to have a full pre-operative assessment of the binocular vision status but less attention has been paid to this aspect.

The objective of this study was to obtain a comprehensive understanding of accommodative and binocular function in middle-aged patients scheduled for monovision refractive surgery and to further investigate the relationship of different parameters with accommodation amplitude (AA).

## Methods and patients

In this prospective study, from November 2022 to March 2024, patients aged over 40 years who were to undergo refractive surgery at Peking University Third Hospital were recruited. The study was conducted in agreement with the ethical standards and the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Peking University Third Hospital (M2023402). All participants were thoroughly informed before written consent was obtained.

Patients were included in the study if they were between 40 and 50 years of age and had elected to undergo refractive surgery for myopic astigmatism with age-related accommodation deficiency. Patients with a history of refractive or corneal surgery, any ecstatic condition of the cornea, anisometropia > 1.50 D, or visually significant cataracts were excluded.

### Visual assessment and accommodative and binocular examinations

All patients underwent routine preoperative examinations, including uncorrected and corrected distance visual acuities (UDVA, CDVA) evaluated with a logMAR visual chart, manifest and cycloplegic refraction, non-contact intraocular pressure (NIDEK Co., Ltd), slit-lamp evaluation, and dilated fundus examination. The necessary addition (NA) for reading Parinaud 2 at 40 cm was obtained using the "minimal addition" method [10].

Accommodative function was assessed by measuring AA with the "minus lens method" [11], positive and negative relative accommodation (PRA and NRA), accommodative response (BCC, ± 0.50 D binocular cross cylinder) [12], and the binocular accommodative facility (BAF) with a ± 2.00 D diagnostic flipper set at a distance of 40 cm [11]. All tests were performed binocularly according to their standard protocols with full near correction (distance correction with NA added to the trial frame) [13]. For analysis, the actual AA and relative accommodations were calculated by subtracting NA added before testing [13]. Recording of BAF was done in cycles per minute (CPM), and each instance of clearing both the plus and minus lenses was counted as one cycle. Near point of convergence (NPC) was measured with full near correction by moving the accommodative target (a vertical line target) closer to the eye until the patient reported diplopia or the examiner observed a fusion break [11]. Examination of the gradient accommodative convergence/ accommodation (AC/A) ratio was also included.

Binocular vision evaluation including simultaneous perception, fusional vergence, and stereovision assessed for distance fixation using synoptophore (TSJ-IV-A; Photoelectric Instrument Co., Ltd. Changchun, China) with distance correction. The amplitudes of convergence and divergence were calculated as the difference between breakpoints minus the points of simultaneous perception [14]. Stereoacuity at distance was determined using a synoptophore, and at near (40 cm) was measured with Yan's stereoscopic test [15]. The results of stereoacuity were classified as follows: stereoacuity greater than or equal to 60 s of arc (central stereopsis); stereoacuity ranged between 80 and 200 s of arc (macular stereopsis); stereoacuity ranged between 300 and 800 s of arc (peripheral stereopsis); and stereoacuity above 800 s of arc (stereo blindness) [16].

Parameters of AA, relative accommodation, BCC, NPC, and AC/A ratio were determined by three well-trained, nationally certified examiners. All examiners

followed a standardized training protocol to ensure consistency in measurement procedures. Additionally, all measurements were conducted under standardized conditions, using identical tools, calibrated equipment, and controlled environmental settings, including consistent lighting. Other orthoptic measurements were performed by a single examiner who had received professional training. Each variable was measured three times, and the mean value was used for analysis.

In addition, a self-developed questionnaire was used to assess subjective visual discomfort experienced after prolonged near work, such as reading or using a computer.

### Statistical analysis

Statistical analysis was performed by SPSS Statistics for Windows (version 22.0., IBM Corp.). The normality of data was assessed by histogram frequency analysis and the Shapiro-Wilks test. Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables were expressed as number (percentage).

The accommodative and binocular parameters were all measured under binocular vision status, and subgroups were divided according to norms derived from the literature of the normal population [17, 18]. To address intereye correlation, we used the mean value of measurements from both eyes in the statistical analysis.

Univariate and multivariate binary logistic regression were used to evaluate the relationship of AA (AA < 4.00 D, AA > = 4.00 D) with demographics, and with other accommodative and binocular parameters separately. As AA and PRA in this study can be considered equivalent, grouping was conducted according to the value of PRA (PRA<=-1.50 D, PRA>-1.50 D).

Only patients with complete binocular vision examination data were included in the logistic regression analysis. A P value less than 0.05 was considered statistically significant.

**Table 1** Accommodative function ($n = 145$)

| Parameters | Mean ± SD/ number | Min | Max | Normative value | *P* |
|---|---|---|---|---|---|
| AA (D) | 3.65 ± 0.98 | 2.50 | 6.50 | | |
| PRA (D) | -1.15 ± 0.98 | 0 | -3.75 | -2.37 ± 1.00 | < 0.001 |
| ≤-2.50 | 21 | | | | |
| ≤-1.50 to >-2.50 | 28 | | | | |
| >-1.50 | 96 | | | | |
| NRA (D) | 1.99 ± 0.56 | 0.75 | 3.50 | 2.00 ± 0.50 | 0.825 |
| < 1.50 | 21 | | | | |
| ≥ 1.50 to ≤ 2.50 | 102 | | | | |
| > 2.50 | 22 | | | | |
| BCC (D) | 0.03 ± 0.31 | -0.75 | 1.50 | 0.25 to 0.75 | |
| < 0.25 | 113 | | | | |
| ≥ 0.25 to ≤ 0.75 | 28 | | | | |
| > 0.75 | 4 | | | | |

AA: accommodation amplitude; BCC: binocular cross cylinder; D: dioptre; NRA: negative relative accommodation; PRA: positive relative accommodation; SD: standard deviation

The p-value was calculated by one sample t-test

* statistically significant

## Results

A total of 145 participants met the eligibility criteria and were included in the study. All the participants underwent accommodation examinations, 97 individuals completed other binocular examinations, and 72 individuals completed the questionnaire.

The mean age of the 94 women (65%) and 51 men (35%) was 42.59 ± 2.89 (SD) years (range 40 to 50 years), and the mean addition for binocular near vision was 0.56 ± 0.53 D (range 0 to 2.50 D). The average spherical and cylindrical errors were – 5.32 ± 2.03 D (range – 1.00 to -11.63 D) and – 0.73 ± 0.63 D (range 0 to -3.75 D), respectively.

Tables 1 and 2 display mean values and ranges of accommodative and binocular parameters in the study participants, as well as the number of people in the corresponding intervals. Norms of Scheiman and Wick's [17] and Lewis's [18] for the various measurements are also presented in tables. In the full data set of 145 patients, 96(66.21%) of patients had PRA (>-1.50 D), 21(14.48%) of patients had NRA (< 1.50 D), and 113(77.93%) of patients had BCC (< 0.25 D). Out of 97 patients, 17(17.53%) had AC/A (< 2), and 54(55.67%) had NPC (> 7.5 cm). There were 51(52.58%) patients who had BAF (< 5 CPM), and the value was denoted as 0 in 30(30.93%) patients who failed for either the plus or minus lenses. As for the simultaneous perception measured using synoptophore, 78(80.41%) of patients had values greater than – 0.5 prism dioptres, and 59(60.82%) had values greater than 0 prism dioptres. All patients showed stereoacuity on the Titmus stereo test.

Correlation analyses were conducted to investigate the association between AA and demographics and refractive error, as well as AA and other accommodative and binocular parameters. A logistic regression model to analyze the factors associated with AA lower than 4.00D is demonstrated in Tables 3 and 4. Results of univariate analysis showed that AA significantly varied by age ($p < 0.001$). In the multivariate logistic regression analysis, spherical refractive error, as well as cylinder refractive error were removed from the model due to its high correlation with mean SE. Adjusting for age, gender, refractive error, scotopic pupil diameter, and visual acuity with glasses, individuals with older age (OR, 2.080; 95% CI, 1.523–2.841) and milder myopia (OR, 1.280; 95% CI, 1.029–1.594) were more likely to have lower AA.

As demonstrated in Table 4, for accommodative and binocular function, univariate analysis showed that BAF

**Table 2** Binocular function ($n=97$)

| Parameters | Mean ± SD/ Number | Min | Max | Normative value | *P* |
|---|---|---|---|---|---|
| AC/A | 3.08 ± 1.46 | 0.33 | 10.00 | 4 ± 2 | < 0.001 |
| < 2 | 17 | | | | |
| ≥ 2 to ≤ 6 | 79 | | | | |
| > 6 | 1 | | | | |
| NPC (cm) | 9.10 ± 5.48 | 2.00 | 30.00 | 5 ± 2.5 | < 0.001 |
| < 2.5 | 4 | | | | |
| ≥ 2.5 to ≤ 7.5 | 39 | | | | |
| > 7.5 | 54 | | | | |
| BAF (cpm) | 4.08 ± 3.49 | 0 | 10 | 10 ± 5 | < 0.001 |
| < 5.00 | 51 | | | | |
| ≥ 5.00 to ≤ 10 | 46 | | | | |
| > 10 | 0 | | | | |
| Simultaneous perception (PD) | 1.36 ± 2.71 | -5.00 | 9.00 | -0.5 to -5.5 | |
| <-5.5 | 0 | | | | |
| ≥-5.5 to ≤-0.5 | 19 | | | | |
| >-0.5 | 78 | | | | |
| Convergence/ Adduction (PD) | 19.56 ± 7.09 | 5.00 | 30.00 | 4 to 52 | |
| Divergence/ Abduction (PD) | 5.82 ± 1.03 | 3.00 | 10.00 | 4.5 to 10 | |
| Near stereoacuity | 81.19 ± 65.28 | 79.67 ± 59.72 | 82.80 ± 71.25 | | |
| Central | 88 | | | | |
| Macular | 6 | | | | |
| Peripheral | 1 | | | | |
| Stereo | 0 | | | | |
| Distance stereoacuity | 67.80 ± 38.43 | 66.23 ± 25.96 | 69.48 ± 48.57 | | |
| Central | 76 | | | | |
| Macular | 19 | | | | |
| Peripheral | 2 | | | | |
| Stereo | 0 | | | | |

AC/A: Accommodative Convergence/ accommodation; BAF: Binocular accommodative facility; cpm: cycle per minute; D: diopter; PD: prism diopter; SD: standard deviation

The p-value was calculated by one sample t-test

* statistically significance

($p<0.001$) significantly differed in different AA groups. The multivariate-adjusted logistic regression model also showed that participants with lower AA were more likely to have lower BAF (OR, 4.990; 95% CI, 1.731–14.386).

**Table 3** Univariate and multivariate analysis of factors associated with AA less than 4.00 D ($n=145$)

| | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|
| | Odds ratio (95% CI) | P | Odds ratio (95% CI) | P |
| Age (years) | 2.040 (1.506–2.763) | < 0.001* | 2.080 (1.523–2.841) | < 0.001* |
| Gender | | | | |
| Male | Reference | | Reference | |
| Female | 0.735 (0.353–1.533) | 0.412 | 1.829 (0.683–4.895) | 0.230 |
| SE (D) | 1.167 (0.986–1.383) | 0.073 | 1.280 (1.029–1.594) | 0.027* |
| Scotopic Pupil diameter (mm) | 0.668 (0.399–1.117) | 0.124 | 0.900 (0.478–1.669) | 0.745 |
| Vision with spectacles | | | | |
| 0 | Reference | 0.158 | Reference | 0.737 |
| 1 | 0.367 (0.039–3.444) | 0.380 | 0.335 (0.031–3.666) | 0.370 |
| 2 | 0.462 (0.047–4.571) | 0.509 | 0.375 (0.032–4.434) | 0.436 |
| 3 | 1.200 (0.110-13.146) | 0.881 | 0.545 (0.041–7.261) | 0.646 |

CI: confidence interval; D: diopter; SE: spherical equivalent

0 = visual acuity with glasses was equal to BCVA of Snellen visual acuity

1 = differed with BCVA by one line of Snellen visual acuity

2 = differed with BCVA by two lines of Snellen visual acuity

3 = differed with BCVA by at least three lines of Snellen visual acuity

* statistically significance

Supplemental Table 1 presents the results of the subjective perceived visual discomfort measured with a self-developed questionnaire. The three most commonly reported visual discomforts associated with reading and close work were eye strain or soreness, ocular pain or headache, and blurred text, with the cumulative number of 63 patients (87.50%), 43 patients (59.72%), and 24 patients (33.33%), respectively, reporting these symptoms "occasionally," "quite often," or "very often". These three items were concordantly seen as the most severe visual discomforts.

## Discussion

For presbyopes, the well-studied topic is that they have varying degrees of age-related decline in AA, which could result in difficulty in near vision. However, this alone could not fully reflect the binocular vision, as it is a dynamic system composting of interactions between various aspects, including accommodative and vergence functions. It could also be influenced by many factors, such as ethnicity, geographical factors, and personal and work habits [19], and there is a need for a more comprehensive population-based evaluation for those at the early stage of presbyopia. Besides, the abrupt change in

**Table 4** Univariate and multivariate analysis of factors associated with AA less than 4.00 D ($n=97$)

| | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|
| | Odds ratio (95% CI) | P | Odds ratio (95% CI) | P |
| NRA (D) | 0.901 (0.403–2.015) | < 0.001* | 1.057 (0.384–2.907) | 0.915 |
| BCC (D) | | | | |
| <0.00 | 1.700 (0.562–5.141) | 0.347 | 1.139 (0.311–4.176) | 0.844 |
| ≥0.00 | Reference | | Reference | |
| AC/A | 1.201 (0.876–1.647) | 0.255 | 1.200 (0.802–1.796) | 0.374 |
| NPC (cm) | 1.073 (0.977–1.179) | 0.140 | 1.064 (0.949–1.193) | 0.286 |
| BAF (cpm) | | | | |
| < 5.00 | 6.286 (2.347–16.831) | < 0.001* | 4.990 (1.731–14.386) | 0.003* |
| ≥ 5.00 | Reference | | Reference | |
| Simultaneous perception (PD) | 1.040 (0.885–1.222) | 0.635 | 1.018 (0.840–1.233) | 0.857 |
| Convergence amplitude (PD) | 1.035 (0.972–1.010) | 0.282 | 1.021 (0.948–1.099) | 0.584 |
| Divergence amplitude (PD) | 1.108 (0.730–1.681) | 0.629 | 1.086 (0.646–1.826) | 0.755 |
| Near stereoacuity | | | | |
| Central | Reference | | Reference | |
| Macular or peripheral | 3.306 (0.893–12.246) | 0.073 | 1.882 (0.430–8.233) | 0.401 |
| Distance stereoacuity | | | | |
| Central | Reference | | Reference | |
| Macular or peripheral | 3.383 (0.397–28.804) | 0.265 | 1.930 (0.160-23.277) | 0.605 |

AC/A: Accommodative Convergence/ accommodation; BAF: Binocular accommodative facility; BCC: binocular cross cylinder; CI: confidence interval; cpm: cycle per minute; D: diopter; NRA: negative relative accommodation; PD: prism diopter; SD: standard deviation

* statistically significance

refraction after refractive surgery leads to sudden, higher accommodative and convergence demands in near-vision tasks, which could precipitate or aggravate an existing accommodative or vergence dysfunction anomaly. Comprehensive binocular vision evaluation is critical for ensuring successful surgeries and can be relevant to reinforce the knowledge about binocular changes postoperatively.

Norms of Scheiman and Wick's and Lewis's in the general population are the recognized guidelines commonly used as a reference for the interpretation of accommodative and binocular findings [17, 18, 20]. Comparison of our results with normative values showed significant differences between many variables, in addition to reduction in AA and consistent PRA insufficiency ($p<0.001$), which occurred due to the physiological decrease in viscoelasticity and geometric changes in the crystalline lens along with reduced ability for accommodative stimulation associated with aging [21]. We also observed that the mean value of BCC lay outside the normal range, with 32(22.07%) participants presented with accommodative lead (BCC < 0), along with increased NPC ($p<0.001$), lower AC/A ($p<0.001$), as well as reduced BAF ($p<0.001$) with a larger proportion of patients failing at even one cycle in the test. As for the simultaneous perception, small angle esotropia for distance fixation was found using a synoptophore. The above results suggested that there may exist some additional complex disruptions besides AA insufficiency. To interpret our findings, physiological characteristics, habits, and customs, as well as social context in China need to be considered simultaneously.

The population around 40 years old is in the "prosperity" stage and has long-term close vision needs. In the context of physiological accommodative ability already degenerated to some extent, the increasing complexity in near visual demands created overloaded pressure on the accommodation and vergence system, thus putting it under a relatively quiescent state with high tension for long periods. The ciliary muscle of the eye remained in a constant contraction state, thus impairing its flexibility and contraction efficiency. Ultimately, this manifested as an accommodative lead and reduced accommodation facility.

Besides, when looking closely at something with less accommodation reserve (PRA), more convergence will be needed to achieve proximal binocular vision, thus leading to the occurrence of tonic convergence, visual proximity convergence, and fusional convergence [22]. Moreover, in this study none of the patients were past contact lens wearers. For myopes with spectacles, the presence of lens vertex distance would reduce the effective power of a lens, thus the far point was located somewhere before one's eyes. The prolonged tension on the vergence system impaired its flexibility and made the patients unable to relax when adjusting their vision, resulting in small-angle esotropia in the farsighted eye position. The tonic convergence could account for why our findings were contrary to most other studies with different age ranges and lifestyle habits, that the mean heterophoria value for distance fixation was found to be exophoric and increased with age [5, 19].

It is a fact that the magnitude of AC depends on the accommodative response (AR), which starts to diminish when the age of 40 years is passed and the accommodation stimulus approaches the limits of the objective amplitude of accommodation [20, 23]. The decrease in AC/A and increase in NPC, as compared to norms of younger adults, seems to be due to the decline in AR and the resultant decrease in AC [20].

Accommodation facility was used to assess the ability to change focus quickly (far–near), and binocular measurement allows assessment of the interrelationship of accommodative and vergence function. The results of our study showed insufficient flexibility and were an indication of an abnormal relationship between accommodative and vergence systems. Notably, there was a considerable proportion of patients failed to pass even one cycle, either with the plus or minus side. Possible reasons included not only the age-related decline in AA and reduced ability for accommodative stimulation but also the relatively inappropriate specification of the flipper set selected, as the values of relative accommodation were smaller than 2D for the vast majority of patients included.

The results of correlation analysis revealed a significant correlation between AA and refractive status, which was consistent with several other studies [11, 24]. However, in contrast to results reported herein that AA deficiency was greater in the eyes of participants with milder myopia, previous studies in myopes generally reported that the motor function of the ciliary muscle, as well as accommodation reserve, decreased with the deepening of myopia [11, 25]. One reason that could be speculated for this opposite result was the special habit of irregular use of glasses in this group of patients. The age-related accommodation deficiency population has an important feature, that the human eye would gradually develop difficulty in near vision with their customary used spectacles, along with decreased accommodation capability, thus they eventually have to change other convex lenses when doing near-work tasks. For people with mild myopia, their refractive error could just play the same role as convex lenses do, and taken together the inconvenience of switching between two pairs of glasses, that prompted them to easily take off glasses when observing near objects, which significantly decreased accommodation demands for near-point viewing. The long-term deficiency of effective stimulation further caused degenerative changes in the ciliary muscle [4]. For patients with higher degrees of myopia, however, removing glasses could only cause whole-course blurry vision, so less removal of spectacles occurred in their daily lives.

Moreover, a positive correlation was found between AA and BAF. Combined with existing evidence, a possible reason could be that individuals with AA insufficiency might require more stress to sustain clear near vision, which causes more severe spasticity of muscles, thus having less flexibility [12].

In the present study, a self-developed questionnaire was used to reflect both accommodative and binocular challenges associated with prolonged near work [26, 27]. Our results were basically the same as former studies using a survey developed by Conlon et al. [28], suggesting that the most common complaints involve reading problems and light sensitivity. Headaches, asthenopia, blur, and diplopia would also occur as symptom severity increased and with prolonged use of digital electronic devices [26, 28, 29].

Considering the above, the following points should be noted carefully before refractive surgery. First, the study of Wang et al. [12] demonstrated that noncycloplegic subjective and automatic refraction measured more myopia than cycloplegic refraction in individuals with older age, milder myopia, and accommodative function abnormalities. It prompted us that for myopes at the early stage of presbyopia, cycloplegia subjective refraction could be crucial for attaining the most accurate optometric prescription before myopia surgery design to avoid overcorrection, regarding the slight hyperopia status after surgery would increase the accommodation demand and bring more visual discomforts. Second, orthoptic training, such as the facility training method, could be applied in patients with obvious accommodation and binocular vision disorders before surgery to strengthen stimulation and relaxation ability [30].

This study did provide a meaningful picture of binocular vision in older myopes, but the limitations should be acknowledged. The most important limitation was that fusional vergence amplitudes were detected only for distance fixation using synoptophor, which was less commonly used in relevant studies from other countries, and the well-defined clinical criteria could not be used to further identify and classify the presence of a binocular vision anomaly in patients scheduled for surgery [17, 31]. As the synoptophor has the advantage of shorter examination time, it could be used for preliminary evaluation of binocular status, and the universally applied horizontal prism bar for both distance and near fixations could be used for further confirmation in patients with questionable or suspicious abnormalities. Besides, this was a single-center clinical study, and a future study with an enlarged sample size across multiple centers could be planned. Third, a comparison with the young myopic group, along with an analysis of the relationship between binocular function and the subjective questionnaire, will be addressed in future research.

In conclusion, this study evidenced that for myopes at the early stage of presbyopia, especially those who had a habit of taking off their glasses to see nearby objects, the continuous tension in the vergence system was also worthy of our attention, in addition to AA insufficiency. Comprehensive assessment of the binocular status and appropriate management is recommended before and after corneal refractive surgery.

**Abbreviations**

| | |
|---|---|
| AA | accommodative amplitude |
| AC/A | accommodative convergence/ accommodation |

| | |
|---|---|
| BAF | binocular accommodative facility |
| BCC | binocular cross cylinder |
| CDVA | corrected distance visual acuity |
| CI | confidence interval |
| CPM | cycles per minute |
| HOAs | higher-order aberrations |
| NA | necessary addition |
| NPC | near point of convergence |
| NRA | negative relative accommodation |
| PD | prism diopter |
| PRA | positive relative accommodation |
| OR | odds ratio; RMS: root mean square |
| SE | spherical equivalent |
| SR | Strehl ratio |
| UDVA | uncorrected distance visual acuity |
| UIVA | uncorrected intermediate visual acuity |
| UNVA | uncorrected near visual acuity |
| FS-LASIK | femtosecond laser-assisted in situ keratomileusis |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-03938-8.

Supplementary Material 1

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Not applicable.

**Author contributions**
Ruiyu Zhang, Yifei Yuan and Yu Zhang participated in the design of the study, Ruiyu Zhang performed the statistical analysis and revised the manuscripts. Yueguo Chen conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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**Data availability**
The data underlying this article cannot be shared publicly due to privacy reasons of the participants. The data will be shared on reasonable request to the corresponding author.

## Declarations

**Ethical approval**
This study adhered to the tenets of the Declaration of Helsinki and received approval from the Ethics Committee of Peking University Third Hospital (M2023402). Informed consent was obtained from each subject.

**Consent for publication**
Not applicable.

**Disclosures**
None of the authors has a financial or proprietary interest in any material or method mentioned.

**Competing interests**
The authors declare no competing interests.

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