Original Article

The effects of myopia and AC/A measuring methodology on AC/A ratio outcome

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Purpose: This study aims (1) to understand the extent of myopia on the AC/A ratio, (2) to examine whether the calculated AC/A ratio would be different from the gradient AC/A ratio in a clinical setup, (3) to investigate the difference between positive and negative spherical lens stimuli on AC/A ratio, and (4) to unveil the mutual effects of different amounts of myopia and AC/A measuring methodology on AC/A ratio outcome.
Methods: volunteered participants (30 males and 42 females) were refractive examined and divided into two groups : 40 low myopes (- 0.50D< spherical equivalents(SE) < - 3.00D) and 32 high myopes (SE≥ - 3.00D). The Von Graefe Technique (VG) was used to measure the distance lateral phoria at 6 m and near lateral phoria at 0.4 m. Binocular additions of positive and negative spherical lenses were used for lateral phoria measurement. The calculated AC/A ratio and the gradient AC/A ratio were then correlated and analyzed by two-way ANOVA.
Results: The average AC/A ratios of the high myopes were higher than those of the low myopes. The average calculated AC/A ratios were higher than the average gradient AC/A ratios. In gradient AC/A ratios, the average value using positive spherical addition was higher than when using negative spherical addition. No significant difference of AC/A ratios was found between the bi-factorial inter-relations of myopia and AC/A ratio determination methods ($F = 0.75$, $P= 0.48> 0.05$). The extent of myopia did not affect AC/A ratio ($F = 3.14$, $P= 0.081> 0.05$). There was a significant difference among measuring methods and the outcomes of AC/A ratios ($F = 6.16$, $P= 0.003< 0.05$). The calculated AC/A ratio was significantly different from the gradient AC/A ratio (both $P=0.003< 0.005$). However, no significant difference was found between the gradient AC/A ratios using positive lenses and those using negative lenses ($P=0.46 >0.05$).
Conclusions: This study shows that the calculated AC/A ratio is significantly greater than the gradient AC/A ratio, probably due to proximal convergence and accommodative lag. A greater amount of myopia has a higher AC/A ratio than that of lower myopia in all AC/A ratio measurement, though the difference was insignificant. This finding suggests that there are deviations between stimulus AC/A ratio and response AC/A ratio. Our data suggest that anomalous binocular factors and accommodative lag should be considered for myopia research, apart from stimulus AC/A ratio.

Key words: AC/A ratio, calculated AC/A ratio, gradient AC/A ratio, stimulus AC/A ratio, response AC/A ratio, lag of accommodation, proximal convergence

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Introduction

When an object is fixed binocularly, the visual axis will adjust the functions of convergence and accommodation, with pupil contraction, in an attempt to make clear single binocular vision possible. The whole process is called "near vision complex"[1]. Fry first proposed the concept of a ratio between accommodation and convergence[2]. Then, Haines introduced the formula of accommodative convergence/accommodation ratio, referred as the AC/A ratio[3]. The AC/A ratio is the ratio of accommodative convergence over the amount of accommodation indicating the convergence for one diopter of accommodation, denoted as △/ D, where △ represents the amount of accommodative convergence and D represents the amount of accommodation.

Clinically, there are two methods for measuring AC/A ratio: calculated AC/C ratio and gradient AC/A ratio. The calculated AC/A ratio is derived from the measurement of near and distance phorias, based on interpupillary distance (PD) and the alterations of convergence capacity as the accommodation is stimulated by clear near target. The gradient AC/A ratio is based on the convergence in response to the addition or reduction of spherical lenses, when the eyes are near-sightedly stimulated[4]. Another classification of AC/A ratio measurements aim for stimulus AC/A ratio and response AC/A ratio, based on the responses of intra- and extra-ocular muscles to motion impulses from the peripheral and central nervous system[5]. The stimulus AC/A ratio reflects the alterations of convergence capacity as the eyes are stimulated with lenses of different fraction power or with different object distances, resulting in different accommodations[6]. Calculated and gradient AC/A ratio methods belong to this genre. The response AC/A ratio reflects the ratio of accommodative response which usually is not measured in the clinic to the alteration of convergence capacity. Alpern et al.[6] reported that the response AC/A ratio should be 1.08-fold greater than the stimulus AC/A ratio due to the lag of accommodation. However, in clinical settings, the stimulus AC/A often plays an important role in binocular vision analysis.

AC/A ratio is a practical application of the linear relationship between accommodation and convergence. Martens and Olge[7] found that, with normal binocular vision within non-diplopia and non-blur domain, the accommodative convergence induced by optic lenses exhibited 90% linear correlation in 250 samples. Thus, AC/A ratio has been used as an important indicator for the assessment and management of binocular anomalies. Wick[8] divided binocular anomalies into nine categories including four convergence anomalies (convergence insufficiency, convergence excess, divergence insufficiency, and divergence excess), four accommodative anomalies (accommodative insufficiency, ill-sustain accommodation, accommodative excess, and accommodative infacility), and ocular motor disorder, etc. according to fixation distance heterophoria and AC/A ratio. Clinically, AC/A ratios are often used to determine added power of spherical lenses for the management of binocular anomalies[9]. Sloan et al.[10] proposed that the normal range of AC/A ratio lies between 3 to 5 △/ D. When the AC/A ratio is greater than 5, it is regarded as over accommodative convergence and less than 3 regarded as insufficient accommodative convergence[10]. However, Morgan reported that the normal range of AC/A ratio should be 4 ± 2 △/D, based on conclusions made from various measuring methodologies[11].

The prevalence of myopia is high in Taiwan and worldwide[12,13]. The cause and control of myopia have become an important issue, both academically and clinically. Gwiazda et al.[14], investigating the correlation of childhood myopia with AC/A ratio, found the greater the myopia, the higher the AC/A. Jiang[15] and Rosenfield[16] reported the same correlation in the adult myopes. Mutti[17] proposed that higher response AC/A could be a risk factor worthy of noticing in schoolchildren starting to be myopic. Gwiazda et al.[18] observed a trend of higher response AC/A ratio at 1 -2 years before the onset of myopia and proposed that near-sighted works in children would cause hyperopic retinal defocus, leading to abnormal eye movements prior to myopia. Bullimore et al.[19] reported that adult myopia factors, including too much near sight work, included higher response AC/A ratio and higher accommodative lag. The alterations of AC/A ratios with myopia surgery have also become an important issue. Prakash[20] compared the changes of AC/A ratios before and after LASIK and reported higher average AC/A ratio after surgery. Higher deviations were found at 3 months after LASIK surgery, which became stable in three to nine months.

The AC/A ratios play an important role in clinical assessments and managements. This study aims (1) to understand the extents of myopia on AC/A ratio, (2) to examine whether the calculated AC/A ratio would be different from the gradient AC/A ratio in a clinical setup, (3) to investigate the difference between positive and negative spherical lens stimuli on AC/A ratio, and (4) to unveil the mutual effects of myopia and AC/A measuring methodology on AC/A ratio outcome.

Materials and methods

Measurement methodology and records

A total of 72 ammetropes, aged between 20 - 35 (average age at 29.3), including 30 males and 42 females, volunteered for this study. All 72 volunteers were free of strabismus and heteropsia abnormalities. All volunteers were examined with static retinoscopy and subject refraction, with OD average refraction at -2.78 D (spherical equivalent; SD at 2.11D) and OS average refraction at -2.76D (spherical equivalent; SD at 2.15D). All of the eyes were able to be corrected to best corrected visual acuity (BCVA) at 20/20. We divided the myopes into two groups according to their spherical equivalents (SE) : low myopes ($-0.50D < SE < -3.00D$) and high myopes ($SE \geq -3.00D$). The measurements were performed by the same optometrist taking appropriate five-minute breaks during the entire examination.

Measurement of calculated AC/A ratio

Von Graefe Technique (VG)[21] was used to measure the distance lateral phoria at 6 M and near lateral phoria at 0.4M. The phoropter was put on the patient's corrected distance prescription, and the Risley Prisms at 12△ base-in (BI) was added for OD and 6△ base-up (BU) was added for OS. At 6 M distance, far distance PD was used and the patient was asked to fixate on a single letter on the distance chart, which is one line larger than the patient's best corrected visual acuity. At 0.4 M distance, near distance PD was used and the patient was asked to fixate on the 20/30 near target. In measuring lateral phoria, the 12△BI OD was used as the measuring lens; the 6△BU OS was used as the separation lens. The patient was able to see two targets on his upper right and lower left field. The patient was instructed to fixate on the lower left target and keep it clear. The examiner adjusted the OD Risley Prisms at a speed of 2△ per second until the patient reported the two separate targets were aligned vertically. The amount of prism and the direction of the base of the prism were then recorded, with the BO prism added when esophoria was positive and the BI prism added when exophoria was negative. The AC/A ratio was calculated as AC/A= IPD + N (Hn – Hd)[22], where IPD is the interpupillary distance in centimeters, Hn the recorded amount of near phoria, Hd the recorded amount of distance phoria, and N the near fixation distance in meters. The recorded unit was △/ D.

Measurement of gradient AC/A ratio

The Von Graefe Technique was applied to measure the amount of prism and the direction of the base of the prism for near lateral phoria at 0.4 M. Afterwards, +1.0D or -1.0 D spherical lens was added. The patients were asked to relax accommodation by +1.0D spherical lens or to stimulate accommodation by -1.0D spherical lens. We recorded the amount of prism and the direction of the base of the prism for near lateral phorias. This AC/A ratio represents as gradient AC/A, which is $(\triangle^0 - \triangle^1) / D$ [23], where $\triangle^0$ is the amount of near lateral phoria, $\triangle^1$ the amount of near lateral phoria after simultaneous addition of spherical lenses to both eyes, and D the added power of spherical lens, with plus spherical lens being positive and with minus spherical lens being negative. The recorded unit is △/ D.

Statistics

The measurements were processed using SPSS for Windows 11.5 tool kit. In addition to descriptive statistics, two-way ANOVA was used to examine deviations and inter-correlations. A P-value of less than 0.05 was considered significant.

Results

The results of calculated and gradient AC/A ratios in the different extents of myopia groups are listed in Table 1. The average calculated AC/A ratio was 4. 70 △/ D (SD=2.17 △/ D) in the high myopes (n=32), which was slightly higher than the 4.63 △/ D (SD=2.17 △/ D) in the low myopes (n=40). In all myopes (n=72), the average calculated AC/A ratio was 4.66 △/ D (SD=2.16 △/ D). The average gradient AC/A ratio with positive spherical lens was 3.20 △/ D (SD=1.71 △/ D) for the low myopes (n=40) and was 4.19 △/ D (SD=3.05 △/ D) for the high myopes (n=72). The overall (n=72) average gradient AC/A ratio with positive spherical lens was 3.64 △/ D (SD=2.43 △/ D). (Figure 1) With regard to the average gradient AC/A ratios with negative lens, the low myopes (n=40) was 3.13 △/ D (SD=1.75 △/ D) and that of the high myopes (n=32) was 3.69 △/ D (SD=2.53 △/ D). The overall (n=72) average gradient AC/A ratio with negative spherical lens was 3.38 △/ D (SD=2.13 △/ D). The average gradient AC/A ratios were higher in the high myopes than in the low myopes regardless whether a positive or negative lens was used. For all of the three methodologies, the data showed the average AC/A ratios in the high myopes to be higher than those in the low myopes. In addition, the overall calculated AC/A ratio (4.66 △/ D) was higher than that of the gradient AC/A ratios with positive lens (3.64 △/ D) which in turn was higher than that of gradient AC/A ratios with negative lens (3.38 △/ D). (Figure 2)

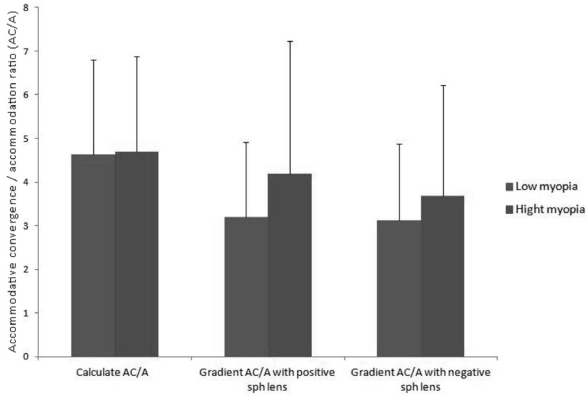

Figure 1. Low myopia group was less than High myopia group in each AC/A measurement, but there was no signification difference (P > 0.05).

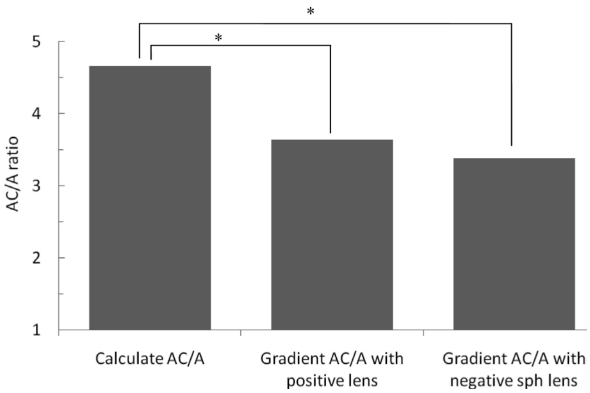

Figure 2. The gradient AC/A with positive Sph lens group and gradient AC/A with negative Sph lens group was significantly different from the Calculate AC/A group (two-way ANOVA; P < 0.05).

Table 1. AC/A measurements and refractive error. (n=72)

AC/A measurements	Refractive Error	Mean	SD	n
Calculated AC/A	Low myopia	4.63	2.17	40
	High myopia	4.70	2.17	32
	Sum	4.66	2.16	72
Gradient AC/A (positive sph lens)	Low myopia	3.20	1.71	40
	High myopia	4.19	3.05	32
	Sum	3.64	2.43	72
Gradient AC/A (negative sph lens)	Low myopia	3.13	1.75	40
	High myopia	3.69	2.53	32
	Sum	3.38	2.13	72

Unit: △ / D SD: Standard Deviation; Sph : Spherical

Table 2. 2-way ANOVA of AC/A measurement and refractive error.

Source of variance	SS	df	MS	F	Sig
refractive error	15.55	1	15.55	3.14	.081
AC/A measurement	61.88	2	30.94	6.16	.003*
refractive error × AC/A measurement	7.5	2	3.75	.75	.48
Group (error)					
Subject(S)	347.15	70	4.96		
Residual(AxS)	703.52	140	5.03		
Total	1135.6	215			

**P<.01; *P<.05

df: Degree of Freedom ; MS: Mean Sum Square; Sig: Significance; SS: Sum Square

The results of 2-way ANOVA analysis between AC/A methodologies and refractive errors are summarized in table 2. We examined three hypotheses: (1) AC/A ratio would be different as related to different amount of myopia , (2) different AC/A measuring methodologies will result in different outcomes of AC/A ratio and (3)different amounts of myopia and different methodologies would have a compound effect on the outcome of AC/A ratio. The results showed no significant inter-correlation between the amount of myopia and the methodologies on the outcome of AC/A ratio (F=0.75; P=0.48 > 0.05). Taking the refractive errors as an independent variation, we had F= 3.14 and P=0.081 > 0.05, indicating that amount of myopia did not have a significant influence on AC/A ratio. Taking methodologies as the independent variation, we found a difference of F= 6.16 and P=0.003 < 0.05, indicating significant difference between different methodologies. Using paired test between the variations (table 3), we found a significant difference between the calculated AC/A ratio and gradient ratio regardless of whether we used a positive spherical lens (deviation in average = 0.97, P= 0.003 < 0.05) or a negative spherical lens (deviation in average = 1.26, P= 0.003 < 0.05). However, the gradient AC/A ratio with positive spherical lens was not significantly different from the gradient AC/A ratio with negative spherical lens (deviation in average = 0.29, P= 0.46 > 0.05).

Discussion

Several potential mechanisms that have been proposed to explain the deviations between the calculated and the gradient AC/A ratios. Flom[24] suggested that the additive effect from proximal convergence could lead to vergence, leading to the difference between calculated and gradient AC/A ratios. Morgan[25] regarded that the deviation could be due to the fact that both the induced proximal convergence and the accommodative response were less intense than the stimuli. Von Noorden [26] proposed that gradient AC/A ratio, not calculated AC/A ratio, was devoid of interference from proximal convergence. Scheiman[27] concluded that the deviation was resulted from both proximal convergence and accommodative lag.

In previous reports[14-19], higher AC/A ratio have been found among higher myopes. Furthermore, it has also been observed that higher accommodative lag and abnormal eye movements are risk factors of myopia. In this study, the results showed no significance difference in the inter-correlation between the extent of myopia and the methodologies. Nor did we find it in the extent

Table 3. Comparative Analysis of AC/A ratio measurements

AC/A ratio measurements	MD	Se	Sig
Calculated AC/A and Gradient AC/A (positive sph lens)	.97	.32	.003*
Calculated AC/A and Gradient AC/A (negative sph lens)	1.26	.42	.003*
Gradient AC/A(positive sph lens) and Gradient AC/A (negative sph lens)	.29	.39	.46

**P<.01; *P<.05

MD: Mean Difference; Se: Standard error; Sig: Significance; Sph : Spherical of myopia alone. Obviously, the deviation found between the stimulated and responsive AC/A ratios lies in the differential modulations between stimuli and responses. Bullimore et al.[19] found that adult myopia factors include not only excessive near-sighted work, but also higher responsive AC/A ratio and higher accommodative lag. Although significant difference between the extent of myopia and AC/A ratio was not found in this study, we observed higher average AC/A ratios in the high myopes as compared to the low myopes using the methods of measuring. The high myopia rate and its relation to the alterations of AC/A ratio have become an important academic and clinical issue. Our results indicated that accommodative lag and binocular abnormalities may also be involved as myopia risk factors and these should be considered apart from AC/A ratios.

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Original Article

近視屈光度，AC/A比測量方法對AC/A比值影響之研究

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目的：探索(1)近視度數高低與AC/A比值有無差異，並比較(2)調節性輻輳與調節之比率(AC/A比)，與計算式AC/A及梯度式AC/A比間整體性的差異，其中包含(3)以正、負球面鏡片刺激調節所產生梯度式AC/A比值之間有無差異性。(4)近視屈光度的高低與AC/A比測量方法兩者有無交互作用的影響。**方法：**30名男性及42名女性，共72名參與本研究計畫，經屈光檢查後分成低近視組(-0.50D <等價球面度SE< -3.00D)有40名，及高近視組(等價球面度SE SE≧-3.00D)有32名。以Von Graefe Technique(VG)測量斜位的方法及步驟，於距離6M及 0.4M測量遠方及近方水平斜位；再分別雙眼同時加入正，負 1.00D球面鏡測量其水平斜位。比較分析計算式AC/A比值及梯度式AC/A比值，並以2way-ANOVA加以檢定交互作用影響及差異性。**結果：**高近視組AC/A平均數均高於低近視組AC/A，計算式AC/A平均數高於梯度式(正球面鏡)AC/A平均數又高於梯度式(負球面鏡)AC/A平均數。近視屈光度及AC/A測量方法影響AC/A比值的交互效果(F = 0.75 ，P= 0.48＞ 0.05)無統計上差異。近視屈光度影響AC/A比值的效果(F = 3.14，P= 0.081＞ 0.05)無統計上差異。但不同AC/A測量方法影響AC/A比值的效果 (F = 6.16，P= 0.003＜ 0.05)具統計上差異，即計算式AC/A與梯度式(正球面鏡)AC/A(P = 0.003＜ 0.05)有顯著差異；計算式AC/A與梯度式(負球面鏡)AC/A(P = 0.003＜ 0.05)有顯著差異；而梯度式(正球面鏡)AC/A與梯度式(負球面鏡) AC/A，(P = 0.46＞ 0.05)則無顯著差異。**結論：**結果顯示計算式AC/A大於梯度式AC/A有顯著差異。原因可能為近接性聚合(proximal convergence)及調節遲緩(Accommodation lag)因素所造成差異。高近視AC/A平均數均高於低近視AC/A，雖然未達顯著性，但其差異顯示刺激式ACA與反應式ACA不同的影響。本研究建議後續近視相關研究除了刺激式AC/A比之外，尚應考量異常雙眼視因素及調節遲緩。

關鍵詞：AC/A比 (Accommodative Convergence/ Accommodation ratio)
計算式AC/A比 (Calculated AC/A ratio)、梯度式AC/A比(Gradient AC/A ratio)、刺激性AC/A比(Stimulus AC/A ratio)、反應性AC/A比(Response AC/A ratio)、調節遲緩(Lag of accommodation)、近接性聚合(Proximal convergence)

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