Comparison of Amplitude of Accommodation in Different Vertical Viewing Angles

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ABSTRACT

Purpose: To compare the measurement of the amplitude of accommodation in different vertical gaze angles among Malaysians.

Methods: A convenience sampling method was used. The subjects comprised 31 Malaysians ages 18 to 26. Relevant demographic and clinical data were obtained. Amplitude of accommodation was measured in different vertical viewing angles with the help of the minus-lens method. The data were analyzed using one-way repeated measures ANOVA to investigate the changes in amplitude of accommodation from 20 degrees upgaze to 40 degrees downgaze.

Results: Among 32 subjects, 31 subjects' data were analyzed. Amplitude of accommodation measured via the minus-lens method was found significantly changed in four sets of viewing angles ($p<0.001$) with the mean difference of 2.52D from 20 degrees upgaze to 40 degrees downgaze. However, the association of amplitude of accommodation in different viewing angles among genders and age groups was not significant ($p>0.05$). Amplitude of accommodation among race was found statistically significant at only 20 degree downgaze ($p=0.001$).

Conclusion: Vertical viewing angle has a significant effect on the amplitude of accommodation in the sense that the amplitude of accommodation increased with a declination of vertical gaze. The vertical viewing angle must be taken into account during clinical measurements of the amplitude of accommodation.

Keywords: amplitude of accommodation, eye movement, gaze direction, subjective measurement

Introduction

Changing vertical gaze direction for different distance tasks is a frequent event in everyday life. When doing near visual tasks such as reading and computer work, most observers prefer to do it with a steeply downward gaze, 20° to 50° below the horizontal line of sight.[1] However, some people who have other different occupational demands (e.g., Librarian) might prefer primary gaze or upgaze when they view intermediate or distant objects. Indeed, the angle of vertical gaze, which we use to perceive our surroundings and objects located in them, plays a crucial part in motor performance.[2] Studies carried out have been directed mostly towards preferred gaze direction or have investigated possible causes for preferred gaze direction.[3-6] In downward gaze, there is evidence of an increase of the optical power of the eye due to accommodation.[6-8] Previous investigators showed that visual discomfort is affected more by the stress of convergence compared with the stress of accommodation.[9,10] Differences in biomechanical forces (e.g., extraocular muscles or eyelid tension) and gravity acting on the components of the eye can have varying effects on the eye with downgaze.[7]

Previous studies have shown that accommodation parameters might be influenced by individual differences such as age, ethnicity, gender, and refractive error.[11-13] However, the effect of ethnicity on other binocular parameters is insignificant among adults.[14]

Variation in vertical gaze for near tasks should be taken into account in work-related disorders such as visual fatigue and musculoskeletal discomfort (e.g., neck and shoulder discomfort).[1,15,16] Specific visual angles may be required for workers who have different occupational needs (e.g., some people who spend more time doing work in front of a computer might prefer to place the computer below eye level) and different body heights.[17] The aim of the present study was to investigate the measurement of amplitude of accommodation at different vertical angles among the Malaysian population.

Methodology

A cross-sectional study was conducted by including thirty-one Malaysian subjects aged 18 to 26 years, regardless of gender and race, from both east and west Malaysia within a period of six months at Twintech Vision Care Center. Written informed consent was obtained from all of the subjects who were included in the study. Subjects within an age group of 18-26 years and had best corrected visual acuity of 6/6 were included in this study, and subjects having any binocular vision disorder, eye movement disorder, or ocular pathology were excluded. Permission to conduct the study was obtained from the Institute,

Table 1. Summary of Subject Distribution According to Age Group, Gender, and Race

Race	Gender	Age			
		18 – 20	21 – 23	24 – 26	Total
Chinese	Male	1	3	2	6
	Female	5	11	5	21
Non-Chinese	Male	0	1	0	1
	Female	1	2	0	3
	Total	7	17	7	31

Table 2. Comparison of Amplitude of Accommodation Within Three Different Age Groups in Four Different Vertical Gazes

Gaze	Age	Mean ± Std. Deviation (D)	p
Primary	18-20	8.92 ± 1.61	0.07
	21-23	9.76 ± 1.89	
	24-26	10.44 ± 1.33	
	Total	9.72 ± 1.77	
20⁰ up	18-20	8.46 ± 1.54	0.05
	21-23	9.52 ± 1.90	
	24-26	9.94 ± 1.14	
	Total	9.33 ± 1.73	
20⁰ down	18-20	11.01 ± 1.39	0.56
	21-23	11.18 ± 2.18	
	24-26	11.71 ± 11.71	
	Total	11.26 ± 1.82	
40⁰ down	18-20	11.30 ± 1.44	0.26
	21-23	11.88 ± 2.30	
	24-26	12.51 ± 1.29	
	Total	11.89 ± 1.95	

and all procedures were performed after obtaining approval from the ethics committee. Detailed history was obtained from each subject followed by the measurements of visual acuity, objective and subjective refraction, pupillary evaluation, phoria measurements, measurements of other accommodative and vergence parameters, slit lamp examination, and fundus examination. After successful completion of initial assessments, those who passed the inclusion criteria were included in the study and were categorized into three age groups (18-20, 21-23, and 24-26 years).

During testing, subjects were positioned in a headrest to ensure consistency of eye and head position with best visual correction. For targets, high contrast N6 texts were attached to the polystyrene at approximately 33cm at 4 different gaze directions (20 degrees up, primary gaze, 20 degrees down, and 40 degrees down from primary gaze). The minus-lens technique was used to determine the amplitude of accommodation of the subjects monocularly. The target

Table 3. Comparison of Amplitude of Accommodation in Different Vertical Gazes Between Genders

Gaze	Gender	Mean ± Std. Deviation (D)	p
Primary	Male	9.17 ± 1.43	0.18
	Female	9.89 ± 1.84	
20⁰ up	Male	8.83 ± 1.32	0.18
	Female	9.53 ± 1.82	
20⁰ down	Male	11.08 ± 1.64	0.68
	Female	11.31 ± 1.88	
40⁰ down	Male	11.78 ± 1.96	0.80
	Female	11.93 ± 1.96	

remained in a fixed position (33cm, corresponding to a stimulus of 3.00DS), and minus lenses were presented in 0.25D steps to move the location of the optical image of this target. All lenses were put in a trial frame with a vertex distance of 12mm. The subjects were instructed to report the first noticeable, sustained blur that could not be cleared by further conscious effort. The total amplitude was equal to the power of the minus lens introduced plus the 3.00D required to focus initially on the target. Targets were placed at 33cm rather than 40cm as the minus lens tends to make the target appear smaller and may make the patient more sensitive to identifying the first noticeable blur. Placing the target closer to the subject induces relative distance enlargement and may reduce the possibility of getting underestimated amplitude of accommodation. In addition, maintaining the constant distance and vertical viewing angles can be achieved easily by using the minus-lens rather than the push-up method. The push-up method may cause a confounding factor in that the vertical viewing angle might be changed when moving the target towards the subject. A set of four gaze directions was tested (20 degrees up, primary gaze, 20 degrees down, and 40 degrees down from primary gaze). When the headrest was in its normal position, subjects were instructed to move their eyes without moving their head. In order to minimize the effects of fatigue, primary gaze always appeared in the first presented set. The order of the other gazes was randomized among subjects. Data analysis was carried out by using SPSS 16.0 software. The normality of the data was checked by using the Shapiro-Wilk test. A repeated measure ANOVA was performed to assess the significance of amplitude of accommodation changes in four different vertical gazes. To avoid type 1 errors, the Bonferroni correction was considered while performing the post hoc analysis.

Results

This study had a total of 31 subjects, out of which 7 subjects were male (23%) and 24 subjects were female (77%). Subjects were categorized into Chinese (87%) and non-Chinese (13%) as shown in Table 1. When the changes in amplitude of accommodation were observed for different vertical viewing angles, there were no statistically significant

Table 4. Comparison of Amplitude of Accommodation with Race in Four Different Vertical Gazes

Gaze	Race	Mean ± Std. Deviation (D)	p
Primary	Chinese	9.64 ± 1.86	0.19
	Non-Chinese	10.28 ± .83	
20⁰ up	Chinese	9.26 ± 1.79	0.12
	Non-Chinese	10.12 ± 1.00	
20⁰ down	Chinese	11.05 ± 1.83	0.00
	Non-Chinese	12.68 ± .94	
40⁰ down	Chinese	11.72 ± 1.97	0.07
	Non-Chinese	13.06 ± 1.39	

Table 5. Mean Amplitude of Accommodation Associated with Four Different Vertical Gazes

Gaze	Amplitude of Accommodation (D) Mean ± Std. Deviation (D)	p
20⁰ up	9.37 ± 1.73	0.00
Primary	9.72 ± 1.77	
20⁰ down	11.26 ± 1.82	
40⁰ down	11.89 ± 1.95	

One way repeated measure ANOVA

Table 6. Comparison of Amplitude of Accommodation in Four Different Vertical Gazes Between Groups

(I) Amplitude of accommodation	(J) Amplitude of accommodation	Mean difference (I-J)	p	95% Confidence Interval for Difference	
				Lower Bound	Upper Bound
20⁰ up	Primary	-0.35	5.83×10^{-5}	-0.51	0.18
	20⁰ down	-1.88	1.01×10^{-18}	-2.18	-1.59
	40⁰ down	-2.52	4.17×10^{-19}	-2.90	-2.13
Primary	20⁰ up	0.35	5.83×10^{-5}	0.18	0.51
	20⁰ down	-1.53	6.74×10^{-17}	-1.80	-1.27
	40⁰ down	-2.16	1.17×10^{-17}	-2.52	-1.80
20⁰ down	20⁰ up	1.88	1.01×10^{-18}	1.59	2.18
	Primary	1.53	6.74×10^{-17}	1.27	1.80
	40⁰ down	-0.63	1.28×10^{-6}	-0.86	-0.39
40⁰ down	20⁰ up	2.52	4.17×10^{-19}	2.13	2.90
	Primary	2.16	1.17×10^{-17}	1.80	2.52
	20⁰ down	0.63	1.28×10^{-6}	0.39	0.86

differences for age group (p>0.05) or gender (p>0.05), but there was a significant change in amplitude by race (p=0.001) for the 20-degree downgaze position, as shown in Tables 2, 3, and 4, respectively. Measurements of amplitude of accommodation via the minus-lens method in different vertical viewing angles (p<0.001) showed a statistically significant difference, with a mean difference of 2.25DS from 20 degrees upgaze to 40 degrees downgaze, as shown in Tables 5 and 6.

Discussion

The prime focus of this study is to find out the effect of vertical viewing angle on amplitude of accommodation. The effects of age, gender, and race were also examined as potential confounding factors. This study showed no statistically significant difference in amplitude of accommodation by gender in four different vertical gaze directions (p>0.05). Our finding of the lack of gender effect on the amplitude of accommodation in primary gaze (p=0.188) is supported by Yavas et al.'s study[18] (p=0.54), although this study and that of Yavas et al. used different techniques to measure the amplitude of accommodation (i.e., minus-lens technique and infra-red photorefractor, respectively). Furthermore, in this study, we also found that there was no statistically significant difference by gender for the angles of 20 degrees up (p=0.189), 20 degrees down (p=0.683), and 40 degrees down (p=0.809) from primary gaze. We could not find any supportive study that either agreed with or contradicted our results for those gaze angles.

This study failed to show any significant effect on amplitude of accommodation by the three age groups for the viewing angles of 20 degrees up (p=0.074), primary gaze (p=0.058), 20 degrees down (p=0.563), and 40 degrees down (p=0.262). These results contradict the findings from Atchison et al.,[19] where they found a significant interaction between age group (18-25 years, 35-45 years) and eye gaze direction for both near point and amplitude (p<0.05) but not for far point (p=0.31). Due to the nature of our study and the fact that the normal amplitude of accommodation needed to be measured, the age group of 18-26 years was recruited for our study. The reason why we did not find any significant difference between the amplitude of accommodation in four vertical gazes and age group compared to Atchison et al. is because of the smaller range and the exclusion of the older group. Furthermore, it was explained by Atchison et al. that there was a shift of nearest points toward the eye when the gaze was changed from up to down for the younger subjects only by using a push-up method, which leads to increased amplitude of accommodation in downgaze in the younger group versus the older group. In this study, the amplitude of accommodation in four vertical viewing angles was measured by using the minus-lens technique, which could be a possible reason for the discrepancy between the two studies.[19]

The limitation we faced was that the age group of this study was smaller than other studies regarding the amplitude of accommodation in different vertical viewing angles. We were not able to support or contradict an already proven relationship between age and amplitude of accommodation in different eye gazes. Next, in this study, we also observed that there was no statistically significant difference in the amplitude of accommodation by race in the viewing angle of 20 degrees up ($p=0.121$), primary gaze ($p=0.193$), and 40 degrees down ($p=0.070$), but there was one in 20 degrees down ($p=0.001$). In primary gaze, our amplitude of accommodation finding contradicts Edwards et al.[12] in relation to race. Edwards et al., using the push-up method, showed that Chinese subjects had lower amplitude of accommodation than Caucasian subjects. This can be due to the methodology difference in both studies and race imbalance among subjects in our study. Furthermore, we found that there was a statistically significant difference in the amplitude of accommodation by race only at the angle of 20 degrees downgaze ($p=0.001$), where Chinese subjects had a lesser amplitude of accommodation compared with non-Chinese (Malay and Indian) subjects. We could not find any supportive study that either agreed with or contradicted our results. For these facts, we cannot draw a conclusion on the effect of different vertical gazes on the change in amplitude of accommodation for non-Chinese races (Malay and Indian).

The present study shows a statistically significant relationship between amplitude of accommodation and vertical viewing angle ($p<0.001$). Furthermore, we showed that the amplitude of accommodation increases from 20 degrees upgaze to 40 degrees downgaze ($p=4.176\times10^{-19}$ or $p<0.001$), with the mean difference of 2.52DS. Our finding is considerably more than Atchison et al. in the young age group, which had a maximum mean difference of 0.69DS happening between 20 degrees upgaze and 45 degrees downgaze. The large discrepancies between the results of the two studies may be due to the methodology difference, as our study was using the minus-lens technique with an N6 target at 33cm, while Atchison et al. used a push-up method with an N7 target to measure far point and near point. In the study by Atchison et al., the far point was measured by using a +3.00D trial lens, and near point was measured without a +3.00D trial lens. During measurement of the far and near point, the test chart was placed in a range of clear vison and then was moved slowly away and inward respectively, until blur was reported. The distance from the cornea to the test chart was measured, and the mean of three measurements was taken as a far point and near point.[19] Another factor which leads to a discrepancy between the two studies is uncorrected refractive error potentially leading to over or under-estimation of accommodation. Atchison et al. measured amplitude of accommodation without refractive correction to avoid the need for auxiliary lenses during near point measurement. By contrast, our finding is found to be quite similar to Ripple's.[8] He found a mean difference of 2.1D between 20 degrees upgaze and 40 degrees downgaze for the group having an amplitude ranging from 10D to 13D; although both studies used different techniques for measuring amplitude of accommodation, still a similar kind of result was obtained, which supports this study.[8] Ripple gave very few details of methodology. Our results also support Gallagher's findings, as they found significant changes in amplitude of accommodation, more in downgaze as compared to upgaze.[20] Different methodology was once again used compared to our study. Gallagher, in his unpublished thesis, used 12 eyes of 8 subjects, aged 13 to 42 years, for the head facing upward, straight ahead, and downward. He measured far point and near point with the Badal optometer and the push-up method. Significant changes in the near point and amplitude, but not the far point, were found for all subjects. Amplitude of accommodation was significantly increased from the head upward (mean 5.6D) to downward (mean 6.7D) position.[20]

The weakness in this study were that parameters such as palpebral fissure height, intraocular pressure, and axial length, which might have altered the study results, were not assessed. Although several studies showed a positive influence of accommodation over the axial length and intraocular pressure, how these factors influence the measurement of amplitude of accommodation need to be assesed precisely. Due to the lack of supportive studies regarding the impact of palpebral fissure height over accommodation, we can not say surely that it influences our study results, but this issue also needs to be assessed in the future.

Conclusion

Vertical viewing angle has a significant effect on the amplitude of accommodation, with amplitude of accommodation increasing with a declination of vertical gaze. There was a statistically significant difference observed in the amplitude of accommodation by race at only 20 degrees downgaze. Gender showed no effect in amplitude of accommodation in any of the four vertical viewing angles.

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