Effect of Low Plus Lenses on Fixation Disparity in Sustained Near Work Users

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Abstract

This paper investigated the effect of low plus lenses on fixation disparity and other associated heterophorias as well as accommodative lag. Asthenopia symptoms have become prevalent due to the extensive use of digital devices. One treatment approach to alleviate these symptoms involves prescribing anti-fatigue lenses.

Eighty participants were randomly assigned to two groups. Each participant underwent a comprehensive examination. This paper focused on the effect of low plus lenses on fixation disparity, assessed after a 30-minute near task, with and without low plus lenses, using Wesson's card.

Consistent with previous reports, most participants exhibited increased exo-fixation disparity, exo-heterophoria, and accommodative lag without low plus lenses after the 30-minute near task. Similar results were observed when low plus lenses were used, except for accommodative lag, which was lower when using low plus lenses. A correlation was found between fixation disparity and heterophoria in both groups, but no correlation was observed with accommodative lag.

Low plus lenses appear to affect fixation disparity and heterophoria, causing them to shift towards the exo-direction, which may stress the vergence system and lead to asthenopic symptoms, especially in patients with exo-fixation or exo-heterophoria. However, these lenses may be beneficial for patients with accommodative anomalies. It is suggested that optometrists perform binocular vision assessments before prescribing low plus lenses.

Keywords: *Fixation Disparity, Heterophoria, Accommodative Lag, Asthenopia, Low Plus Lens, Antifatigue Lens, Digital Eye Strain*

1. Introduction

Nowadays, the extensive use of digital devices for work, education, and entertainment has led to a condition known as digital eye strain. Optometrists are increasingly dealing with this issue. In the past, optometrists prescribed low plus lenses for accommodative support to alleviate symptoms in individuals who frequently used digital devices at close range (Iyer, & Harris, 2013; Press, 1985). At present, however, lens companies have introduced antifatigue lenses (Del Mar Seguí-Crespo et al., 2022), which they claim can alleviate symptoms of digital eye strain. Nevertheless, it is important to note that the accommodative system works in conjunction with the vergence system to achieve optimal binocular vision at close distances (Goss, 1995; London, & Crelier, 2006; Vojnikovi, & Tamajo, 2013).

From previous studies (Jaiswal et al., 2019), it has been found that prolonged use of binocular vision at close range leads to an increase in accommodative lag and heterophoria, particularly exophoria. Additionally, fixation disparity also tends to increase, indicating an exo-deviation (Pickwell et al., 1987). The mechanism behind the use of low plus lenses involves reducing accommodative lag, which in turn can affect the vergence system. This study focuses on the interaction between the accommodative and vergence systems (Sreenivasan, & Bobier, 2015), particularly on fixation disparity (Švede et al., 2011). During prolonged near vision tasks, the closed-loop feedback system should create a neuromuscular bias to sustain fixation near and prevent the eyes from drifting (Hung, 1992, 1997; Jainta et al., 2010; Jainta, & Jaschinski, 2010; Jaschinski, 2017; Jaschinski et al., 2010). While low plus lenses may alleviate symptoms of digital eye strain, it is essential to consider the potential side effects. Thus, this study aims to investigate the effects of these lenses on fixation disparity and associated binocular vision parameters, including accommodative lag and heterophoria, before and after using the lenses for 30 minutes at near distance.

2. Objectives

1) To study the effect of low plus lenses on fixation disparity

2) To compare heterophoria and fixation disparity before and after the use of low plus lenses

3) To demonstrate changes in accommodative lag, fixation disparity, and heterophoria after the use of low plus lenses

4) To compare fixation disparity, accommodative lag, and heterophoria with and without low plus lenses during a 30-minute near task

3. Materials and Methods

This study used a prospective, randomized, single-blind, controlled trial, methodology. Participants were recruited through a snowball sampling method, where existing participants were encouraged to refer colleagues. Inclusion criteria consisted of individuals aged between 20 and 35 years, with a visual acuity no worse than 20/30 and stereopsis no worse than 40 seconds of arc. Exclusion criteria included strabismus, neurological abnormalities affecting eye fixation, and ocular diseases. A sample size of 78 participants was calculated using G Power 3.1.9.7, with an alpha level of 0.05, a beta level of 0.95, and an effect size of 0.76 derived from the mean difference in a previous study (Pickwell et al., 1987). The author intended to use 80 participants, and the participants were randomly assigned to one of two groups after a comprehensive examination. They were unaware of their group assignment and the type of lens they were using.

Each participant was informed of the purpose of the experiment and asked to consent before beginning. During the eye examination, in the unlikely event that any pathology was detected requiring medical attention, the participant was referred according to local protocols and excluded from the research study. The examiner conducted comprehensive eye examinations, including refractive measurements, binocular vision assessments, and anterior and posterior eye segment evaluations. Additionally, fixation disparity was assessed with Wesson's card to investigate binocular vision for this paper (Dittemore et al., 1993; van Haeringen et al., 1986), while heterophoria was measured using the prism-dissociated method (Schroeder et al., 1996), and accommodative lag was measured by the monocular estimate method with retinoscopy. At the end of the eye examination, participants were divided into two groups by a random number assignment. If the random number was odd, the participant was allocated to Group A; if even, to Group B. These two groups underwent different experiments in phase one. Group A did not use low plus lenses (+0.75D), whereas Group B did. If a participant had a refractive error, they wore a trial frame consisting of the best-corrected lenses. The experiment was divided into two phases, with a 30-minute duration between phases. In phase one, participants were asked to perform near tasks at 50 cm using the digital devices they typically use. After completing phase one, the examiner measured fixation disparity, accommodative lag, and heterophoria. Following these measurements, participants were instructed to rest by walking around the Faculty of Optometry and refraining from engaging in near tasks for 15 minutes. Once phase two began, the two groups switched the use of low plus lenses, with group A using them and group B not using them.

Participants then performed near tasks for another 30 minutes. After completing phase two, the examiner re-measured fixation disparity, heterophoria, and accommodative lag.

In the statistical analysis, the Shapiro-Wilk test was employed to assess the normality of continuous variables separately within each group. Parametric and non-parametric analyses were then used as appropriate. When correlations were investigated, Spearman's correlation was used if one or more variables had a non-parametric distribution. Because the normality test showed that most variables, such as fixation disparity and accommodative lag, did not follow a normal distribution in both groups, and only heterophoria was normally distributed in group B, it was more appropriate to analyze them using non-parametric statistics, which are more suitable for such results. To compare between phases of the experiment, the Wilcoxon signed-rank test was used when a non-parametric distribution was obtained. Between groups, the Mann-Whitney U test was utilized.

4. Results and Discussion

4.1 Results

All 80 participants were equally divided into two groups. The mean age of the participants across the groups was 23.21 ± 3.32 years. Participants were randomly assigned to one of two groups. Group A used low plus lenses during phase two of the near task, while Group B used low plus lenses during phase one. All binocular vision parameters between the groups are presented in Table 1.

Table 1 Descriptive statistics for accommodative and binocular functions in both groups

	Group A **Median/IQR**	**Group B** **Median/IQR**
Age	23 (21 to 24)	23 (21 to 24)
Amplitude of Accommodation	10.00/ (8.50 to 10.88)	10.00 (8.50 to 10.88)
Accommodation lag	+0.75 (+ 0.50 to +0.75)	+0.75 (+0.50 to +0.75)
Accommodation lag phase 1	+0.75 (+0.50 to +0.75)	+0.50 (+0.25 to +0.50)
Accommodation lag phase 2	+0.38 (+0.25 to +0.69)	+0.63 (+0.50 to +0.75)
Phoria Distance	-1.75 (-4.00 to 0.00)	-2.00 (-3.00 to 0.00)
Phoria Near	-7.50 (-10.00 to -5.00)	-8.00 (-11.37 to -4.00)
Phoria Near phase 1	-7.00 (-9.75 to -6.00)	-9.00 (-12.00-6.00)
Phoria Near phase 2	-9.00 (-12.00 to -6.00)	-8.00 (-9.75-4.00)
Near Fixation disparity	-8.6 (-8.6 to -4.3)	-8.6 (-8.6 to -4.3)
Near Fixation disparity phase 1	-4.3 (-8.6 to -4.3)	-4.3 (-8.6 to -4.3)
Near Fixation disparity phase 2	-4.3 (-4.3 to -11.8)	-4.3 (-8.6 to 0.00)
Base in blur	18.0 (15.00 to 22.00)	20.00 (15.00 to 22.00)
Base in break	23.00 (20.00 to 25.00)	24.00 (18.50 to 28.00)
Base in recovery	12.00 (12.00 to 18.00)	12.00 (8.00 to 18.00)
Base out blur	18.00 (12.00 to 26.00)	0.00 (0.00 to 18.00)
Base out break	24.00 (17.50 to 30.00)	20.00 (14.00 to 30.00)
Base out recovery	7.00 (5.00 to 12.00)	8.00 (6.00 to 16.00)

In phase one, Group A exhibited no statistically significant difference in fixation disparity before and after the 30-minute near task (p=0.416), and the same result was observed in phase 2 (p=0.940). Similarly, Group B showed no statistically significant difference in fixation disparity during phase one (p=0.904) but showed a statistically significant difference in phase two (p=0.006) All statistical results are listed in Tables 2 and 3.

Table 2 Comparison between baseline, phase one and phase two fixation disparity, heterophoria and accommodative lag in Group A

	Baseline Group A Median/IQR	**Phase 1 Group A Median/IQR**	**Willcoxon Baseline/ phase 1**	**Phase 2 Group A Median/IQR**	**Willcoxon Phase 1/ Phase 2**
Fixation disparity	-8.6 (-8.6 to -4.3)	-4.3 (-8.6 to -4.3)	0.992	-4.3 (-4.3 to -11.8)	**<0.001**
Heterophoria	-7.50 (-7.50 to -5.00)	-7.00 (-9.75 to -6.00)	0.992	-9.00 (-12.00 to -6.00)	**<0.001**
Accommodative lag	+0.75 (+0.50 to +0.75)	+0.75 (+0.50 to +0.75)	0.883	-0.38 (+0.25 to +0.69)	**<0. 001**

As seen in Table 2, heterophoria in Group A was not significantly different from baseline heterophoria after Phase 1 (0.992) but was significantly different from baseline after Phase 2 (<0.001). For accommodative lag, Group A Phase 1 did not differ from baseline (0.883), but Phase 2 was significantly different from baseline (<0.001). In Group A, there were no significant differences between baseline and Phase 1 or Phase 2 findings for fixation disparity.

Table 3 Comparison between baseline, phase one and phase two fixation disparity, heterophoria and accommodative lag in Group B

	Baseline Group B Median/IQR	**Phase 1 Group B Median/IQR**	**Willcoxon Baseline/phase 1**	**Phase 2 Group B Median/IQR**	**Willcoxon Phase 1/ Phase 2**
Fixation disparity	-8.6 (-8.6 to -4.3)	-4.30 (-8.6 to -4.3)	0.940	-4.3 (-8.6 to 0.00)	**0.006**
Heterophoria	-8.00 (-11.4 to -4.00)	-9.00 (-12.00 to -6.00)	**0.002**	-8.00 (-9.75 to-4.00)	**<0.001**
Accommodative lag	+0.75 (+0.50 to +0.75)	+0.50 (+0.25 to +0.50)	**<0.001**	+0.63 (+0.50 to +0.75)	**<0.001**

As seen in Table 3, heterophoria in Group B was significantly different from baseline in both Phase 1 (0.002) and Phase 2 (<0.001). Accommodative lag in Group B differed significantly from baseline in both Phase 1 (<0.001) and Phase 2 (<0.001). In Group B, Fixation disparity was not significantly different in Phase 1 compared to baseline (0.940) but Phase 2 was significantly different from baseline (0.006).

Table 4 Comparison between Group A and Group B in fixation disparity, heterophoria and accommodative lag measurements

	Group A Median/IQR	**Group B Median/IQR**	**Mann-Whitney U Test**
Fixation disparity baseline	-8.6 (-8.6 to -4.3)	-8.6 (-8.6 to -4.3)	0.501
Fixation disparity phase one	-4.3 (-8.6 to -4.3)	-4.3 (-8.6 to -4.3)	0.905
Fixation disparity phase two	-4.3 (-4.3 to -11.8)	-4.3 (-8.6 to 0.00)	0.192
Heterophoria baseline	-7.50 (-10.00 to -5.00)	-8.00 (-11.37 to -4.00)	0.858
Heterophoria phase one	-7.00 (-9.75 to -6.00)	-9.00 (-12.00 to -6.00)	0.080
Heterophoria phase two	-9.00 (-12 to -6.00)	-8.00 (-9.75 to -4.00)	**0.048**
Accommodative lag baseline	+0.75 (+0.50 to 0.75)	+0.75 (+0.50 to +0.75)	0.885
Accommodative lag phase one	+0.75 (+0.50 to +0.75)	+0.50 (+0.25 to +0.50)	**<0.001**
Accommodative lag phase two	+0.38 (+0.25 to +0.69)	+0.63 (+0.50 to +0.75)	**<0.002**

As seen in Table 4, there was no significant difference in baseline, phase one, or phase two fixation disparity measurements when comparing Group A and Group B. Similarly, heterophoria baseline and phase one measurements did not differ, but there was a significant difference between Group A and Group B in the phase two heterophoria measurements (p=0.048). Additionally, a significant difference between Group A and Group B was found in accommodative lag measurements in phase one (<0.001) and phase two (<0.002), but no difference was found in baseline measurements.

Table 5 Correlation between confounding factors with fixation disparity in phase one

Group A		**Fixation disparity (Phase 1)**	**Near Heterophoria (Phase 1)**	**Accommodative lag (Phase 1)**
Fixation disparity (Phase 1)	r	1.00	0.422	0.078
	p		0.007	0.632
Near Heterophoria (Phase 1)	r	0.422	1.00	0.025
	p	0.007		0.879
Accommodative lag (Phase 1)	r	0.078	0.025	1.00
	p	0.632	0.879	
Group B		Fixation disparity (Phase 1)	Near Heterophoria (Phase 1)	Accommodative lag (Phase 1)
Fixation disparity (Phase 1)	r	1.00	0.464	-0.049
	p		0.003	0.762
Near Heterophoria (Phase 1)	r	0.464	1.00	0.005
	p	0.003		0.973
Accommodative lag (Phase 1)	r	-0.049	0.005	1.00
	p	0.762	0.973	

Table 6 Correlation between confounding factors with fixation disparity in phase two

Group A		**Fixation disparity (Phase 2)**	**Near Heterophoria (Phase 2)**	**Accommodative lag (Phase 2)**
Fixation disparity (Phase 2)	r	1.00	0.452	0.059
	p		0.003	0.719
Near Heterophoria (Phase 2)	r	0.452	1.00	0.101
	p	0.003		0.535
Accommodative lag (Phase 2)	r	0.059	0.101	1.00

	p	0.719	0.535	
Group B		Fixation disparity (Phase 2)	Near Heterophoria (Phase 2)	Accommodative lag (Phase 2)
Fixation disparity (Phase 2)	r	1.00	0.398	-0.136
	p		0.011	0.402
Near Heterophoria (Phase 2)	r	0.398	1.00	0.030
	p	0.011		0.855
Accommodative lag (Phase 2)	r	-0.136	0.030	1.00
	p	0.402	0.855	

In Spearman's correlation analysis between fixation disparity, heterophoria, and accommodative lag, fixation disparity showed a correlation with heterophoria of r=0.509, p<0.001 in Group A at baseline in phase one. In phase one, both Group A and Group B exhibited correlations between fixation disparity and heterophoria (r=0.422, p=0.007; r=0.464, p=0.003, respectively). In phase two, however, a correlation between fixation disparity and heterophoria was only found in Group A. All statistical results are listed in Tables 5 and 6.

4.2 Discussion

In this study, the researchers explored how low plus lenses impact the treatment of asthenopia, focusing on their capacity to affect fixation disparity, heterophoria, and accommodative lag. The objective was to understand how these lenses affect vergence eye movements, given the changes in vergence and accommodation associated with near tasks and electronic device use (Jaiswal et al., 2019; Rosenfield et al., 1994). This can result in increased exo-fixation disparity (Jaschinski, 2017), exo-heterophoria, and increased accommodative lag. In the initial experiment, two groups were assigned different conditions: Group A did not use low plus lenses, while Group B used them for 30 minutes after the experiment. In Group A, fixation disparity changed by 0.97 exo-fixation disparity, while heterophoria changed by 0.08 exophoria, and accommodative lag increased by +0.006D, consistent with previous findings (Padavettan et al., 2021). In Group B, fixation disparity decreased by 0.26 exo-fixation disparity, while heterophoria increased by 1.5 exo, and accommodative lag decreased by 0.25D, indicating effects attributable to the low plus lenses, consistent with findings using +2.00D low plus lenses (Sreenivasan et al., 2008). The second experiment confirmed the effects of low plus lenses on fixation disparity by switching their use between groups: Group A used low plus lenses, while Group B did not. In Group A, fixation disparity changed slightly, heterophoria increased, and accommodative lag decreased. In Group B, fixation disparity decreased significantly, heterophoria decreased, and accommodative lag increased, confirming the effects of low plus lenses. Correlation analysis revealed a statistically significant correlation between fixation disparity and heterophoria, but not with accommodative lag. Using low plus lenses increased exo-fixation disparity (Wick, & Joubert, 1988) and decreased accommodation, leading to changes in heterophoria similar to fixation disparity. However, accommodative lag decreased (Sreenivasan et al., 2008), contradicting the accommodation response to increased exo-fixation disparity, consistent with research using +2.00D plus lenses. The choice of using low plus lenses with a power of +0.75D was based on studies determining the most appropriate power, considering participants' preferences (Yammouni, & Evans, 2020, 2021). However, the impact on binocular vision was not discussed, and it was advised that these lenses be used for patients with eso-fixation disparity. However, most participants in both groups had exo-fixation disparity and exo-heterophoria, making it difficult to draw conclusions about the impact of the lenses on binocular vision. Although changes in fixation disparity were observed, they were not statistically significant, except for Group B in the second experiment. Future studies should employ more precise measurement tools with objective methods, as subjective techniques could introduce errors. Overall, the study demonstrated that low plus lenses affect fixation disparity, heterophoria, and accommodative lag, with statistically significant changes observed. However, significant changes were only observed in heterophoria and accommodative lag, suggesting that low plus lenses may be beneficial to patients with high accommodative lag, but should be used cautiously in patients with exo-fixation disparity and exo-heterophoria.

5. Conclusion

This research demonstrates that the use of low plus lenses affects fixation disparity, heterophoria, and accommodative lag. While there was no statistically significant change in fixation disparity, significant changes were observed in heterophoria and accommodative lag, suggesting that prolonged near work may lead to changes in fixation disparity towards exo and heterophoria towards exo, with a decrease in accommodative lag. In clinical practice, low plus lenses may benefit patients with accommodative anomalies but should be prescribed cautiously to those with exo-fixation disparity and exo-heterophoria to avoid symptoms of eyestrain. Optometrists should evaluate binocular vision thoroughly before prescribing these lenses.

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7. References

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