The Effects of Vertical Yoked Prism on Horizontal Dissociated Heterophoria

Vertical yoked prisms (VYPs) are prisms with the same magnitude over each eye and with the bases orientated in the same direction, either base up (BU) or down (BD). Prisms cause light rays from an object to deviate towards the prism base, which in turn shifts the image in the opposite direction towards the prism apex. The amount of deviation is proportional to the power of the prism and the distance of the object. VYPs also change spatial perception by shifting the image vertically and altering the magnification along the base-apex axis with greater magnification of objects viewed towards the apex compared to objects viewed toward the base.[1]

The optical effects and distortions of VYPs have formed the basis of their use to treat aesthenopic symptoms and modify body posture and aspects of movement. Birnbaum[2] described BU VYP as “spatially compressive, creating decreased size, decreased distance, downward spatial shift, and downward gaze shift, associated with convergence…” with the opposite effect occurring with BD prism. Kaplan stated that, by modifying object percept qualities such as size and direction, VYPs also modify visuo-motor responses. [3]

Kaplan[3] also recommended the use of VYP for treatment of ‘vergence malfunction’ with low powers such as 2-3Δ[4] used for constant wear spectacles and higher powers (5Δ or greater) used for training.[3] The stated rationale behind VYP use for vergence disorders includes (1) VYPs cause vertical image displacement, resulting in a vertical eye movement and (2) the optical distortion of space produced by the VYPs leads to an alteration of vergence.[2,]

[4] Moreover, Kaplan, in one brief case report, suggested that the dissociated heterophoria (hereafter, ‘phoria’ will refer to dissociated heterophoria) changes with VYP wear.[4]

According to the classical Maddox viewpoint of vergence[5], the convergence required to view a target consists of tonic, accommodative, proximal and fusional vergence. If fusion is prevented, such as when measuring a phoria, the position of the eyes is determined by tonic, accommodative, and proximal vergence. If the spatial distortions caused by VYPs change one of these sufficiently, the magnitude of the phoria should change. For example, the spatial distortions caused by VYP might alter proximal awareness, the perceived distance of a target, and in turn change either or both proximal vergence and proximal accommodation, thus influencing the measured phoria.

The effect of VYPs on binocularity is unknown. Despite the claim that VYPs alter convergence and divergence,[4] no studies have investigated the effect of VYPs on phoria. We specifically ask in this study whether there is an immediate effect of VYP on the magnitude or direction of the phoria. We hypothesized that BU VYP, by nature of the reported downward and inward spatial shift associated with convergence[2] would result in a shift toward less exophoric or more esophoric. For similar reasons, BD VYP would result in an exophoric shift.

Methods

Subjects

This study adhered to the Declaration of Helsinki for research on human subjects and was approved by the UNSW Human Ethics Advisory

Panel. Written informed consent was obtained from all subjects after explanation of the nature and consequences of the study.

Inclusion criteria were distance and near corrected visual acuity of at least logMAR 0.20 or N8, respectively, in each eye, and no history of ocular pathology. Exclusion criteria included presence of amblyopia or strabismus, presence of vertical or horizontal prism of any kind in current spectacles, or a history of diplopia, previous ocular surgery, trauma, past or current vision training, patching, or past prismatic correction. Subjects were not excluded on the basis of magnitude or direction of phoria. Optometry lecturers and students from 3rd year and above in a 5-year program were excluded to ensure a more naïve sample with respect to expectations about possible effects of VYPs.

Procedure

Each participant's refractive error, if any, was corrected by full aperture trial lenses in a trial frame or by contact lenses. Horizontal phoria measurement was performed in primary gaze with the Modified Thorington technique. The Modified Thorington technique has been described elsewhere.[6] In short, the target is a card or board with a small central light, and numbers indicating the deviation magnitude. Dissociation is achieved by placing a red Maddox rod over one eye. Subjects were asked to look at the numbers on the card and to keep them clear, to encourage accurate accommodation. Subjects reported the number closest to the red (Maddox rod) line. Phoria magnitude was measured to the nearest 0.5 prism diopter. To avoid changes in posture, subjects were seated and head position was held constant by use of a head and chin rest.

The first baseline (without yoked prism) phoria findings were measured at distance (3m) and then at near (40 cm). The phorias were then measured again through the following magnitudes and directions of VYP randomly presented: 2Δ BU, 2Δ BD, 5Δ BU, and 5Δ BD, each at distance and then at near. Twenty -six of the 40 participants also had their phorias measured with control lenses of +0.125 DS OU (due to unavailability of Plano trial lenses) at distance and then at near. These control lenses were randomly presented among the other prism conditions. Randomization was achieved using Latin squares. All VYP and control lenses were fitted on the participant, in a trial frame, with correct vertical and horizontal centration. The first examiner positioned the lenses and Maddox rod. The second examiner instructed the patient and recorded the phorias without viewing the patient or prism/lenses, and was therefore masked as to which prisms/lenses the subject was wearing. The total wearing time of the prisms was less than 1 minute.

After recording, VYP or control lenses were removed for a 1-minute (min) rest period to limit any adaptation effects due to the previous lenses. This period was based on previous findings, regarding VYPs and gait, of an immediate return to baseline on prism removal[7]. A 2-min rest period was taken after the final test condition to further limit possible adaptation effects on the final (second) baseline phoria measurement.

Statistical analysis

The statistical program SPSS version 22 was used. The data were not normally distributed (Shapiro-Wilk normality test), so the nonparametric

Friedman test was used for comparisons across 3 or more related samples and the Wilcoxon signed-rank test was used for 2 related samples. Posthoc pairwise comparisons were not performed because the Friedman test showed no overall significant effect of condition. Analysis was performed on the sample as a whole and again on the subset of 11 subjects whose near baseline phorias were outside the norm of 0 to 6 Δ exo.[8]

Results

Subjects

Forty non-presbyopic subjects (26 female) participated in this study. Mean age was 19.2 +/- 2.0 (range 18-28) years. Thirty of the subjects were year 1 or 2 Optometry and/or Vision Science students.

Refractive error

The spherical equivalent refractive error was between +0.50 to -0.50 diopters (D) for 49% of eyes. Another 24% had mild myopia of -0.62 to -2.87D, 21% had moderate myopia of -3.00 to -5.87D, and 6% had more than 6.00D of myopia. Note that data from six anisometropes (1.00D or more difference in refractive error measured in vertical meridian) were included in our data analysis. Anisometropia in those six subjects ranged from 1.00 to 3.25 D, (mean 2.04 +/- SD 0.94D in the vertical meridian), and would have resulted in less than 0.50 Δ induced vertical prism in all cases.

Binocularity

The sample included some participants whose phorias were outside the normal range. Specifically, eleven subjects had nearpoint phorias outside the norms of 0 to 6 exo. The magnitude and direction of these phorias can be determined from figure 1.

VYPs and horizontal heterophorias

Tables 1 (distance) and 2 (near) give details of the results and statistical analyses. There was no significant difference overall between baseline and VYP phorias, between baseline and control phorias, nor between baseline and final post-wear phorias, at distance or near.

In the subset of eleven subjects with abnormal baseline near phoria, no significant difference in phoria was found ($p = 0.18$) between conditions. Figure 1 illustrates the relationship between near baseline phoria and phoria measured with the VYPs.

Insert Figure 1 near here

Discussion

Vertical yoked prisms did not immediately affect magnitude or direction of horizontal dissociated heterophoria when body posture was controlled in this sample of young nonstrabismic adults. The hypothesized esophoric shift with BU VYP and exophoric shift with BD VYP was not evident.

There are no previous studies concerning the effect of VYPs on dissociated phoria, and the present findings disagree with Kaplan's anecdotal report.[4] This may be due to methodological factors. For example, the present study was masked, a relatively large sample was used, and the method of phoria measurement controls accommodation well and is quite repeatable,[9-11] perhaps more so than the unspecified method used by Kaplan. Moreover, we looked at the possibility of an immediate effect, and Kaplan noted the change in phoria at a progress exam after an undisclosed duration of prism wear.[12]

The similarity of baseline findings to those with the control lenses suggests that the phoria measurement technique used here had no induced test condition bias.

Since VYPs may be recommended for near-point vergence disorders[3] such as convergence insufficiency or convergence excess, we wondered whether subjects with esophoria or high exophoria at near might exhibit different responses than those with normal near-point phorias. However, VYPs did not affect horizontal phorias on these subjects either. In addition, one of the subjects (baseline 18 Δ exo) always changed in the esophoric direction regardless of the base direction of VYPs, and another (baseline 14Δ exo) always changed in the exophoric direction.

Although we found no previous studies directly investigating the effect of VYP on phoria, the effects of gaze and eye position on horizontal phoria have been investigated. Both Stuart and Burian[13] and Osuobeni and Al-Amir[14] found that fairly large changes in vertical gaze result in minimal horizontal phoria changes. Extrapolating from data reported in these papers, one could predict, assuming linear changes in phoria during vertical gaze shifts, the 5Δ VYPs used in the current study would induce less than 1Δ horizontal phoria difference. This corresponds well with our findings that mean phorias did not change more than 0.28Δ.Thus any proposed effect of VYPs on horizontal phoria based entirely on optical shift of the image and resulting eye position is unlikely.

However, image shift is not the only optical effect of VYPs. For example, VYPs distort perceived visual space.[1] Perhaps this perceived distortion influences vision and related function over a more protracted period of time, in which case the period of prism wear used here may have been too brief to elicit a measurable change in phoria. Gizzi, et al[15], using horizontal YPs, found that changes in body posture became more evident over time. This suggests that some effects of yoked prism take place over time and are not immediate. On the other hand, Suttle et al (in press) found that changes in head posture with base down VYPs occurred only up to 10 minutes of wear, with constant head position from 10 to 30 minutes, suggesting that any such changes occur during a few minutes after prism wear.

Research on motor adaptation to horizontal yoked prism indicates that there is an initial effect of the prism followed by an adaptation while wearing the prism, and an after-effect when the prism is removed, indicating that the adaptation persists for some time after prism removal.[16] The initial effect is thought to be caused by the optical displacement by the prism.[17] Adaptation during prism wear involves modifying planned motor activity in response to feedback and error, a recalibration of visual space. After-effects are due at least in part to a spatial realignment of visuo-motor with perceptuo-motor maps (for review, see Redding, 2005[16]). The current study procedure included no motor task or feedback, so it would be unlikely that recalibration of visual space took place during the short time that VYPs were in place. This may explain the lack of an after-effect in the current study.

On the other hand, perhaps the VYPs in the current experiment induced an effect that was adapted to within the few seconds between initial prism wear and phoria testing, and thus was not evident. There is evidence that adaptation occurs quickly in some conditions. Huang and Ciuffreda[18] found egocentric localisation shifted initially in most participants wearing 20Δ BD VYP, with adaptation happening primarily within the first 30 minutes of prism wear. Redding found that prism adaptation to 20Δ horizontal YP, indicated by correction of initial pointing errors, occurred within the first minute of prism wear).[17] Both of these studies found an aftereffect. The lack of aftereffect seen in the current study makes it unlikely that an effect and subsequent adaptation occurred within seconds of prism wear.

Our sample consisted entirely of nonstrabismic subjects, most of whom demonstrated phorias of normal magnitude and direction. Although it is possible that those with poor or unstable binocularity might respond differently to VYPs, our small subsample of those with abnormal near phorias did not support this. However, further investigation into the effect of VYP on those with poor binocularity is warranted.

Conclusion

In summary, VYP did not exert any immediate effect on horizontal phoria in young adults when body posture was controlled. This suggests that if VYP do indeed improve binocularity, they do not do so by a direct or immediate impact on horizontal phoria. While our results do not support the therapeutic use of VYPs to immediately affect binocular alignment, further work is needed to confirm whether they can be beneficial in cases of vergence dysfunctions such as convergence insufficiency or excess.

Acknowledgements: This study was presented as a poster at the Association for Research in Vision and Ophthalmology (ARVO) meeting in Orlando Florida in May 2014. We gratefully acknowledge the helpful reviews by the anonymous reviewers.

References

1. Ogle KN. Researches in Binocular Vision. Philadelphia: WB Saunders Company; 1950, p. 130-132.

2. Birnbaum MH. Optometric Management of Nearpoint Vision Disorders. Stoneham, MA: Butterworth-Heinemann; 1993, p. 186-189.

3. Kaplan M. Vertical Yoked Prisms. In: Optometric Extension Program Continuing Education Courses. Santa Ana, California: Optometric Extension Program Foundation; 1978-1979. p. 1-6.

4. Kaplan M. Vertical yoked prisms. In: Opotmetric Extension Program Continuing Education Courses. Santa Ana, California: Optometric Extension Program Foundation; 1978-1979. p. 21-8.

5. Schor CM, Ciuffreda KJ, editors. Vergence Eye Movements: Basic and Clinical Aspects. Boston: Butterworths; 1983, p. 16.

6. Scheiman M, Wick B. Clinical Management of Binocular Vision. Philadelphia, PA: Lippincott Williams & Wilkins; 2008, p 9 and 38-40.

7. Errington JA, Menant JC, Suttle CM, Bruce J, Asper LJ. The effects of vertical yoked prisms on gait. Invest Ophth Vis Sci 2013;54:3949-56.

8. Scheiman M, Wick B. Clinical Management of Binocular Vision. Philadelphia, PA: Lipincott Williams & Wilkins; 2008.

9. Rainey BB, Schroeder TL, Goss DA, Grosvenor TP. Inter-examiner repeatability of heterophoria tests. Optom Vis Sci 1998;75:719-26.

10. Wong EP, Fricke TR, Dinardo C. Interexaminer repeatabiity of a new, modified Prentice card compared with established phoria tests. Optom Vis Sci 2002;79:370-5.

11. Goss DA, Reynolds JL, Todd RE. Comparison of four dissociated phoria tests: Reliability and correlation with symptom survey scores. Journal of Behavioural Optometry 2010;21:99-104.

12. Kaplan M. Vertical yoked prisms. In: Optometric Extension Program Continuing Education Courses. Santa Ana, California: Optometric Extension Program Foundation; 1978-1979. p. 2.

13. Stuart JA, Burian HM. Changes in horizontal heterophoria with elevation and depression of gaze. Am J Ophthalmol 1962;53:274-9.

14. Osuobeni EP, Al-Amir OM. Gaze-related near heterophoria incomitance. Clin Exp Optom 1996;779:76-81.

15. Gizzi M, Khattar V, Eckert A. A quantitative study of postural shifts induced by yoked prisms. J Optom Vis Dev 1997;28:200-3.

16. Redding GM, Rossetti Y, Wallace B. Applications of prism adaptation: A tutorial in theory and method. Neurosci Biobehav Rev 2005;29:431-44.

17. Redding GM, Wallace B. First-trial adaptation to prism exposure. J Mot Behav 2003;35:229-45.

18. Huang MA, Cuiffreda KJ. Short-term adaptation to vertical yoked prisms. Optom Vis Sci 2006;83:242-8.

Figure legend:

Figure 1: Near (40 cm) phorias through BU (A) and BD (B) plotted against near baseline phoria. Data points above the diagonal line indicate a shift in phoria to the eso direction and those below indicate a shift in phoria to the exo direction.

Figure 1

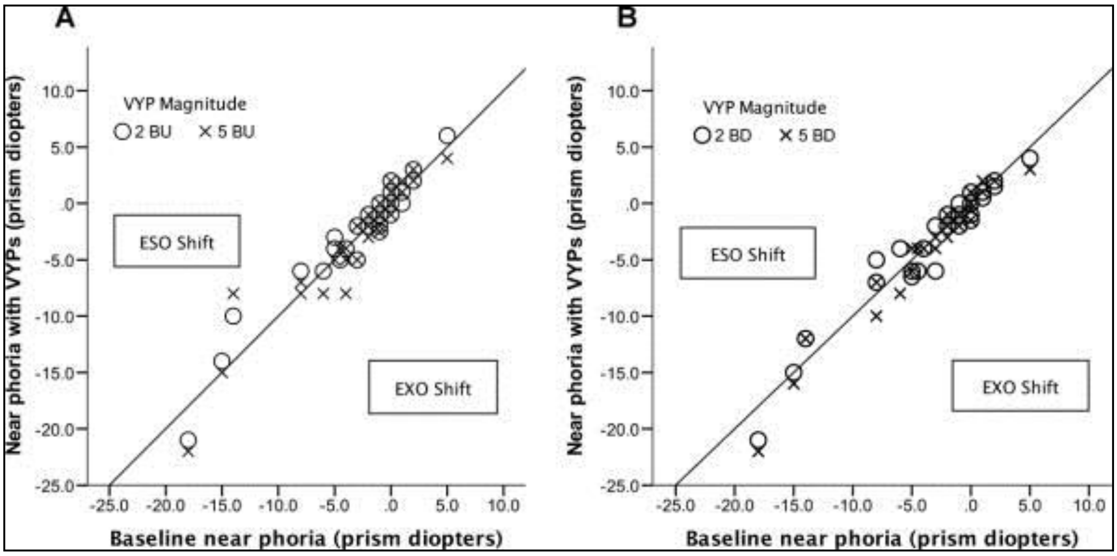
A
VYP Magnitude
2 BU
5 BU
ESO Shift
EXO Shift
Near phoria with VYPs (prism diopters)
Baseline near phoria (prism diopters)
B
VYP Magnitude
2 BD
5 BD
ESO Shift
EXO Shift
Near phoria with VYPs (prism diopters)
Baseline near phoria (prism diopters)

Table 1.
Mean, Standard deviation (SD), and statistical results for the distance dissociated heterophoria in all test conditions. A negative mean difference indicates that subjects became more exo compared to baseline. n = number of subjects

	3 M Dissociated Heterophoria					
Test condition	Mean (Δ)	SD (**Δ)**	Mean Difference from Baseline (**Δ)**	n	Test Statistic	Degrees of Freedom (or Effect Size (ES)
Baseline	1.2 exo	2.6	0	40		
5 BD	1.3 exo	2.5	-0.1	40		
2 BD	1.0 exo	2.6	0.2	40	X^2 = 8.38	df = 4
2 BU	1.0 exo	2.5	0.2	40		
5 BU	1.2 exo	2.6	0.0	40		
+-.125 Control	0.9 exo	2.5	-0.3	26	T = 36.0, Z = -1.40	ES = -0.19
2^{nd} Baseline	0.9 exo	2.3	0.3	40	T= 133.5, Z = -1.37	ES = -0.15

Table 2.
Mean, SD and statistical results for the near dissociated heterophoria for all test conditions. A negative mean difference indicates that subjects became more exo compared to baseline. n = number of subjects

	40 cm Dissociated Heterophoria					
Test condition	Mean (**Δ**)	SD (**Δ**)	Mean Difference from Baseline (**Δ**)	n	Test Statistic	Degrees of Freedom (or Effect Size (ES)
Baseline (n=40)	2.6 exo	4.6	0.0	40	X^2 = 6.72	df = 4
5 BD	2.8 exo	5.0	-0.2	40		
2 BD	2.7 exo	4.7	-0.1	40		
2 BU	2.4 exo	4.6	0.2	40		
5 BU	2.7 exo	4.9	-0.1	40		
+-.125 Control	2.2 exo	4.4	-0.1	26	T = 26.5 Z = -0.60	ES = -0.08
2nd Baseline	2.8 exo	4.7	-0.2	40	T= 154.5, Z = -0.84	ES = -0.09