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Effects of 10 minutes Opened-Loop Vergence training on accommodation parameters

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Abstract

Monocular pencil push-up training (PPT), is usually prescribed to improve accommodation abilities monocularly, such as in accommodation weakness and unequal accommodation conditions. This study investigated the 10 minutes effects of the monocular PPT exercise, as opened-loop vergence training, on the accommodation parameters. Ten normal young adults with a mean age of 23.3 ± 1.0 years participated in this study. Four components of accommodation were tested. They were the amplitude of accommodation (AA), the accommodative response, the accommodative facility and the relative accommodation. The baseline data were conducted prior to the PPT, and were assessed again, immediately after the PPT was performed for 10 minutes on the right eye. The results showed that the 10 minutes of monocular PPT significantly changed the AA with the RE AA increasing from 11.10 D to 12.80 D ($F(1, 9) = 11.13$; $p = .009$), LE increased from 11.48 D to 13.74 D ($F(1, 9) = 9.93$; $p = .014$) and binocular AA from 13.10 D to 14.73 D ($F(1, 9) = 8.81$; $p = .016$). No significant changes were found on the other accommodation parameters. This study concluded that the 10 minutes of monocular PPT had changed the AA monocularly and binocularly but not the other accommodation parameters. It showed that the monocular PPT is effective as a therapy for accommodation insufficiency problems, with close monitoring of the patient's progress to avoid possible induction of accommodation spasm or convergence excess.

Key words—visual therapy, accommodation, vergence, opened-loop system

I. INTRODUCTION

The monocular pencil push-up training (PPT) is a variation of binocular PPT. It is commonly prescribed to enhance the amplitude of accommodation (AA) monocularly. Patients who require this exercise usually have a low accommodation capability such as in cases of accommodation insufficiency, accommodation weakness as well as in cases of unequal accommodation between the eyes (Scheiman & Wick, 2008). The monocular PPT is often prescribed as a home-based accommodation therapy for its ease of execution.

The model of oculomotor control (Hung, 2001) explains the interactions between accommodation and vergence in a mathematical model to define the functions of the two systems within a negative feedback driven closed-loop mechanism. This feed-back control theory has been used to describe both static and dynamic interactions between vergence and accommodation systems. During monocular PPT, the closed-loop interaction between accommodation and vergence is disrupted hence affecting the negative feedback mechanism between the two systems.

It is an interest of this study to observe the possibility of fatigue tonic adaptation of accommodation that can cause changes to cross-link interactions. Schor and Tsuetaki (1987) in their study found that excessive tonic adaptation of accommodation is reduced, and brought into balance with adaptable tonic vergence by repetitious cyclic stimulation of accommodation. However, there is another characteristic of this cross-link relationship that may restrict the changes in the vergence system when tonic of accommodation is reduced. It is the filter that is placed at the output of the feedback models which acts as a saturation limit to the amplitude of tonic adaptation. This filter serves to limit the enhancement of cross-link interactions by tonic adaptation (Schor, 1992).

Studies on the effects of accommodative adaptation on the vergence and accommodation system have been reported by several researchers. Rosenfield and Gilmartin (1990) investigated the effects of a change in the target distance on the opened-loop accommodative responses. They found that the level of accommodative adaptation with respect to stimulation of accommodation by target proximity will influence the accommodative responses even when both blur and vergence cues have been dissociated. Cheng et al. (2008) studied the effects of positive lenses and base-in prism on the accommodative errors measured as lag of accommodation, and the horizontal near phoria. Their data clearly showed that positive lenses before the eyes at near will reduce the lag of accommodation but results in large exophoric shift. This indicates that altering the accommodative status could result in the same alteration of the vergence posture. However, their study did not show what happens if the changes were made while either one or both of the systems is under an open-loop condition.

A study by Sreenivasan et al. (2008) on the effects of binocular adaptation to near addition lenses in emmetropic adults explains that the changes occur on the vergence and accommodative systems. They evaluated the changes to accommodation and vergence responses when the subjects sustained fixation at 33 cm while wearing +2 D lenses.The results demonstrated that the introduction of near addition lenses reduced the excessive lags of accommodation, initiated an increase in convergence and thereby increased the convergence driven accommodation. Brautaset and Jennings (2006) studied on the effects of binocular PPT on convergence insufficiency (CI) which showed only improvement on the binocular amplitude of accommodation but not the monocular amplitude of accommodation. In addition, they also found that the NPC, the near associated phoria and the PFV at near were all improved. The results indicated an enhanced disparity-driven fast vergence after the training.

Although there were some researchers studying the effect of opened-loop vergence training and adaptation to accommodation stimulus, no report on the immediate effect of the therapy on accommodative components have been documented so far. Furthermore, no known study has been attempted to see the performances of monocular PPT on the accommodation system as the PPT is commonly prescribed binocularly in an attempt to improve the amplitude of convergence. Hence, the objective of this study is to investigate the effect of 10 minutes of monocular PPT on the accommodation parameters.

II. METHODS

Ten young adults with a mean age of 23.3 ± 1.0 years old were randomly identified and their suitability was selected based on the inclusion and exclusion criteria of the study. The collection of data was conducted in two sessions, which was session 1 and session 2. Session 1 (pre-PPT) involved a comprehensive optometric examination and the pre-PPT measurement of the accommodation parameters. Session 2 (post-PPT), was performed in less than a week's interval, and entailed 10 minutes monocular PPT followed by a measurement of the accommodation parameters. The measurement of the accommodation parameters included four components of accommodation. They were the accommodative amplitude (AA) using RAF rule, the accommodative response using MEM retinoscopy, the accommodative facility using ±2.00 DS and the relative accommodation using lens rack. These accommodation statuses were performed while the subjects were viewing the target at a symmetrical convergence position.

The data from the pre-PPT and post-PPT were tested using one-way repeated measures ANOVA. The Bonferroni multiple comparison adjustment was used to observe the effect of the monocular PPT on the accommodation parameters.

III. RESULTS

The comparison of the accommodation parameters between pre and post 10 minutes monocular PPT are presented in the Table 1.

The mean of the right eye AA had significant increment of the amplitude after the training. The right eye AA increased by 1.70 D from 11.10 D to 12.80 D with $F(1,9) = 11.13$ D with significant value $p < 0.05$. The mean left eye AA also had a same pattern of changes in which the amplitude increased by 2.26 D after the 10 minutes monocular PPT from 11.48 D to 13.74 D. As for the left eye AA, it showed $F(1,9) = 9.93$; $p < 0.05$. These values showed that the changes were highly significant. The mean difference between pre and post monocular PPT for binocular AA was 1.63 D, with an increase from 13.10 D to 14.73 D. This pattern of changes followed the monocular increment of the monocular AA. The statistical values supported the observation in which $F(1,9) = 8.81$ with significant value $p < 0.05$. This also indicated significant changes of the binocular AA after the 10 minutes monocular PPT.

As for the mean accommodative response, both eyes had almost an equal change after the 10 minutes monocular PPT. However, these changes were not statistically significant. The mean right eye accommodative response only increased by 0.05 D ($F(1,9) = 1.00$; $p = 0.34$) and the mean left eye accommodative response only had an increment of 0.07 D ($F(1,9) = 1.98$; $p = 0.19$).

Table 1 *Comparison of the accommodation parameters of pre and post of 10 minutes monocular PPT*

Accommodation Parameters		**Mean Pre-PPT Data**	**Mean Post-PPT Data**	**p**
AA (D)	RE	11.10	12.80	0.01*
	LE	11.48	13.74	0.01*
	BE	13.10	14.73	0.02*
Accommodative Response (D)	RE	0.45	0.50	0.34
	LE	0.43	0.50	0.19
Accommodative Facility (cpm)	RE	10.45	11.10	0.42
	LE	10.20	9.95	0.83
	BE	8.40	7.65	0.53
Relative Accommodation (D)	NRA	2.50	2.58	0.54
	PRA	3.93	3.98	0.72

*assumption of significant difference when $p < 0.05$

For the mean accommodative facility results, no significant changes were found between before and after the 10 minutes monocular PPT. The mean right eye accommodative facility only increased by 0.65 cpm while the mean left eye accommodative facility only had a decrement of 0.25 cpm. Statistical analysis showed changes were $F_{1,9)} = 0.72$; $p = 0.42$ for the right eye and $F_{(1,9)} = 0.05$; $p = 0.83$ for the left eye. The mean binocular accommodative facility meanwhile had decreased by 0.75 cpm after the 10 minutes monocular PPT with $F_{(1,9)} = 0.43$; $p = 0.53$. However, this value did not cause a significant change in the binocular accommodative facility.

The mean NRA and PRA were not affected by the 10 minutes monocular PPT. The NRA had an increment of 0.08 D but the PRA had a decrement of 0.05 D. But these values were statistically and clinically insignificant. The NRA had $F_{(1,9)} = 0.40$; $p = 0.54$ and the PRA had $F_{(1,9)} = 0.14$; $p = 0.72$.

IV. DISCUSSION

The impact of the 10 minutes monocular PPT caused statistically and clinically significant changes for both monocular and binocular AA measurements. These increments of the AA might be due to the fact that the repetitive stimulation and relaxation of the accommodation results in the leaky integrator controller to build up its innervations (Schor, 1999). A leaky integrator controller acts as a neurological storage mechanism which can respond by building up innervations when stimuli are presented, and dissipate its response when the stimuli are removed. A physiological analog to this is how the tonic cells would gradually increase its firing rate when they are stimulated and would store the response for a limited time when the stimulus is removed. As shown in this study, the continuous stimulation of the accommodation would result in the increase of the innervations in the leaky integrator controller and the result is the improvement of the amplitude. This amplitude may be reduced by time after the stimulus is removed since the integrator has time constant for it to decay. However, if the stimulus is kept on presented to the system, it might eventually alter the tonic state of the accommodation and would result in permanent change of the amplitude of accommodation. This characteristic is in agreement with the study done by Ebenholtz (1983) who found that the accommodation system manifested the capability of adaptively altering its resting levels in response to sustained accommodation. This argument supports that the monocular PPT, if prescribed to the patient with accommodative insufficiency, will improve the amplitude of accommodation, hence helping to restore the condition. But, it has to be prescribed with caution and close monitoring is required since the change of the accommodative amplitude is rapid and perhaps over-doing the exercise may result in therapy-induced accommodation spasm or excess.

Other components of accommodation such as accommodative response did not show significant changes after 10 minutes of the monocular PPT. These are not in agreement with the findings by Hasabe *et al*. (2001) who found that after putting the eyes under intense accommodative task by using lens flippers, it influenced the measures of tonic accommodation. They concluded that the combination of accommodative fatigue and accommodative hysteresis caused by the flippers exercise shifted the tonic accommodation in the negative direction. In addition, in this study, the changes to the accommodative response could not be observed perhaps due to the techniques used to measure the response. Hasabe *et al*. (2001) employed highly refined measures of the accommodative response using infrared autorefractor to measure the accommodative response directly, compared to the use of MEM retinoscopy, which is an indirect measure of the accommodative response as shown by the lag of accommodation, employed in this study. Hence, more accurate reading of accommodative response was obtained in their study.

The 10 minutes monocular PPT also did not show significant changes in the accommodative facility and the relative accommodation. This might be the result of fast decay of the phasic response which acts rapidly to provide a clear image of the object and a slower time course of the adaptive components to dissipate (Schor, 1986). Since all the measurements were done immediately after the exercise and it involves the response of the accommodation system, perhaps the subsequent rapid changes in stimuli from the tests

combined with the adaptive state of the tonic accommodation due to the exercise masked the changes of the parameters.

V. CONCLUSION

This study concludes that the 10 minutes monocular PPT affects the amplitude of accommodation (AA) and not the other accommodation parameters. The change was towards an increase in the AA. The repetitive stimulation and relaxation of the accommodation enhances the accommodation capabilities through the changes in the tonic and phasic components of the accommodation. The tonic accommodation adapts to the condition and causes the improvement of the amplitude of accommodation.

Hence, it showed that the monocular PPT is effective as a therapy for accommodation insufficiency problems, in which the patient has weakness in the ability to accommodate at a presented target at near. However, the therapy needs to be prescribed with close monitoring of the patient's progress to avoid a possible induction of accommodation spasm that can lead to symptoms like intermittent blurred vision and difficulty in changing focus from near to far distances.

VI. DISCLOSURE

This paper had followed the recommendations of the Declaration of Helsinki (1964) for ethical standards for human research. No financial grant was utilized for this study.

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