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Original Article

Effect of eye movements and proprioceptive neuromuscular facilitation on balance and head alignment in stroke patients with neglect syndrome

Si-Eun Park, PT, PhD[1], Kyung-Ok Min, PT, PhD[2], Sang-Bin Lee, PT, PhD[3], Wan-Suk Choi, PT, PhD[4], Soon-Hee Kim, PT, PhD[5]*

[1] *Department of Physical Therapy, Pohang College, Republic of Korea*
[2] *Department of Physical Therapy, Yongin University, Republic of Korea*
[3] *Department of Physical Therapy, Namseoul University, Republic of Korea*
[4] *Department of Physical Therapy, International University of Korea, Republic of Korea*
[5] *Department of Physical Therapy, Yongin University: 470 Samga-dong, Cheoin-gu, Yongin-si, Gyeonggi-do, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to assess the effect of eye movements and proprioceptive neuromuscular facilitation (PNF) on patients with neglect syndrome. [Subjects and Methods] The subjects were randomly allocated to 2 groups: the eye movements (EM) group; and the PNF with eye movements (PEM) group. The program was conducted five times each week for 6 weeks. Balance (both static and dynamic) and head alignment (craniovertebral angle and cranial rotation angle) were measured before and after testing. [Results] In measurements of static balance, the EM group showed significant improvement in sway length and sway area when examined in the eyes-open condition, but not when examined in the eyes-closed condition. The PEM group showed significant improvement when examined under both conditions. In the assessment of dynamic balance, both groups showed significant improvement in measurements of sway areas. With respect to head alignment, there were no significant differences pre- and post-testing in either the craniovertebral angle or the cranial rotation angle in the EM group, but the PEM group showed significant differences in both measurements. [Conclusion] These results suggest that in stroke patients with neglect syndrome, PNF with eye movements, rather than eye movements alone, has a greater positive effect on balance and head alignment.

Key words: Eye movements, Proprioceptive neuromuscular facilitation, Neglect syndrome

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INTRODUCTION

Neglect frequently appears due to brain damage and impedes everyday life as well as rehabilitation[1]. Perennou et al. found that stroke patients with neglect showed postural instability more clearly compared to those without neglect[2]. The syndrome frequently occurs in left hemiplegic patients because while the right hemisphere of the brain recognizes left and right spaces, the left hemisphere recognizes only right spaces. Damage to the left hemisphere can be compensated by the right hemisphere, while damage to the right hemisphere cannot be compensated by the left hemisphere but the converse is not true[3].

Stroke patients with neglect show diverse kinds of damage to their eye movements, such as decreased saccadic movements and difficulties in space observation[4]. Hornak showed that patients with neglect showed difficulties in perceiving and

*Corresponding author. Soon-Hee Kim (E-mail: shkim2776@empas.com)

drawing pictures placed in the left visual field and that stimulating these affected visual fields was important[5], Kerkhoff et al. reported that optokinetic stimulation activates many regions involved in vision and hearing such as the temporo-parietal cortex, basal ganglia, brain stem, and cerebellum. They emphasized the importance of optokinetic stimulation for patients with damage to the nervous system[6].

The roles of vision, the vestibular system, and the somatosensory system are very important in postural control. Visual inputs provide important information about one's environment, postures, and head movements[7, 8].

In the present study, proprioceptive neuromuscular facilitation (PNF) training was implemented in combination with eye movements in order to induce head movements. PNF can activate the neuromuscular system by stimulating the proprioceptors in the muscles and tendons thereby activating or suppressing certain muscle groups[9]. The main characteristic of PNF patterns is the occurrence of spiral and diagonal movements. These movements enhance functional movements[10, 11]. In this study, PNF training was implemented in the neck region to induce head movements. Kim and Oh reported that neck proprioceptive training has a good chance of improving the balance function of stroke patients with hepiparesis[12].

Although the importance of eye and head movements for postural control has been emphasized, most previous studies have been conducted on healthy adults[8, 13]. The present study was conducted to examine the effects of eye movement and PNF training in neglect patients.

SUBJECTS AND METHODS

The present study was conducted on 20 patients in two rehabilitation hospitals located in Gyeonggi-do. Patients who were diagnosed at least six months previously with hemiplegia due to stroke, had at least moderate neglect symptoms, and had a total score of at least 11 points on the Catherine Bergego Scale (CBS) were selected[14].

The study was limited to those who had scored not lower than 24 points on the Korean version of the Mini-Mental State Examination (MMSE-K), and who could carry out instructions[15], had no visual or hearing impairment, and could stand independently for at least one minute. This study complied with the ethical principles of the Declaration of Helsinki. The subjects agreed to participate in the study after receiving explanations regarding its purpose and procedures. They all signed an informed consent statement before participation. The protocol for this study was approved by the local ethics committee of Yongin University (2-1040966-AB-N-01-201503-HSR-025-1). The general characteristics of the subjects and their CBS values are summarized in Table 1.

Balance ability, static balance, and dynamic balance were measured using a BioRescue apparatus (SyCoMORe, France). Subjects stood on the footplate with their feet spread at an angle of approximately 30° while looking straight ahead. Static balance was measured by measuring the sway length and sway area while standing for one minute with eyes open and eyes closed. Dynamic balance was measured as the limit of stability (forward/backward and left/right). Lower values for static balance and higher values for dynamic balance denoted better balance ability.

Head alignment was measured as the craniovertebral angle (CVA) and cranial rotation angle (CRA) using the Global Postural System (GPS) (Fig. 1). Smaller values for CVA indicated increased bending of the lower cervical vertebrae and larger values for CRA indicated increased extension of the upper cervical vertebrae leading to upward turning of the head.

The eye movements program used cards and comprised four steps: intermittent saccadic eye movements, pursuit eye movements, adapting movements 1, and adapting movements 2 (Table 2, Fig.2)[13]. The movements in each step were performed 10 times, constituting one set, and two sets were performed in total.

With the subject's face stationary, the therapist held one card in each hand at a distance of 30 cm from the subject's eyes. The subject looked at the card in the two hands alternately. A card maintained 30 cm from the subject's eyes was moved. The subjects followed the card's movement by eye movement alone. Next, the therapist held a card stationary at the same distance from the subject's eyes. The subject repeatedly turned their head from right-to-left and from left-to-right while maintaining their gaze on the card. Next, the therapist held a card at a fixed distance of 30 cm from the subject's eyes. The subject repeatedly turned their head from right-to-left and from left-to-right while keeping their eyes on the card, with the therapist moving the card in the direction opposite to the direction of the head movement.

The PEM group underwent PNF training after implementing the eye movements program. The PNF training was implemented using the neck extensor pattern while the subject was in a sitting position. The movements began with the contraction of the neck extensor group by neck flexion, right rotation, and left lateral flexion, and ended with neck extension involving left rotation and right lateral flexion. The therapist verbally instructed the subject to push their head in the opposite direction, with another instruction to the subject to move their eyes upward along with the movement of the head. The contract-relax training was implemented by performing the movements 10 times as a set and repeating the set three times with a rest period of two minutes after each set. The PNF training was implemented by one researcher who had completed PNF Level I and Level II courses.

Data were analyzed using SPSS for Windows version 20.0 software. The mean and standard deviation of the general characteristics were calculated using descriptive statistics. ANOVA was used to evaluate the changes in balance and head alignment. In all analyses, $p<0.05$ was considered significant.

Table 1. General characteristics of subjects

		EM group	PEM group
Gender	Male	4	5
	Female	6	5
Age (years)		60.2±7.85	61.1±8.17
Time since stroke (months)		22.2±10.21	23.3±7.00
Stroke type	Infarction	5	3
	Hemorrhage	5	7
Affected side	Left	10	10
	Right	0	0
CBS (score)		13.1±1.66	13.1±1.60

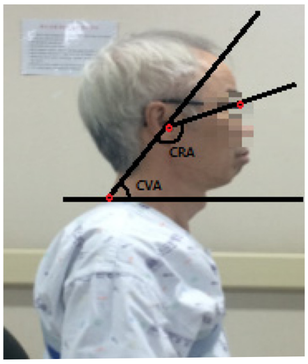

Fig. 1. Measurement of CVA and CRA

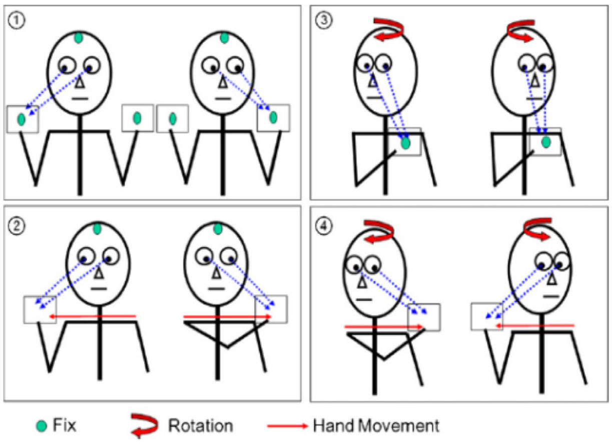

Fig. 2. Eye movements exercises using a card
1: saccadic eye exercise, 2: pursuit exercise, 3: adaptation exercise 1, 4: adaptation exercise 2

Table 2. Eye movements exercise program

Stage	Content
Saccadic eye exercise	With the subject's face stationary, the therapist held up a card in each hand at a distance of 30 cm from the subject's eyes and the subject looked at the card in the two hands alternately.
Pursuit eye exercise	With the subject's face stationary, the therapist repeatedly moved a hand-held card from the left to the right, and from the right to the left, at a distance of 30 cm from the subject's eyes and the subject kept their eyes on the card, moving their eyeballs to follow the card.
Adaptation exercise 1	The therapist held a card in one hand at a fixed distance of 30 cm from the subject's eyes and the subject repeatedly turned their head from the right to the left, and from the left to the right, while keeping their eyes on the card.
Adaptation exercise 2	The therapist held a card in one hand at a fixed distance of 30 cm from the subject's eyes. The subject repeatedly turned their head from the right to the left, and from the left to the right, while keeping their eyes on the card and the therapist moved the card in the direction opposite to the direction of the movement of the subject's head while the subject's head was turning.

RESULTS

Neglect patients were divided into an EM group and a PEM group. Measurements of balance and head alignment were performed before and after testing. In measurements of static balance, the EM group showed significant differences in sway length and sway area in the eyes-open condition ($p<0.05$), but showed no significant differences in the eyes-closed condition

Table 3. Measurement of static balance: comparison of EM and PEM groups

		Pre-test	Post-test
EM group	Eyes open		
	sway length (cm)	37.6±1.7	36.6±1.6*
	sway area (mm^2)	450.7±21.7	447.4±18.6*
	Eyes closed		
	sway length (cm)	47.2±3.6	46.2±3.6
	sway area (mm^2)	545.8±49.9	532.0±33.7
PEM group	Eyes open		
	sway length (cm)	36.4±2.4	33.6±1.2*
	sway area (mm^2)	440.9±24.5	410.9±19.8*
	Eyes closed		
	sway length (cm)	47.2±3.9	41.0±5.6*
	sway area (mm^2)	545.2±82.8	489.4±56.7*

*p<0.05

Table 4. Measurement of dynamic balance: comparison of EM and PEM groups

		Pre-test	Post-test
EM group	Forward (mm^2)	310.5±48.3	332.2±45.9*
	Backward (mm^2)	133.6±33.8	150.4±34.3*
	Left (mm^2)	148.5±22.3	160.5±15.8*
	Right (mm^2)	231.8±19.5	238.2±16.7*
PEM group	Forward (mm^2)	318.6±40.2	381.0±48.1*
	Backward (mm^2)	160.3±37.0	189.8±49.4*
	Left (mm^2)	165.8±22.4	179.2±21.8*
	Right (mm^2)	239.6±21.0	254.3±12.4*

*p<0.05
Forward: forward sway area, Backward: backward sway area, Left: left sway area, Right: right sway area

(p>0.05). The PEM group, however, showed significant differences in both these conditions (p<0.05). In measurements of dynamic balance, both the EM group and the PEM group showed significant differences pre- and post-testing (p<0.05) (Tables 3, 4).

With respect to head alignment, the EM group showed no significant differences in the craniovertebral angle and the cranial rotation angle (p>0.05). However, the PEM group showed significant differences in both measurements (p<0.05) (Table 5).

DISCUSSION

Stroke patients with neglect symptoms exhibit problems with eye movements and balance[4]. Karnath reported that vestibular and neck proprioceptive stimulation with visual inputs was a useful method for the treatment of neglect patients[16]. In the present study, eye movements and PNF in the neck region of neglect patients were applied to examine their effects.

In measurements of static balance, the EM group showed significant differences in sway length and sway area in the eyes-open condition (p<0.05), but not in the eyes-closed condition (p>0.05). In measurements of dynamic balance, both the EM and PEM groups showed significant differences after intervention (p<0.05).

Morimoto et al. reported that when healthy adults performed eye movement and gaze stability exercises, their postural stability was improved[13]. Another study reported that optokinetic stimulation activated many regions of the brain (temporoparietal cortex, basal ganglia and cerebellum)[6]. The study concluded that eye movements activated regions of the brain that positively affected balance ability. Moreover, no such positive effect on balance ability was noted when vision was blocked.

The PEM group in our study showed significant differences in both eyes-open and eyes-closed conditions (p<0.05). Proprioceptive inputs to the neck muscles are important for postural control[17]. PNF training stimulates proprioceptors of muscles and tendons by activating the neuromuscular system[9]. Stimulation of the vestibular system and the proprioceptors of

Table 5. Measurement of head alignment: comparison of EM and PEM groups

		Pre-test	Post-test
EM group	CVA (°)	45.9±1.4	46.6±1.2
	CRA (°)	150.0±1.7	149.3±1.6
PEM group	CVA (°)	46.8±1.4	48.1±1.4*
	CRA (°)	148.7±1.4	147.7±1.2*

*p<0.05

the neck region with visual inputs provide asymmetric stimulation to sensory organs, improving coordination in neglect patients[15]. Therefore, the PNF training on the neck employed in this study appears to have stimulated the neck proprioceptors, resulting in positive effects on postural control. In stroke patients, abnormal trunk alignment appears because of weakened muscles, particularly in the flexion position of the upper trunk[18]. This causes forward head postures and extension of the cervical vertebrae[19].

Posture is an essential element of normal balance[20]. Therefore, in this study, the head alignment of stroke patients with neglect symptoms was measured. The EM group showed no significant differences in the craniovertebral angle and the cranial rotation angle ($p>0.05$). We conclude therefore that eye movements alone have no positive effect on head alignment. However, the PEM group showed significant differences in both the craniovertebral angle and the cranial rotation angle ($p<0.05$). Sarig-Behat reported that proprioceptive training is effective for mechanical problems in the neck region[21]. This indicates that PNF training has stimulated the proprioceptors, leading to positive effects on head alignment. Hindle et al. reported that the contract-relax method in PNF is effective for the improvement of the range of motion[22] and they concluded that PNF training has a positive effect on the range of motion of cervical vertebrae.

In the present study, the eye movements had positive effects on static balance with the eyes open, and on dynamic balance, but they had no positive effects on static balance with the eyes closed, or with head alignment. However, PNF training with eye movements had positive effects on both static and dynamic balance as well as on head alignment. Therefore, we conclude that for neglect patients, PNF training with eye movements is a more effective intervention than eye movements alone.

Since the present study was conducted with only 20 neglect patients, the results cannot be generalized to all neglect patients. Nevertheless, our study demonstrates the importance of eye and head movements for postural control . More extensive studies should now be done to test the effectiveness of this treatment for neglect patients.

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