



Original Article

Effects of oculo-motor exercise, functional electrical stimulation and proprioceptive neuromuscular stimulation on visual perception of spatial neglect patients

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Abstract. [Purpose] The purpose of this study was to identify the effects of oculo-motor exercise, functional electrical stimulation (FES), and proprioceptive neuromuscular facilitation (PNF) on the visual perception of spatial neglect patients. [Subjects and Methods] The subjects were randomly allocated to 3 groups: an oculo-motor exercise (OME) group, a FES with oculo-motor exercise (FOME) group, and a PNF with oculo-motor exercise (POME) group. The line bisection test (LBT), motor free visual test (MVPT), and Catherine Bergego Scale (CBS) were used to measure visual perception. These were performed 5 times per week for 6 weeks. [Results] The OME group and POME group showed significant improvements according to the LBT and MVPT results, but the FOME group showed no significant improvement. According to the CBS, all 3 groups showed significant improvements. The OME and POME groups showed improvement over the FOME group in the LBT and MVPT. However, there was no significant difference among the three groups according to the CBS. [Conclusion] These results indicate that oculo-motor exercise and PNF with oculo-motor exercise had more positive effects than FES with oculo-motor exercise on the visual perception of spatial neglect patients.

Key words: Spatial neglect, Visual perception, Oculo-motor exercise

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INTRODUCTION

Spatial neglect is a deficit in attention that may occur following stroke¹⁾. It is a failure to report, respond to, or orient towards stimuli located on the contralesional side. It also occurs when converting not only a visual landscape but also body schema to a visual image²⁾. Spatial neglect is caused by a disturbance of both hemispheres after unilateral cortical lesions³⁾.

Spatial neglect is more common after a right hemisphere lesion than after a left hemisphere lesion⁴⁾. When the right hemisphere is damaged, spatial neglect leads to visual perception problems such as asymmetrical division of lines or failure to perceive the picture of the neglected side⁵⁾. There are diverse methods that can be used to treat spatial neglect such as perception retraining, visual scanning treatment, and cognitive therapy but more effective and diverse interventions for the treatment of spatial neglect are necessary⁶⁾.

Neglect patients show multiple eye movement impairments, including reduced saccade amplitude and difficulty in retaining spatial locations across saccades⁷⁾. Eye movements are increasingly being used as a tool for the elucidation of relatively complex neuropsychological processes relating to attention, spatial memory, motivation and decision-making⁸⁾. Oculo-motor

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Table 1. General characteristics and CBS values of the subjects

		OME	FOME	POME
Gender	Male	4	7	5
	Female	6	3	5
Age (years)		60.2±7.8	56.7±7.7	61.1±8.1
Time after stroke (months)		22.2±10.2	28.6±12.1	23.3±7.0
Stroke type	Infarction	5	6	3
	Hemorrhage	5	4	7
Affected side	Left	10	10	10
	Right	0	0	0
CBS (score)		13.1±1.6	12.7±1.4	13.1±1.6

OME: oculo-motor exercise group, FOME: FES with oculo-motor exercise group, POME: PNF with oculo-motor exercise group, CBS: Catherine Bergego Scale

exercise modulates many facets of neglect syndrome, and pursuit eye movement especially represents an effective and easily applicable technique for the treatment of neglect patients⁹. Karnath reported that oculo-motor exercise was effective at improving body orientation in spatial neglect patients¹⁰.

Functional electrical stimulation (FES) has been developed as a method for artificially activating the sensory motor system after central nervous system injury¹¹. It is useful for activating muscle paralyzed by upper motor neuron injury, and is used to strengthen weakened muscles, to decrease spasticity, and to enhance the range of motion of joints¹². Rushton noted that FES activates motor and sensory nerve fibers and promotes cortical reorganization through sensory stimulation of paralyzed muscle¹³. FES also activates a proprioceptive map within the right parietal lobe, and alleviates unilateral spatial neglect¹⁴.

Most stroke patients experience loss of proprioceptive sensation, which results in body sway increases, and failure to receive appropriate location information about the body reduces their efficiency of movement¹⁵. The proprioceptive neuromuscular facilitation (PNF) approach utilizes a typical diagonal pattern to stimulate proprioceptive sensation¹⁶. The PNF patterns may permit muscles to act in ways that are close to the actions and movements¹⁷. PNF can also have a positive effect on the active and passive ranges of motion¹⁸. Silva and Johnson reported that proprioceptive afferent input from the neck muscles plays an important role in postural control¹⁹. And Kim and Oh reported that the neck is an essential component in the regulation of head and body orientation in space, and is necessary for maintaining balance²⁰. Accordingly, this study applied FES and PNF to the neck area, to increase the proprioceptive input to the neck muscles and induce head movement.

There have been many studies on balance and gait using oculo-motor exercise, FES, and PNF with stroke patients as subjects, but studies analyzing the visual perception of neglect patients are lacking. Accordingly, this study examined the effects of FES and PNF with oculo-motor exercise on the visual perception of stroke patients with spatial neglect.

SUBJECTS AND METHODS

This study was conducted at the Rusk Rehabilitation Hospital and LOHAS Hospital located in Gyeonggi-do, and the subjects were 30 stroke patients with spatial neglect. In order to select neglect patients, patients scoring 11 or higher on the Catherine Bergego Scale (CBS) were included²¹. The subjects did not have visual or hearing disorder, and their score in the Korean version of the mini-mental state exam was 24 points or higher²². Table 1 outlines the general characteristics and CBS values of the subjects.

This study complied with the ethical principles of the Declaration of Helsinki. The subjects agreed to participate in the study after receiving explanations regarding the purpose and procedures of the experiment, and signed an informed consent statement before participation. The protocol for this study was approved by the local ethics committee of Yonjin University (2-1040966-AB-N-01-201503-HSR-025-1).

The subjects were equally and randomly divided into three groups: an oculo-motor exercise (OME) group, a FES with oculo-motor exercise (FOME) group, and a PNF with oculo-motor exercise (POME) group. The intervention was conducted five times per week, for a total of six weeks. The study was design is schematically illustrated as in Fig. 1.

The oculo-motor exercise was designed according to the method used by Morimoto et al²³. A total of four different exercises were performed (saccadic eye movement, smooth pursuit exercise, and the adaptation 1 & 2 exercises). The saccadic eye movement exercise is a movement of the eyes horizontally between two stationary targets while keeping the head still. The smooth pursuit exercise involves moving the targets horizontally and tracking them with the eyes while keeping the head still. The adaptation 1 exercise involves moving the head horizontally while keeping the stationary target in focus. The adaptation 2 exercise requires movement of the head and a target in opposite horizontal directions while tracking the target with the eyes (Fig. 2)²³. Those in the OME group each conducted two sets of each exercise, with each exercise performed 10 times per set.

The FOME group performed the oculo-motor exercise program and FES was additionally applied to the neck area of the

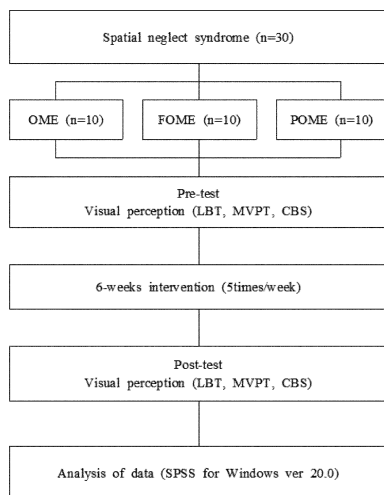


Fig. 1. Schematic diagram of the study

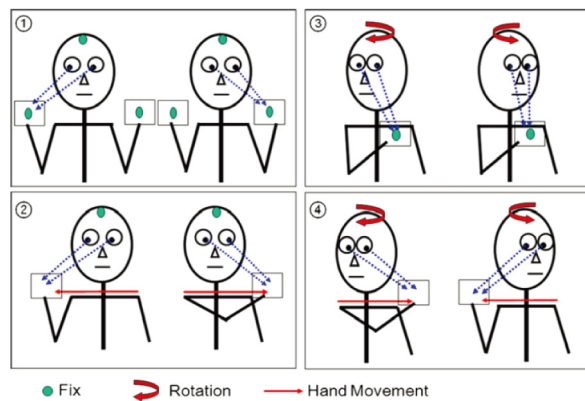


Fig. 2. Oculo-motor exercise (1: saccadic eye exercise, 2: smooth pursuit exercise, 3: adaptation 1 exercise, 4: adaptation 2 exercise)

Table 2. Comparison of the pre-test and post-test visual perception tests' results

		Pre-test	Post-test
OME group	LBT (mm)	15.1±2.6	13.2±3.0*
	MVPT (score)	17.7±2.2	18.7±1.8*
	CBS (score)	13.1±1.6	11.3±1.4*
FOME group	LBT (mm)	16.1±1.3	15.7±1.5
	MVPT (score)	16.5±1.3	16.8±1.2
	CBS (score)	12.7±1.4	11.7±1.4*
POME group	LBT (mm)	15.2±2.5	13.3±2.5*
	MVPT (score)	17.8±2.2	18.5±1.9*
	CBS (score)	13.1±1.6	11.8±1.7*

*p<0.05

LBT: line bisection test, MVPT: motor-free visual perception test, CBS: Catherine Bergego scale

paretic side, to induce movement of the head. The FES equipment used was a Microstim (Medel GmbH, Germany) was used and two electrodes were attached to the origin and insertion of the paretic splenius capitis of the neck extensor. FES was applied for a total of 15 minutes and the electricity on-time and off-time were six and two seconds, respectively. The frequency was set at 30 Hz, and the stimulation intensity was less than 15V, to avoid muscle contraction.

The POME group performed the oculo-motor exercise program, and PNF additionally was applied to the neck area, to induce movement of the head. The PNF pattern used was a neck extensor pattern, and the technique used was a contract-relax technique. The starting posture was neck flexion, followed by right rotation, and left lateral flexion. The last posture was neck extension, followed by left rotation, and right lateral flexion. The subjects conducted exercises for a total of three sets, 10 exercises per set. The PNF training was conducted by a therapist who had completed PNF courses at levels I and II.

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

RESULTS

This study involved thirty subjects: 10 subjects in the OME group, 10 subjects in the FOME group, and 10 subjects in the POME group. The line bisection test (LBT), motor free visual test (MVPT), and Catherine Bergego Scale (CBS) were used as outcome measures.

Changes in visual perception within each group are shown in Table 2. In the OME and POME groups, significant differences were found in the LBT, MVPT and CBS results (p<0.05). In the FOME group, no significant differences were found in the LBT and MVPT results (p>0.05). However, a significant difference was found in the CBS results (p<0.05).

Table 3 presents a comparison of the results of the groups. In the OME and POME groups, the LBT and MVPT results

Table 3. Comparison of the groups visual perception tests' results

		M±SD	Duncan
LBT (mm)	OME	13.2±3.0	
	FOME	15.7±1.5	b<a,c*
	POME	13.3±2.5	
MVPT (score)	OME	18.7±1.8	
	FOME	16.8±1.2	b<a,c*
	POME	18.5±1.9	
CBS (score)	OME	11.3±1.4	
	FOME	11.7±1.4	
	POME	11.8±1.7	

*p<0.05

a: OME group, b: FOME group, c: POME group

were significantly different from those of the FOME group ($p<0.05$). However, according to the CBS test, there were no significant differences among the three groups.

DISCUSSION

Spatial neglect is characterized by a lack of awareness of sensory events located towards the contralesional side of space. Indeed, neglect patients often behave as if half of their world is no longer in existence²⁴). Therefore, visual perception is one of the major problems of spatial neglect patients. This study conducted FES and PNF with oculo-motor exercises, and compared their results in order to verify their effects on the visual perception of spatial neglect patients.

The OME group showed significant improvements according to the LBT, MVPT, and CBS results. Pierrot-Deseilligny et al. noted that saccadic eye movement and pursuit eye movement are organized in the cerebral cortex and play an important role in spatial memory and concentration⁸). Kerkhoff et al. reported that oculo-motor exercise activates multiple brain regions (temporo-parietal cortex, basal ganglia, brainstem, cerebellum) involved in auditory and visual space coding⁹). Therefore, the physiological effects of oculo-motor exercise are considered to have positively affected the visual perception of the spatial neglect patients in this study.

In the FOME group, there were no significant improvements according to the LBT and MVPT results, but there was a significant difference according to the CBS result. Alon et al. reported that FES can enhance the recovery of upper extremity function in stroke patients²⁵). FES has been developed to restore function to the upper extremity, lower extremity, bladder, bowel, and respiratory system²⁶). However, in this study, FES with oculo-motor exercise did not have an effect on the visual perception of the spatial neglect patients.

The POME group showed significant improvements according to the LBT, MVPT, and CBS results. Karnath reported that visual input, together with vestibular and neck proprioceptive input has a positive effect on the body orientation of spatial neglect patients¹⁰). This supports the notion that PNF training applied to the neck area has a positive effect on visual perception. Furthermore, Hindle et al. reported that the contract-relax technique of PNF is effective at improving and maintaining range of motion¹⁸). It is considered that the contract-relax technique applied to the neck area in this study increased the range of motion of the neck, positively affecting visual perception. Meesen et al. reported that head movement triggered coordination of the arms and legs, positively affecting postural balance²⁷). Therefore, head movement through the PNF technique is considered to have had a positive effect on postural adjustment as well as visual perception.

In the comparison of the three groups, there were no significant differences according to the CBS results. However, the LBT and MVPT results showed there were significant differences between the OME and POME groups and the FOME group. This indicates that the intensive application of oculo-motor exercises or PNF with oculo-motor exercise is more effective than FES with oculo-motor exercises in the improvement of the visual perception of spatial neglect patients.

The number of subjects included in this study was insufficient for the generalization of the results to all spatial neglect patients. However, the results indicate that head movement through oculo-motor exercise and PNF is effective and more diverse interventions should be developed for spatial neglect patients.

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