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Original Article

Correlation of knee proprioception with muscle strength and spasticity in stroke patients

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Abstract. [Purpose] The purpose of this study was to investigate the relationship of knee proprioception with muscle strength and spasticity in stroke patients. [Subjects and Methods] The subjects were 31 stroke patients. The subjects received an explanation of the procedures and methods and provided informed consent before the experiment. A measurement board was used to determine the the proprioception deficit of the knee as a proprioception test. The proprioception test consisted of a passive and active angle reproduction test. A manual muscle test and modified Ashworth scale were used to evaluate knee muscle strength and spasticity level. The data were analyzed using an independent t-test and Spearman correlation. [Results] The results of this study revealed a significant difference between the affected side and non-affected side in the passive angle reproduction test and a significant difference in the correlation of the proprioception level with muscle strength and spasticity level. [Conclusion] This study indicates that the knee proprioception level is associated with spasticity and muscle strength in stroke patients.

Key words: Proprioception, Spasticity, Stroke

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INTRODUCTION

A stroke is a disorder that results from a dysfunction in the brain anatomically due to problems in the cerebrovascular blood supply and vessel hemorrhage. Depending on the location and seriousness of the damaged in the brain, stroke patients can have sensory-motor dysfunction, proprioception deficits and hypertonus[1)].

The sensory-motor dysfunction in stroke patients includes not only muscle weakness and abnormal muscle tone but also proprioception deficits. Proprioceptiors such as the mechanoreceptor and free nerve ending, are found in the skin, facia, muscles, tendons, joint capsules, and ligaments. When active or passive movement occurs, receptors transmit the mobility information to the central nervous system[2)]. The proprioception provides the angles and angular speed of every joint involved in body position or postural perception and movements. It plays the largest part in maintaining dynamic joint stability, induces normal movements, and protects joints from external damages[3)]. If proprioception is degraded by a stroke, it could also undermine muscle strength, normal muscle tone, posture control, protective reflex ability, and joint motor ability. Clinically, the proprioception level has emerged as an important assessment item used for stroke patient assessment clinically together with treatment procedures[4)].

In the months following an upper motor neuron (UMN) lesion in stroke patients, muscle tone increases as a result of changes within the muscle, producing excessive resistance to muscle stretch, which is usually called spasticity. When a UMN lesion interrupts descending motor commands, the lower motor neuron (LMN) is affected and becomes temporarily inactive. This condition is called cerebral shock, depending on the location of the lesion. During nervous system shock, stretch reflexes cannot be elicited, and the muscles are hypotonic; that is, the muscles have abnormally low tone because facilitation of LMNs has been lost due to interruption of descending motor commands by a UMN[5)]. Many stroke patients have a somatic sensory deficit and abnormal muscle conditions. The most important goal is restoration of somatic sensory function, as this can have a positive effect on abnormal muscle conditions.

The purpose of this study was to compare the proprioception levels of knee joints between the affected and non-affected sides in stroke patients and analyze the correlation of proprioception with muscle strength and spasticity level. The hypotheses were as follows: the knee joint proprioception in stroke patients will be different in their affected side compared with the non-affected side, and the loss of proprioception will be correlated with muscle strength and spasticity level.

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SUBJECTS AND METHODS

This study examined 31 patients with stroke selected from among the candidates who were receiving physical therapy services at S hospital in Daejeon, South Korea, and consented to participate in this study. The criteria for selection of the study subjects were as follows: 1) patients who agreed to participate in this study experiment, 2) patients who could understand and follow a therapist's instructions (those with an MMSE-K score of at least 24), 3) patients without any orthopedic or neurosurgical history in their ankle joint, hip joint, and lumbar spine, and 4) patients with no problems in range of motion in the knee joint. The research protocol was approved by the Research Ethics Committee for Human Research of Daejeon University, South Korea.

In this study, to evaluate the joint position sense on both affected and non-affected knee joints of stroke patients, the passive angle reproduction test was utilized, and to evaluate the kinesthesia in both affected and non-affected knee joints of stroke patients, the active angle reproduction test was employed. The direction of movement during assessment and assessment method were determined by randomly drawing ball marked with flexion and extension (movement direction), passive angle reproduction test, and active angle production test (assessment method), respectively.

Participants lay in the side-lying position, flexed slightly their hip joint comfortably, and flexed 70 degrees (for extension test) and extended 10 degree (for flexion test) their knee joint. A measuring board was used for subjects in this position. The flexion test started at 10 degree extension. The knee joints were moved by a tester to a target angle without any help. The flexion angles were set in advance at 50 and 60 degrees[6, 7]. To exclude learning effects during the test, 60 degrees was used in the active angle reproduction test if 50 degrees was used in the passive angle reproduction test. The extension test was performed based on 90 degrees of flexion in the knee joints and started from 70 degrees of flexion. The subjects were instructed to allow a tester to move them passively to a target angle. In the active angle reproduction test, the subjects were instructed to move actively to the target angle. The angles were set at 20 and 30 degrees for the extension test. If 20 degrees was used in the passive angle reproduction test, 30 degrees was used in the active angle reproduction test. Both passive and active angle reproduction tests were done in the same position. A 10-minute break was given in between the tests. To block any visual information from patients, their eyes were covered with a shade during the tests. A tester caused passive movement by holding the patients' ankle and upper part of their knee joint. The speed of these passive and active movements was one cycle/30 sec. The holding time for each target angle was 10 seconds so that the subjects could remember the position. After returning to a starting position passively or actively, the subjects took a 5-second rest. During the passive angle reproduction test, the subjects said "stop" when they thought their knee joint flexion or extension reached the target angle. During the active angle reproduction test, the subjects moved to the target angles on their own.

The tester marked the results on the measuring board with a sticker and measured the angle with a goniometer. The measured angles were recorded as negative if they were smaller than the target angle and positive if they were larger than the target angle. Their absolute values were used for data analysis. Measurements were performed for 3 rounds in total, and the average values were recorded.

Table 1. General characteristics of the subjects (N=31)

Variables (unit)		Subjects	Mean±SD
Gender (male/female)		22/9	
Age (years)			51.1±11.4
Height (cm)			164.2±7.3
Weight (kg)			66.9±12.1
Onset (years)	>0.6	5	
	1<onset≥3	5	
	<3	21	
Side of lesion (left/right)		16/15	

The affected-side knee muscle strength of the stroke patients was measured by manual muscle test. The subjects lay in a side-lying position for the flexion and extension muscle strength test. Before the test, the subjects were examined for any pain and were given a sufficient explanation about the measurement procedures. Muscle strength was recorded in 6 different grades. A higher score means better muscle strength[8].

The Modified Ashworth Scale (MAS) was employed in this study to evaluate the spasticity level of the affected-side knee joint. The MAS expresses the degree of spasticity of patients with a damaged central nervous system. Its inter-rater reliability is 0.75, a higher level[9]. The patients sat comfortably on the treatment stand, and the rater evaluated and recorded the spasticity in the flexion and extension directions. The larger the number indicating spasticity grade, the more spasticity a patient would have.

The measurement data were statistically processed with PASW Statistics for Window Version 18.0. For the general characteristics of the subjects, the average and standard deviations were calculated by using technical analysis. Spearman correlation analysis was employed to analyze the correlation of knee joint proprioception with muscle strength and spasticity in the stroke patients. The independent t-test was adopted to compare the difference in knee joint proprioception between the affected and non-affected sides. The significance level was set at 0.05.

RESULTS

This study performed a knee joint proprioception test for 31 stroke patients and analyzed the correlation of the proprioception level with muscle strength and spasticity. Table 1 shows subjects' characteristics such as gender, age, height, weight, onset and side of lesion. Comparison of the difference in proprioception levels in the knee joints on the affected and non-affected side in the stroke patients revealed the error angles for joint position sense in the flexion-direction 14.25 degrees on the affected side and 5.33 degrees on the non-affected side, representing a significant difference ($p<0.01$). For the extension direction, the error angles were

Table 2. Comparison of proprioception between the affected and non-affected knee

Test type	Direction	Affected (n=31)	Non-affected (n=31)	Mean difference
PAR	Flexion	14.25±11.94[a]	5.33±4.76*	8.91±2.30
	Extension	12.25±9.90	5.15±4.99*	7.10±1.99
AAR	Flexion	5.37±2.36	3.56±3.46	1.81±0.94
	Extension	4.65±2.62	3.45±3.79	1.20±1.04

PAR: passive angle reproduction test (joint position sense); AAR: active angle reproduction test (kinesthesia)
[a]Mean (error angle)±SD
*p<0.01

Table 3. Correlation for coefficients the correlation of proprioception with muscle strength and spasticity in the affected knee

		PAR		AAR	
		Flexion	Extension	Flexion	Extension
MMT	Flexor	−0.836**	−0.821**	−0.521*	−0.218
	Extensor	−0.847**	−0.843**	−0.411	−0.411
MAS		0.722**	0.708**	0.599	0.600

PAR: passive angle reproduction test (joint position sense); AAR: active angle reproduction test (kinesthesia);
MMT: manual muscle test; MAS: Modified Ashworth Scale
*p<0.05, **p<0.01

12.25 degrees on the affected side and 5.15 degrees non-affected side, representing a significant difference (p<0.01). In both the flexion and extension directions, the affected sides were found to have a larger error angles in joint position sense than the non-affected sides (Table 2).

The correlation of proprioception levels with muscle strength and spasticity in the stroke patients was analyzed. Muscle strength was found to have a negative correlation with the flexors and extensors with respect to joint position sense and the flexors with respect to kinesthesia. Spasticity showed a negative correlation with joint position sense (p<0.05) (Table 3).

DISCUSSION

This study examined 31 stroke patients who had been hospitalized or received outpatient treatment by conducting active and passive angle reproduction tests and analyzed the correlation of proprioception with muscle strength and spasticity.

Proprioception is a sensory system that plays a key role in maintaining human body stability through motor control by integrating information from peripheral receptors in the central nervous system[10]. Stroke patients collect information from peripheral receptors normally, but their central nervous system processes information abnormally, causing errors in original information[11, 12]. Proprioceptors are located in contractive tissues and non-contractive tissues. Previous studies reported that activation of contractive tissues comprising muscles, rather than non-contractive tissues such as ligaments and joint capsules, was more effective in treating a proprioception deficit[13, 14]. In addition, active movement rather than passive movement was said to increase proprioception perception ability[15, 16].

The results of this study showed a significant difference between the affected and non-affected sides in the passive angle reproduction test but not in the active angle reproduction test. This means that the errors were smaller in the active reproduction test, in which muscle receptors are activated, than in the passive reproduction test, in which muscle receptors are not activated much.

Stroke patients have damage in the central nervous system that could cause limb muscle weakness or hypertonus[17]. Kim and Ahn[18] reported that for stroke patients, muscle strength was a significant factor determining movement and that therapy to improve muscle strength improving was more effective than therapy to reduce hypertonus. They also argued that to restore the sensory-motor system, muscle strength should be reinforced and spasticity should be reduced.

In this study, examination of the correlation of proprioception with muscle strength and spasticity revealed a negative correlation with muscle strength in the passive angle reproduction test and a positive correlation with spasticity. This is because weaker muscle and higher spasticity generate larger errors, and this is consistent with previous studies.

This study is limited with respect to the ability to generalize its findings to adult stroke patients in general, as it only examined patients of a single general hospital who met the specific criteria for the study. Another limitation is the small number of subjects, as there were only 31 subjects in this study. Follow-up studies are needed to further study the effects of muscle strength exercise, gait, and balance exercises on proprioception of stroke patients.

In summary, 31 stroke patients were examined through a proprioception test on the affected and non-affected sides of the knee joint. Then their muscle strength and spasticity were analyzed for correlations. In comparison of proprioception between the affected and non-affected knee joints, the affected side was found to have a significantly larger error than the non-affected side. In the analysis of the correlation of proprioception with muscle strength and spasticity, the spasticity levels and joint position sense showed a positive correlation, and muscle strength showed a negative correlation.

In conclusion, this study reported that knee joint proprioception deficits are associated with muscle strength and the spasticity level in stroke patients.

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