The Correlation between Hand Function and Sensibility on Constraint-Induced Movement Therapy in Hemiplegia

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Purpose The Purpose of this study was to determine correlation between hand function and sensibility on contraint-induced movement therapy in hemiplegic side. **Method** Ten subjects without a control group were given CIMT to the hemiplegic side for 3 weeks. The effects of their hand function and sensibility were examined using a MAL and two point discrimination Test. Repeated ANOVA was carried out for an analysis of the effects of the application of CIMT before and after treament. Data was analyzed using pearson product correlation between MAL quantitative and qualitative and two-point discrimination. **Result** The participants showed significant improvement in their functional aspect with CIMT. There was significant improvement in the quantitative and qualitative aspect of MAL, as well as significant improvement in the two-point discrimination function in all fingers. There was a statistically significant difference between MAL quantitative and qualitative and two-point discrimination. **Conclusion** CIMT can enhance the motor function and sensory function of the hand in hemiplegic patients. The hand function and sensibility had a correlation on CIMT.

Key words Constraint-induced movement therapy, Hand function and sensibility, Learned nonuse.

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Ⅰ. Introduction

The typical clinical symptoms of stroke are functional disorders such as motor disturbance, perceptual and cognitive impairment, sensory impairment, and visual impairment which cause dysfunction in patients' daily movement and eventually lead to deprivation and depression and lower the patient's quality of life because of the fact that the patient cannot act on his or her behalf (Chung, 2000). In order for the patients to obtain maximum functional recovery and live an independent life, not only should the highest quality of neurological treatment should be provided, but also active rehabilitation, which prevents the development of complication and recovers the patient's ability to live a daily life, is extremely important (Granger et al., 1979). However, although rehabilitation for stroke patients is broadly in operation, there are many cases where motor disturbance remain continuous. A research study on stoke patients, five years after the onset, showed that 56% of them have serious motor disturbance and that this is their worse problem (Wilkinson et al., 1997). Also, most of the patients whose central nervous system is injured, along with stroke and traumatic brain injury, have sensory deficit. Sensory deficit hinder proper motion and decline movement based on sensory input and feedback. Patients with sensory deficit avoid movement and even though they move the action is slow and inharmonious. The loss of proprioception and tactile sensation makes it difficult to recognize passive movement, tactile discrimination, and perception and discrimination (Mauguiere et al., 1983).

Especially, considering that the functional performance of daily movements are mostly done by the upper limbs and the hand, the function of the hand is a creative and emotional technique of expression. Therefore, the hopelessness of stroke patients, who are unable to use their hands and must use alternative methods, can be considered larger than anything (Lee et al., 1999; Trombly et al., 1997). Also, the loss of proprioception of the hand disables the sensation of body parts and negatively affects stability, recognition of objects detected by the hand, motion control of the hand, and the rehabilitation of motor function (Jeannerrod, 1988; Kusoffsky et al., 1982; Loo et al., 1983; McClatchie, 1980). The hand functions as the final link of the mechanical chain of the leverage which starts from the shoulder joint, and enables to move the mobility of the shoulder joint, elbow joint, and wrist joint independently. The hand itself can be coordinated into a moving organ (Cho et al., 2007). Ultimately, the function of the hand includes movement and sensation (Hogan et al., 1990) because without using the hand, it is hard to distinguish the size, shape, material, and temperature of an object. Thus, movement is needed to active the receptors and to feel sensation. Because motor activity and sensation are intimately associated with each other, motor activity can be considered as the tool for sensation (Brodal, 2001).

Patients with hemiplegic due to stroke reported that so far conservative rehabilitation in upper limb is especially insufficient than the lower limb (Basmajian et al. 1989). The reason is that while walking requires a minimal recovery, moving the upper limb requires delicate activities such as grasping, holding, coordinating (Van der Lee et al., 1999). If one leg is healthy, it is possible to move the body and forces the paralyzed leg to move. However, one healthy arm does not help the paralyzed arm to move. Also, if a patient moves the paralyzed upper limb during the convalescent stage after the onset of stroke, harmful consequences such as pain, ataxia, and fall can occur. If a patient experiences such results, they tend show learned nonuse phenomenon, which is the phenomenon of using only the non-paralyzed upper limb, and eventually become impossible to use their damaged upper limb (Taub et al., 1999). Because of these reasons, patients with hemiplegic rely on their non-paralyzed upper limb, which is relatively normal in the range of motion of joints, muscle tone, and muscle strength, to live their daily lives, but then avoid using and touching their paralyzed upper limb. As the period of hemiplegic increases, the usage of the paralyzed upper limb decreases and because of such tendency, the function of the paralyzed upper limb worsens. Also, excessive use of the non-paralyzed upper limb in performing daily life could have an adverse effect upon the functional recovery of the paralyzed upper limb exercise (Davies, 1985). Ultimately, treatments that concentrated only on the paralyzed upper limb did not have a long-term curative effect due to the durability of the effect, motor paralysis and sensory disability, and reluctance towards the paralyzed side (Carmick, 1993; Powell et al, 1999). However, constraint induced movement therapy (CIMT) applied to hemiplegic patients is known to have an exceeding effect to chronic stroke patients with paralyzed upper limb (Ducan, 1997). Katrak and colleagues (1998) reported the effect of the paralyzed side hand of stroke patients on the function of the paralyzed upper limb while Boissy and colleagues (1999) reported that by evaluating the a stroke patient's degree of grasping power, the prognosis of the function of the upper limb can be known.

Therefore, in this study, we applied and verified CIMT to hemiplegic patients along with the hand function of the paralyzed side reported by the existing previous studies; we included two-point discrimination on each finger in order to examine the functional aspects of the ability of the hand when used for subtle tasks and established a hypothesis that will have an effect on hand function and sensibility, and because there are insufficient research on the correlation of hand function and sensibility, we hypothesized that there is a correlation between hand function and sensibility.

II. Method

1. Participants

Ten hemiplegic patients who were admitted to or received ambulatory care services at Eulji University Hospital Rehabilitation Center from August 2006 to October 2006 participated in this study. The chosen patients were diagnosed stroke by brain CT or MRI, received a MMSE-K score of 25 or more, understood the inspector's orders, had an active guardian, the paralyzed side wrist active dorsi flexion was 20° or more, and an active finger extension of 10° or more.

2. Research Method

1) Measurement Instrument

(1) Cognitive Intelligence Test- MMSE-K

This is a test which Kwon, Yong-Cheol and Park, Jong-Hwan (1989) adapted and modified from MMSE, developed by Folsten and Mchugh (1975), into Korean situations. It is composed by 12 items that measure memory recall, concentration of attention, calculation and language skills, and comprehension and judgment. More than 24 or more out of 30 are considered to be normal.

(2) Functional Evaluation of Upper Limb Test- MAL (Motor Activity Log)

The purpose of this test is to evaluate the motor ability of the hands. It includes 30 items divided into quantitative and qualitative measures. The patient's each performance is graded 0-5 while the perfect score is 150. The level of the upper limb is considered to be higher when the score is closer to 150.

(3) Sensory Function Test- Two-point Discrimination.

This test is divided into dynamic and static Two-point discrimination. The former evaluates the hand's sensation which requires touch while moving. The latter evaluates the patient's performance ability to grab which also requires touch.

3. Research Method

(1) Research Procedure

The patients were to immobilize their non-paralyzed upper limb to an armrest and had it on for 90% or more of the time they were awake for three weeks. They were allowed to remove it when they had a wash, used to bathroom, or when it made their activity instable. The patients received neurological developmental therapy for an hour, once per day and five hours a week. During the therapy, the patients were to stand up and put their upper limb on the bed. While the non-paralyzed upper limb was covered by a handkerchief, the paralyzed upper limb received therapy. In addition to the therapy, 50 tasks are standardized and used for shaping and the therapist trained the guardian to choose 10 of the tasks and administer it for 2 hours a day, 10 hours a week. Before the therapy, a week after the therapy, two weeks after the therapy, and three weeks after the therapy were evaluated as above research methods.

Shaping is a frequently used operant conditioning method where the difficulty of the behavioral objective (in this case, movement) increases in each stage. The subject is heavily complimented for the improvement but is not criticized (punished) for the failure. The basic principle is to improve the motor ability a bit more than the performance ability that is is already acquired. Individuals choose and use 12-20 tasks among 50 stylized tasks). Commonly used tools are household tools such as water, jar, household goods, spring, and modified clothespin, and children's toys such as building blocks and marbles, and standard tools used for physical therapy and occupational therapy.

4. Data Analysis

SPSS for Windows 10.0 was used for statistical analysis. Repeated measure ANOVA was used to investigate two items on the hand's function before and after the subjects received CIMT and five items on the increase of the hand's sensibility. Pearson(n) correlation analysis was used to investigate the mutual relevance between hand's function and hand sensibility. The statistical significance level was set at $\alpha = 0.05$.

III. Result

1. Difference of MAL score before and after the

therapy

After the therapy was administered, the MAL quantitative average score increased from 16.60±7.00, prior to the therapy, to 20.50±7.58, a week after the therapy, 25.00±8.22, two weeks after the therapy, and 30.90±8.77, final week of the therapy, and showed a statistical significant difference ($p<0.05$). The MAL qualitative average score increased from 29.30±17.28, prior to the therapy, to 36.00±18.47, a week after the therapy, 46.90±18.98, two weeks after the therapy, and 57.50±18.88, final week of the therapy, and showed a statistical significant difference ($p<0.05$). (Table 1)

Table 1. Change the score of MAL before and after CIMT

(unit: score)

	Before	1 week	2 week	3 week	p
MAL quantitative	16.60±7.00	20.50±7.58	25.00±8.22	30.90±8.77	0.00*
MAL qualitative	29.30±17.28	36.00±18.47	46.90±18.98	57.50±18.88	0.00*

ME±SD: Mean±Standard Deviation
*: p<.05

2. Difference of Two-point Discrimination before and after the therapy

The two-point discrimination distance for the thumb decreased from 7.30mm±1.95, prior to the therapy, to 6.20mm±2.04, a week after the therapy, 5.70mm±1.49, two weeks after the therapy, and 4.40mm±1.51, final week of the therapy, and showed a statistical significant difference ($p<0.05$). Also, two-point discrimination distance for the forefinger decreased from 7.20mm±1.99, prior to the therapy, to 6.10mm±1.73, a week after the therapy, 5.00mm±1.76, two weeks after the therapy, and 3.50mm±1.58, final week of the therapy, and showed a statistical significant difference ($p<0.05$) as the number of therapy increased. The two-point discrimination distance for the middle finger steadily decreased from 7.20mm±2.10, prior to the therapy, to 5.80mm±1.87, a week after the therapy, 4.70mm±1.49, two weeks after the therapy, and 4.00mm±1.15, final week of the therapy, and showed a statistical significant difference ($p<0.05$). The two-point discrimination distance for the ring finger decreased from 7.20mm±1.75, prior to the therapy, to 5.40mm±1.84, a week after the therapy, 4.90mm±1.91, two weeks after the therapy, and 4.30mm±1.25, final week of the therapy, and showed a statistical significant difference ($p<0.05$). The two-point discrimination distance for the little finger decreased from 7.50mm±1.72, prior to the therapy, to 6.20mm±2.35, a week after the therapy, 5.30mm±2.00, two weeks after the therapy, and 4.60mm±1.71, final week of the therapy, and showed a statistical significant difference ($p<0.05$). (Table 2)

Table 2. Change two-point discrimination before and after CIMT

(unit: mm)

	Before	1 week	2 week	3 week	p
Thumb	7.30±1.95	6.20±2.04	5.70±1.49	4.40±1.51	0.00*
Index finger	7.20±1.99	6.10±1.73	5.00±1.76	3.50±1.58	0.00*
Middle finger	7.20±2.10	5.80±1.87	4.70±1.49	4.00±1.15	0.00*
Ring finger	7.20±1.75	5.40±1.84	4.90±1.91	4.30±1.25	0.00*
Little finger	7.50±1.78	6.20±2.35	5.30±2.00	4.60±1.71	0.00*

*: p<.05

3. The Correlation of MAL quantitative, MAL qualitative, two-point discrimination

The MAL quantitative had a high correlation of $r = 0.815$ with MAL qualitative, and a negative correlation with $r = -0.435$, the thumb, $r = -0.558$, the forefinger, and $r = -0.455$, the middle finger. There were no significant correlation with the ring finger, $r = -0.552$, and the little finger, $r= -0.218$. The MAL qualitative had a significant negative correlation with the thumb, $r = -0.542$, the forefinger, and $r = -0.552$, the middle finger, $r = -0.386$, and the ring finger, $r = -0.338$. There were no significant correlation with the little finger, $r = -0.291$. (Table 3)

IV. Discussion

The impaired function of the upper limb hinders most of the daily lives of stroke patients (Page et al, 2002). Choi and colleagues (1997) claimed that when a patient has hemiplegic due to stroke,

the damage of central proprioceptive has an effect on

Table 3. Pearson correlation of MAL quantitative, MAL qualitative, Two-point discrimination.

	MAL quantitative	MAL qualitative	Thumb	Index finger	Middle finger	Ring finger	Little finger
MAL quantitative							
MAL qualitative	.815**						
Thumb	-.435**	-.542**					
Index finger	-.558**	-.552**	.794**				
Middle finger	-.455**	-.386**	.757**	.763**			
Ring finger	-.279**	-.338**	.747**	.704**	.651**		
Little finger	-.218	-.291	.624**	.484**	.638**	.698**	

Values are correlation coefficients(r)
*: $p<.05$, **: $p<.001$
MAL: Motor Activity Log

the recovery of the upper limb rather than the lower limb, and that the treatment period increases. Considering that most of the stroke patients only use the non-paralyzed side for their daily lives, CIMT research are being conducted to make the patients constrain the use of the non-paralyzed side and instead use the paralyzed side.

CIMT, developed based on the plasticity theory, restrains the non-paralyzed side of the arm and heavily exercises the paralyzed side of the upper limb. It is a method which helps stroke patients overcome the learned nonuse phenomenon. It also enhances the arm function permanently by the extension of the cerebral motor cortex in charge of the upper limb function or by the creation of a new motor area through repetitive and functional exercise of the paralyzed side of the arm (Lipert et al., 1998; Koop et al., 1999). The primary purpose of CIMT is to overcome the learned nonuse phenomenon by a concentrative and repetitive exercise, and to use the paralyzed side upper limb so that a relocation of the cortex can occur (Taub and Wolf, 1997). In the study of Wolfgang and colleagues (1999), fifteen stroke patients receive CIMT. For 90% of the time they were awake, the patients restricted their non-paralyzed side by inserting it into an armrest for twelve days. The patients exercised their paralyzed arm for seven hours for eight days during the study period which resulted in an extraordinary and significant improvement after the training. Blanton and colleagues (1999) reported that the follow-up test before and after applying CIMT to a patient, whose onset of stroke was less than four month, showed that the upper limb function improved.

Thus, this study applied CIMT method by referring to Taub's research method in which the stroke patient was able to reuse the paralyzed side after curing the patient's paralyzed side by immobilizing the non-paralyzed side (Lipert et al., 2000). The research subject selection method was also referred from Taub's subject selection minimum standard (Kunkel et al., 1999). The non-paralyzed side was immobilized by an arm sling which was chosen based on the capability of balancing.

Cognitive function tests were administered when the subjects were chosen. Trombly (1989) mentioned that for the physical therapy of brain damaged patients, an appropriate evaluation of the cognitive function and a therapy for that has to be operated. Kim and colleagues (1998) reported that the score of MMSE-K had an effect on function enhancement and that MMSE-K and function enhancement had a significant correlation. Therefore, this study used MMSE-K with subjects who received a score of 25 or higher, meaning that they could perform therapy orders.

In order to evaluate the hand function, this study used MAL and MAL, the proper upper limb function evaluation tool for CIMT. MAL, developed by Taub (Kunkel et al., 1999) had 30 items, both quantitative measure and qualitative measure, with the purpose to evaluate hand function. Also, this study used two-point discrimination evaluation to measure the effect of CIMT on hand sensibility. The two-point discrimination evaluation reflects the numbers and functions of sensory receptors. Static two-point discrimination is an especially significant test because it is deeply related to the regular and continuous sense of touch and measures the use of hand ability of subtle tasks (Mackinnon, 1992).

Neurological developmental therapy was operated for therapy method. Henry and colleagues (1986) reported that functional recovery after brain damage is typically affected by repetitive actions and specific manual therapy technique. Neurodevelopmental treatment focuses on hastening normal movement pattern and postural reaction and decreasing abnormal reflex pattern (Mayo, 1991). The manipulation technique used in neurodevelopmental treatment regulates weight bearing and shifting, intermittent control active range of motion and height, and traction. It also improves the quality of movement, and regulate the functional performance and tension, posture and reflex (Degagi et al., 1994). These neurological development treatments were applied to the therapy by covering the non-paralyzed side hand with a handkerchief and, thus, focusing on key point of control of the trunk and upper limb which are related to the paralyzed side upper limb. Also, to enhance the hand's sensation and function of the paralyzed side, there was hand movement exercise, such as drinking soda, an hour a day, five hour a week.

After they applied CIMT, Kunkel and colleagues (1999) used repeated measure ANOVA to decide the variation of before the therapy and during follow up check, and the variation between before and after the therapy by using MAL and WMFT as the evaluation tool. The upper limb usage increased by 166% after the therapy for MAL, and increased by 165% for the follow up check. In the functional evaluation of WMFT, 17% increased after the therapy and 10% increased in the follow up check, thus reporting that there were significant variation for both after applying CIMT for both before and after the therapy.

After applying CIMT to the therapy, Kim (2002) used MAL and Actual Amount of Use Test (AAUT) to as an evaluation tool to compare the recovery degree of the paralyzed upper limb of the experience group and controlled group. Kim used nonparametric statistical verification method (NPARIWAY) and for the Wilcoxon Singned Rank Test, which showed that both AAUT and MAL had statistical significant difference ($p<0.01$).

Thus, this study used repeated measure ANOVA for three weeks to the therapy applied with CIMT. The result showed that MAL qualitative and quantitative both had statistical significant difference ($p<0.01$). This result was similar to the results of Kunkel and colleague.

In the two-point discrimination, the thumb($p<0.01$), forefinger($p<0.01$), middle finger($p<0.01$), ring finger($p<0.01$), and little finger($p<0.01$) had a statistical significant difference and showed that CIMT was helpful for the hand sensibility enhancement.

The result of this study, which added two-point discrimination to the existing research and showed that there were a statistical significance on hand function test and sensibility test, pointed that CIMT caused a variation to hand function and sensibility. MAL quantitative and MAL qualitative showed a high significant correlation ($r = 0.815$) and implied that the qualitative and quantitative aspect of hand function has a close relationship. Also, MAL quantitative had a negative correlation in thumb($r = -0.435$), fore finger($r = -0.558$), and the middle finger($r = -0.455$) which showed that the quantitative aspect of hand function and the sensibility of the thumb, forefinger, middle finger has a close relationship, while the ring finger($r = -0.279$) and the little finger($r = -0.218$) indicated that there is no relationship between the quantitative aspect of hand function and the sensibility of the ring finger and little finger.

Also, MAL qualitative had a correlation in thumb($r = -0.542$), fore finger($r = -0.552$), middle finger($r= -0.386$), and the ring finger($ = -0.338$) which showed that the qualitative aspect of hand function and the sensibility of the thumb, forefinger, middle finger, and ring finger has a close relationship, while the ring finger($r = -0.291$) had no relationship.

The clinical significance of this study could contribute to the paralyzed side hand treatment, and the hand function has a statistical significant correlation with the thumb, forefinger, and the middle finger which could be considered that there is a close relationship between the hand function and the sensibility. However, because there are a small number of participants, it is limited to be generalized and interpreted. Also, it is not known how long the treatment lasts, and the duration of the patient has not been considered. The neural plasticity should be considered thus objective evaluation tool such as functional CT and transcranial magnetic stimulation should also be used.

V. Conclusion

The purpose of this study was to determine the correlation between hand function and sensibility because it is important to enhance the upper limb function, which has an essential effect on stroke patient's daily life but is slower in recovery than the lower limb, and, thus, investigate the correlation between the hand function and sensibility and to see the effect of CIMT on the paralyzed hand function enhancement by applying CIMT to ten hemiplegic patient's.

As a result, MAL qualitative and quantitative aspects both showed statistical significance before and after applying CIMT and all five fingers showed enhancement on two-point discrimination. Also, hand function and sensibility had a close correlation and indicates that the hand function will enhance if the sensibility enhances. By these results, it can be considered that CIMT can contribute to the enhancement of hand therapy, hand function, and sensibility of hemiplegic patients.

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