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# Effects of Treatment With Bilateral Upper Limb Approach Combined with Electromyography-Induced Neuromuscular Electrical Stimulation on Upper Limb Function and Daily Living in Hemiplegic Patients after STROKE

Ha-Na Kim[1], So-Young Han[2], Jung-Woo Jeong[2], Sung-Ryong Ma[3], Byung-Il Yang[4], Bo-Kyoung Song*[5]

[1]*Doctoral Course, Graduate School, Kangwon National University, 346 Hwangjo-gil, Dogye-eup, Samcheok-si, Gangwon-do, 24949, Republic of Korea, Chung Dam Hospital, Republic of Korea*

[2]*Doctoral Course, Graduate School, Kangwon National University, 346 Hwangjo-gil, Dogye-eup, Samcheok-si, Gangwon-do, 24949, Republic of Korea, Department of Occupational Therapy, Bobath Memorial Hospital, Republic of Korea*

[3]*Professor, Department of Occupational Therapy, Shinsung University, Dangjin-si 31001, Republic of Korea*

[4]*Professor, Department of physical Therapy, Sanggi University, Wonju, 26339, Republic of Korea*

[*5]*Professor, Department of Occupational therapy, Kangwon National University 346 Hwangjo-gil, Dogye-eup, Samcheok-si, Gangwon-do, 24949, Republic of Korea*

mydream57@naver.com[1], gksthdud7000@naver.com[2], j2wot@naver.com[2], masung77@hanmail.net[3], ybi4485@sangji.ac.kr[4], bksong@kangwon.ac.kr*[5]

*Corresponding author[*]: Bo-Kyoung Song, E-mail : bksong@kangwon.ac.kr*

**Background/Objectives**: This study was conducted to confirm effect of the bilateral upper limb training (BULT) with neuromuscular electrical stimulation (NMES) in stroke patients with upper limb dysfunction.

**Methods/Statistical analysis**: The experiment was executed on 33 stroke patients. They were divided into the NMES combined with BULT (NMES-BULT) (n=16) and the general bilateral upper limb training GBULT (n=17). Intervention was conducted for 4 weeks/ 5 times/ a week/ 30 minutes. The test of manual Function (MFT) was utilized as upper limb function evaluation, and Modified Barthel Index (MBI) was used as the daily life evaluation, and the evaluation was performed before and after the intervention.

**Findings**: The change in UL function after intervention between the NMES-BULT group and general BULT was 4.06±0.58 before intervention and 3.55±3.19 after intervention, showing significant differences in the grasp and manipulation of MFT ($p<.05$). In the MFT of the NMES-BULT group, changes in grasping and manipulation items before and after intervention were 3.12±2.38 before intervention, 4.06±0.58 after intervention. It was significantly different after intervention ($p<.01$). And total scores were 13.10±6.93 before intervention, and 13.99±5.23 after intervention. It was significantly different after intervention ($p<.01$). In addition, personal hygiene and clothing improved significantly at MBI ($p>0.5$). Changes in UL function in the general BULT group were 3.42±3.25 before intervention and 3.65±3.19 after intervention in the grasping and manipulation of MFT ($p<0.05$). There was no meaningful difference in the total score ($p>0.05$). And there was no meaningful difference before and after the intervention in daily life ($p>0.05$).

**Improvements/Applications**: It was confirmed that BULT combined with NMES in stroke patients improves manipulation and grasp and influences the ability to perform normal life related to upper limb function.

***Keywords*:** Stroke, Bilateral upper limb training, Upper limb function, Daily living activity, Neuromuscular electrical stimulation

## 1. Introduction

Among patients with hemiplegia due to stroke, only 5% of patients with severe upper limb (UL) paralysis recover completely, and 20% of patients recover partially[1]. In addition, more than 50% of patients develop disability in daily life due to the affected UL[2]. Since activities of daily life have high dependence on UL and are related to the quality of life, it is necessary to enhance the function of UL in order for the patient to return to their pre-stroke life[3]. There are various treatments based on

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brain plasticity for the restoration of UL function in stroke patients[4]. In previous studies, it was confirmed that various treatments combined with electromyography-induced neuromuscular electrical stimulation (NMES) can be beneficial to stroke patients[5]. It has been found to induce neuroplasticity as well as increase the cortical density of the damaged hemisphere[6]. Therefore, movement recovery and functional ability can be improved after various treatments and NMES are used in stroke patients. Bilateral upper limb training (BULT) is a neurological background that promotes voluntary muscle contraction of the affected side by inducing similar movements of the affected UL through the movement of the healthy UL, and activating the primary and supplementary motor areas through the symmetrical movement of both UL[7]. It was reported that BULT had a positive effect on UL function of stroke patients by showing a significant improvement in hand ability and muscle contraction response rate through EMG than in affected side UL training[8]. Even when the placement task such as inserting a cup or putting on a peg was compared with the movement of bilateral UL and the movement of affected side UL, the speed was improved in the bilateral UL[9]. According to a recent study, various attempts have been made to apply NMES treatment to the bilateral UL training of stroke patients. There is clear evidence that the conjunction of the two treatments can reduce neurotic injury and improve spontaneous movement of UL after stroke[10]. However, most of the studies consisted of symmetrical movements of bilateral UL, asymmetrical simple alternating movements, or simple placement tasks, so improvement in the proximal part was confirmed, but it was difficult to expect improvement in activities of daily living(ADLs) or hand function[10]. Therefore, based on previous studies, this study was undertaken to verify the resilience of UL function and daily life by applying NMES training with both hands and UL, rather than simple repetitive training for hemiplegic patients.

# 2. Materials and Methods

## 2.1. *Subjects*

All subjects comprehended the object of this study and concurred to participate after hearing the explanation of the experimental procedure. The criteria for selecting a subject are as follows. Inclusion criteria were: 1) those who were diagnosed with a stroke, 2) those who were more than 6 months after the onset, 3) those who could perform verbal instructions, 4) those whose wrist extension was at least 20 degrees, 5) those who had a metacarpophalangeal joint Those who can extension at least 10 degree in the state of maximum flexion, 6) those who do not have visual defects, 7) those who do not have musculoskeletal disorders

## 2.1. *Materials*

### *2.1.1. Test of manual tunction (MFT)*

MFT is a tool to measure UL function in stroke patients, and it can evaluate dexterity and fine motor of hand. This evaluation has a high level of reliability at r=.95, both between raters and within raters [11].

### *2.1.2. Modified barthel index (MBI)*

MBI was developed by Mahoney and Barthel (1965) as a tool to measure the performance of daily life. It consists of the lower 10 areas, and is given from 0 to 100 points depending on the degree of independence of daily life activities. In daily life activities, complete dependence on others is evaluated as 0 points and complete independence is evaluated as 100 points. The reliability of this tool between evaluators is r=.95 and the reliability within evaluators is r=.89 [16].

## 2.2. *Methods*

The experiment was conducted on 33 stroke patients 6 months after onset, and randomly divided into NMES-BULT group (n=16) and general bilateral upper limb training (GBULT) group (n=17). Intervention was executed for 30 minutes a day, 5 times a week, 4 weeks. The method of BULT is as follows. “ball rolling with both hands, push the incline board with both hands, bar placing on adjustable shoulder exercise Ladder, playing catch bean bag ball, linking rings toy, connecting rubber bands, cutting food, zip up & undo the zipper, washing dishes”. The tasks of both hands were used simultaneously or alternately. The task was selected and applied by an occupational therapist to comfortable the patient's condition. Electrical stimulation (NOVASTIM CU-FS1, CU Medial systems, INC., Korea) was applied with an intensity of 30-70 mA. The amplitude was applied at 250 μsec and the frequency was applied at 35 Hz. It lasted for 5 seconds and then stopped for 5 seconds. It was attached to the extensor digitorum muscles and the extensor pollicis brevis of the affected side upper limb with an aim at hand extension movement. This was applied simultaneously with the BULT.

## 2.3. *Statistical analysis*

The results of the gathered data were statistically analyzed using the Windows SPSS 18.0 program. The general characteristics of the data gathered through the study were analyzed using descriptive statistics, and the normality distribution was confirmed by performing the Shapiro-Wilk test method to verify normality. So as to compare the difference between the NMES-BULT group and the GBULT group, an independent sample t-test was executed. A paired sample t-test was carried out to compare

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the differences after intervention. The statistical meaning level was set to .05.

# 3. Results and Discussion

## 3.1. *Results*

There was no meaningful difference between the two groups as a result of verifying the homogeneity of the general characteristics of the NMES-BULT group and the GBULT group (p=.05). There was no statistically meaningful difference between the UL function and ADLs of the NMES-BULT group and GBULT group before intervention (Table 1). The changes in UL function of the NMES-BULT group and GBULT group after intervention were significantly different in items of grasp and manipulation of MFT, 4.06±0.58 before intervention and 3.55±3.19 after intervention (p<.05). As a result of comparing daily life activities, there was no statistically meaningful difference (Table 2). In the MFT of the NMES-BULT group, the change in pre- and post-intervention grasp and manipulation items was 3.12±2.38 before intervention, 4.06±0.58 after intervention, and the total score was 13.10±6.93 before intervention and 13.99±5.23 after intervention. There were significant differences (p<.01) (p<.01). There was no significant difference, 69.72±21.99 before intervention and 69.90±21.18 after intervention in MBI, but there was a significant increment in the detailed items score of personal hygiene and dressing (p>0.5) (p<.05) (Table 3). In the GBULT group, the change in UL function was 3.42±3.25 before intervention and 3.65±3.19 after intervention in grasp and manipulation, a sub-item of MFT, but there was no meaningful difference in the total score (p<.05) (p>.05). In addition, there were no significant differences before and after intervention in ADLs (Table 4).

**Table 1. Comparison of UL function and ADLs between two groups before intervention**

| | | NMSE-BULT | GBULT | *t* | *p* |
|---|---|---|---|---|---|
| | | M±SD | M±SD | | |
| MFT | Arm motions | 9.31±4.55 | 10.63±3.57 | 1.68 | .41 |
| | Grasp & Manipulation | 3.12±2.38 | 3.42±3.25 | .62 | .53 |
| | Total | 13.10±6.93 | 13.45±6.82 | 1.43 | .16 |
| MBI | | 69.68±20.99 | 74.56±2.93 | .77 | .45 |

*$p$<.05, **$p$<.01 The values are mean (standard deviation), NMSE-BULT: neuromuscular electrical stimulation-bilateral upper limb training, GBULT: general bilateral upper limb training, MFT: test of manual function, MBI:modified barthel index, ADLs: activities of daily living, UL: upper limb

**Table 2. Comparison of UL function and ADLs between two groups after intervention**

| | | NMSE-BULT | GBULT | *t* | *p* |
|---|---|---|---|---|---|
| | | M±SD | M±SD | | |
| MFT | Arm motions | 9.38±3.55 | 10.72±5.01 | 1.32 | .19 |
| | Grasp & Manipulation | 4.06±0.58 | 3.55±3.19 | 2.16 | .04* |
| | Total | 13.89±5.23 | 13.60±7.20 | .93 | .35 |
| MBI | | 69.85±21.18 | 73.92±21.86 | .78 | .42 |

*$p$<.05, **$p$<.01 The values are mean (standard deviation), NMSE-BULT: neuromuscular electrical stimulation-bilateral upper limb training, GBULT: general bilateral upper limb training, MFT: test of manual function, MBI: modified barthel index, ADLs: activities of daily living, UL: upper limb

**Table 3. Changes of ADLs and UL functions in NMES-BULT group**

| | | pre | post | *t* | *p* |
|---|---|---|---|---|---|
| | | M±SD | M±SD | | |
| MFT | Arm motions | 9.31±4.55 | 9.38±3.55 | -1.58 | .44 |
| | Grasp & Manipulation | 3.12±2.38 | 4.06±0.58 | -3.14 | . 00** |
| | Total | 13.10±6.93 | 13.99±5.23 | -2.02 | . 00** |

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| | | | | | |
|---|---|---|---|---|---|
| MBI | Personal hygiene | 3.85±1.36 | 4.01±1.39 | -2.21 | .03* |
| | Dressing | 7.21±4.26 | 7.84±1.26 | -2.09 | .04* |
| | Total | 69.72±21.99 | 69.90±21.18 | -2.02 | .05 |

*$p$<.05, **$p$<.01 The values are mean (standard deviation), NMSE-BULT: neuromuscular electrical stimulation- bilateral upper limb training, MFT: test of manual function MBI: modified barthel index, ADLs: activities of daily living, UL: upper limb

**Table 4. Changes of ADLs and UL in GBULT group**

| | | pre | post | *t* | *p* |
|---|---|---|---|---|---|
| | | M±SD | M±SD | | |
| MFT | Arm motions | 10.63±3.57 | 10.62±5.01 | -1.00 | .32 |
| | Grasp & Manipulation | 3.42±3.25 | 3.65±3.19 | -1.44 | .04* |
| | Total | 13.45±6.82 | 13.60±7.20 | -1.42 | .05 |
| MBI | Total | 74.56±20.55 | 75.12±22.83 | -2.01 | .05 |

*$p$<.05, **$p$<.01 The values are mean (standard deviation), GBULT: general bilateral upper limb training, MFT: test of manual function MBI:modified barthel index, ADLs: activities of daily living, UL: upper limb

### 3.2. *Discussion*

The object of this study was to divide the patients with UL dysfunction after stroke into the GBULT group and the NMES-BULT group to confirm the treatment effect and to compare the differences between two groups. In the results of this study, in the NMES-BULT group, the items corresponding to the grasp and manipulation of the MFT showed a significant improvement. In addition, this seems to be because the direct application site of electrical stimulation is the extensor muscles of the wrist and fingers, and this was a part reported in previous studies[12]. According to previous studies, NMES is used for the purpose of restoring functional movement through neuromuscular relearning, and is known to be effective in recovering function through contraction of paralytic muscle in stroke patients[13]. In the results of MBI measurement to evaluate daily life, there was no significant improvement in daily life activities in both groups. However, in the detailed items, statistically significant improvements were found in personal hygiene and clothing items before and after intervention in the NMES-BULT group. In everyday life, coordination of both UL and function recovery of upper limbs are essential to improve daily activities such as closing buttons on shirts or blouses, zipping jumpers, and pouring water into a cup[14]. Accordingly, in this study, it is probable that the combination of NMES enhanced the function of the paralyzed UL, resulting in better performance than before the intervention. BULT can improve the speed and accuracy of movement by increasing the activation of the primary and secondary motor cortex[15]. In addition, it significantly increases the activation of the globus pallidus of the basal ganglia, thereby reducing unnecessary movements and increasing movement efficiency[16]. Park and Choi (2013) said that even if there is an improvement in MFT, it cannot be seen as a substantial improvement in UL function unless these movements extend to daily life[17]. Several other critical diseases and their strategic solutions were studies [18-28]. Thus, in this study, changes in daily life were evaluated using MBI, and resultingly, it was proved that the group applying NMSE to the fingers and wrist extensors showed a greater improvement in the daily life performance ability related to hand function. In the future, more subjects, onset dates, lesion sites, etc. should be considered and applied to BULT and NMES, and studies on specific treatment programs and effect persistence should be conducted.

## 4. Conclusion

This study probed the effectiveness of applying NMES and BULT on the paralytic side of the UL function and recovery of daily activities in stroke patients. It was divided into the NMES-BULT group and the GBULT group and it was conducted for 4 weeks, and MFT and MBI were measured before and after intervention to evaluate functional and daily life changes in the paralyzed UL. It was confirmed that the NMSE-BULT group significantly improved the function of the grasp and manipulation compared to the BULT group. In addition, BULT was able to confirm that the application of NMES to the extensor muscles of the wrist and fingers further improved the ability to perform daily life using the UL.

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