The Impact of NEURO-15 on Performance Skills and Related Factors in Activities of Daily Living in Patients in the Chronic Phase of Stroke

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Abstract: NEURO-15 is a 15-day program that combines low-frequency repetitive transcranial magnetic stimulation (rTMS) and intensive occupational therapy for patients with chronic hemiparesis following stroke. Though the evaluation of upper-limb function has been used in the past to verify the effects of NEURO-15, the reacquisition of performance skills required for daily living has not been sufficiently evaluated.

Therefore, we conducted this study with an objective of clarifying the effectiveness of NEURO-15 from the viewpoint of regaining performance skills in daily living. We conducted the Assessment of Motor and Process Skills (AMPS) and evaluated upper-limb function before and after NEURO-15 to evaluate performance skills in activities of daily living (ADL) in 20 patients with chronic hemiparesis after stroke.

Our results found that not only upper-limb function performance, but also ADL performance skills changed significantly. Significant difference was found in the Wolf Motor Function Test (WMFT) log performance time, the Simple Test for Evaluating Hand Function (STEF), and paralysis of the dominant hand between those who improved and not improved on the AMPS. In particular, the results of this study on dominant hands would be a key findings for applying NEURO-15.

This study showed the effectiveness of NEURO-15 in patients with chronic hemiparesis after stroke from the viewpoint of regaining performance skills.

Keywords: NEURO-15; AMPS; cerebrovascular disease

Introduction

Over 85% of stroke patients develop hemiplegia, 55–75% of who are left with upper-limb dysfunction [1]. Since upper-limb function is closely related to functions of daily living, patients strongly desire improvement in such functions, and approaches to improve upper-limb functions in hemiplegic patients are actively being studied.
The application of rTMS in the treatment of upper-limb function in patients with upper-limb paralysis following the chronic stage of stroke has been reported [6, 7]. Fregni et al. performed continuous stimulation using rTMS for five days, and found it to be safe and effective in improving upper-limb function [7]. A meta-analysis of rTMS treatment for stroke patients reported when comparing the low-frequency and the high-frequency rTMS in the subgroup analysis, the effect size was 0.69 and 0.41, respectively, which means that low-frequency rTMS is superior [8].

Kakuda et al. developed NEURO-15 as a rehabilitation intervention that uses low-frequency rTMS for patients in the chronic phase of stroke [9, 10]. NEURO-15 is a 15-day intervention program that combines low-frequency rTMS and intensive occupational therapy. After increasing the plasticity of the cerebrum with low-frequency rTMS, an occupational therapist uses a one-on-one approach of intensive frequency to improve the use of the upper limbs in daily living through intensive occupational therapy. High effectiveness of NEURO-15 in patients in the chronic phase of stroke has been reported in a randomized comparative study that used constraint-induced movement therapy as the control group [11]. Kakuda et al. [12] reported on the safety and improved upper-limb function in a comparative study of over 1,700 stroke patients in the chronic phase of stroke.

However, there are some issues with NEURO-15 that have not been sufficiently examined. Though the effects of NEURO-15 on upper limb function have been verified in the past, there has not been sufficient evaluation of the reacquisition of performance skills in daily living.

The objective of this study was to show the effectiveness of NEURO-15 for patients with chronic hemiparesis after stroke from the viewpoint of not only upper-limb functions but also regaining performance skills in daily living. We examined if the significant difference was found in upper limb function evaluation with NEURO-15 and subject characteristics between those who improved and not improved on the AMPS.

**Methods**

**Schedule (Fig. 1)**

Evaluation was performed on the day of admission, and treatment sessions began the following day. NEURO-15 consisted of two sessions per day, one in the morning and one in the afternoon. Patients were given Sundays off, so 15 days of hospitalization resulted

| Tuesday | Wednesday–Saturday | Sunday | Monday–Saturday | Sunday | Monday | Tuesday |
|---------|---------------------|--------|-----------------|--------|--------|---------|
| Morning | Admission           |        |                 |        |        |         |
|         | Low-frequency rTMS (20min) |        | Low-frequency rTMS (20min) |        |        | Low-frequency rTMS (20min) |
|         | One-to-One (60min)  |        | One-to-One (60min) |        |        | One-to-One (60min) |
|         | Intensive OT        |        | Intensive OT    |        |        | Intensive OT |
|         | Self exercise (60min) |        | Self exercise (60min) |        |        | Self exercise (60min) |
| Afternoon| Pre-treatment evaluation | | Post-treatment evaluation |
|         | Low-frequency rTMS (20min) | | Low-frequency rTMS (20min) |
|         | One-to-One (60min)  | | One-to-One (60min) |
|         | Intensive OT        | | Intensive OT |
|         | Self exercise (60min) | | Self exercise (60min) |

**Fig. 1.** The schedule of 15-day combination protocol of low-frequency rTMS and intensive OT. Two sessions of 20-min rTMS and 120-min Intensive OT are provided daily, except for Sundays and the days of admission/discharge.
in 21 treatment sessions. Patients were re-evaluated the day prior to discharge. Evaluations at admission and at discharge were performed in the same order.

Subjects

In this study, we used the inclusion criteria for NEURO-15 established by Kakuda et al. [9] (Table 1). The study population consisted of 20 patients who were hospitalized for NEURO-15 in our hospital for the research period (2016.09.01−2017.08.31) approved by the ethics committee of Nishi-Hiroshima Rehabilitation Hospital. Table 2 shows the pre-treatment demographic information. Nine males and 11 females were included in the study, and had a mean age of 64.85 ± 8.52 years. The mean time from stroke onset to study enrollment was 37.95 ± 29.76 months. There were 11 individuals with right hemiplegia and nine with left hemiplegia in the study population. The Brunnstrom Recovery Stage (BRS) score for the upper limbs was III for two, IV for eight, V for six, and VI for four subjects. The BRS score for the fingers was III for four, IV for nine, and V for seven subjects. All subjects lived in the area, were not hospitalized or in a facility, and were independent in terms of personal activities of daily living (PADL) in their own homes.

Informed consent for the study and treatment was obtained from all patients. The ethics committee of Nishi-Hiroshima Rehabilitation Hospital approved the implementation of this study.

Procedure

Low-frequency rTMS

For low-frequency rTMS, we used a coil in the shape of a figure eight with a diameter of 70 mm and a Mag Pro R30 Mag Venture stimulator (Farum, Denmark). For each rTMS session, 1 Hz low-frequency rTMS was applied to the motor cortex of the unaffected side of the cerebrum for 20 minutes (1,200 stimulations total). The area stimulated by the low-frequency rTMS corresponded to the fingers in the motor cortex of the unaffected side of the cerebrum; in other words, the area in which the motor evoked potential (MEP) of the first dorsal interosseous muscle in the unaffected upper limb was induced at its maximum on the electromyogram (EMG) (Fig. 2). The intensity of stimulation was set at 90% of the motor threshold (the minimum intensity of stimulation able to induce MEP in the stimulation site). Subjects were seated in reclining wheelchairs, and their heads were fixed during stimulation.

Intensive occupational therapy

Intensive occupational therapy consisted of one 60-minute individual occupational therapy session and one 60-minute voluntary training session. The objective of the intensive occupational therapy was to improve the function of the paralyzed upper limb and reacquire the performance skills required for activities of daily living (ADL). The training was determined by an occupational therapist upon obtaining relevant information from physicians, nurses, and medical social workers, and consid-

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Table 1. Inclusion Criteria for NEURO-15

| Criteria                                                                 | Details                                                                 |
|-------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1. More than 12 months since stroke onset.                               |
| 2. Brunnstrom stage 3–5 for hand–fingers of the affected upper limb.    |
| (ability, at least subjectively, to flex the fingers with/without        |
| extension).                                                             |
| 3. Attainment of a plateau state of motor functional recovery at study   |
| entry. Confirmation of the plateau state of recovery established by an    |
| experienced physician and occupational therapist.                        |
| 4. History of a single stroke only (no bilateral cerebrovascular lesions)| |
| 5. No history of seizure. No documented epileptic discharge on the       |
| pretreatment electroencephalogram.                                      |
| 6. No cognitive impairment (i.e., pretreatment Mini Mental State         |
| Examination Score of 26).                                               |
| 7. High level of motivation toward rehabilitation.                       |
| 8. Sufficiently understands the theory and content of NEURO-15, and      |
| consents to its implementation.                                          |
| 9. Independent ADL at home.                                              |
| 10. No pathological conditions referred to as contraindications for      |
| rTMS in the guidelines suggested by Wasserman (e.g. cardiac pacemakers,  |
| intracranial implants, implanted medication pumps, epilepsy, pregnancy)  |

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Table 2. Demographic data of the study population

| Age at admission (years) | Gender | Diagnosis                        | Affected side | Brunnstrom stage | Hand–fingers | Handedness | Hemiparesis of dominant upper limb | Time since stroke onset (months) |
|-------------------------|--------|---------------------------------|---------------|-----------------|--------------|------------|----------------------------------|-------------------------------|
| 64.85 ± 8.52            | Male   | Cerebral infarction             | Right         | III             | III          | Right      | 11 (55)                          | 37.95 ± 29.76                 |
|                         | Female | Intracerebral hemorrhage        | Left          | IV              | IV           | Left       | 9 (45)                           |                               |

Values are numbers (%) or mean ± standard deviation.
erating the needs, living condition, and degree of disorder of the subjects. Training differed slightly depending on the skills and conditions of the subjects. However, the purpose of the training was common, and the duration of training was the same for all subjects.

In actual individual occupational therapy, an occupational therapist with at least five years of experience working with cerebrovascular disease patients worked with patients one-on-one, while a team of occupational therapists worked with each patient. The occupational therapists discussed the development of each program. Specific training was based on the evaluation of skeletal alignment and muscle tone of the upper limbs and torso for each subject, and aimed to improve support for the upper limbs and extend the functional range of motion in joints. For the upper extremities, group flexion and extension exercises and movements that separated the fingers were used depending on the characteristics of the subject. As the upper limb function of subjects changed, training was focused on upper limb use in actual daily living.

After individual occupational therapy, subjects performed voluntary training for 60 minutes in an individual booth within the occupational therapy room. The occupational therapist and subjects discussed the creation of the individual occupational therapy plan. Specifically, training began with stretching as warm up, followed by actual training using daily items related to ADL and APDL.

Assessment Tools

Upper limb evaluation

Evaluation of the upper limbs included upper limb items of the Fugl-Meyer Assessment (FMA), the Wolf Motor Function Test (WMFT), the Simple Test for Evaluating Hand Function (STEF), and the Modified Ashworth Scale (MAS) for elbow flexors, wrist flexors, and finger flexors, and was implemented by the occupational therapist in charge.

The FMA is a comprehensive evaluation battery for motor function that can comprehensively evaluate upper and lower limb dysfunction from voluntary movement, balance, sensation, and range of motion. The reliability and validity of the FMA have been confirmed [14]. In this study, we implemented 33 items from upper limb items: A (shoulder, elbow, and forearm, with a maximum score of 36); B (wrist, with a maximum score of 10); C (hand, with a maximum score of 14); and D (cooperation and speed, with a maximum score of 6). As each item was rated on a three-point ordinal scale (0 = cannot perform, 1 = can perform partially, 2 = can perform fully), the maximum motor performance score for the upper limbs was 66 points.

The WMFT is an objective evaluation created to evaluate functions of the paralyzed upper limb before and after CIMT. The reliability and validity of the WMFT has been confirmed [15]. It consists of 15 items: 6 motor items and 9 object operation items. The time taken for each task was measured and the total time used as the score. However, since the total time score needed to perform the 15 tasks has bias, in this study, similar to Wolf et al. [16], we used the natural logarithm of the time taken to perform tasks. The quality of such movements can be evaluated on a six-point scale, such as the Functional Ability Scale (FAS), which ranges from 0 (no attempt) to 5 (normal movement).

The STEF measures the time taken to move or operate 10 different types of objects, and evaluates using a ten-point scale to calculate the total score. It is widely used as a highly reliable test for patients who are in the process of recovering upper limb function [17]. The scores range from 10 to 100.

The MAS is a semi-quantitative scale that evaluates the degree of spasticity. Bohannon improved the scale developed by Ashworth as a six-step evaluation method by adding “grade +1”, and many have reported its high reliability [18]. In this study, we measured elbow flexors, wrist flexors, and finger flexors and converted “1+” in MAS to 1.5 according to the method of Kaji et al. [19]. Higher scores indicate higher muscle tone.
Evaluation of performance skills in ADL

In this study, to evaluate performance skills in daily living, we used the assessment of motor and process skills (AMPS) [20], which evaluates performance skills in PADL and instrumental activities of daily living (IADL). The AMPS has been standardized using multi-faceted Rasch analysis, and there are no significant differences in mean ADL ability measure (logits) in AMPS between persons with right or left hemispheric stroke, despite hemisphere-specific differences in underlying cognitive and physical impairments [21].

The AMPS has 125 daily living tasks that are standardized at different difficulties, and subjects choose and perform at least two tasks they feel are familiar from their daily living. The evaluator evaluates 16 motor skill items and 20 process skill items on a four-point scale through observation. Motor skill items are a group of skill items that indicate the action of moving themselves or objects when interacting with objects and the environment during tasks. Process skill items are a group of skill items that indicate the actions of choosing and using tools and materials, logically advancing actions and tasks, and correcting actions when there is a problem. Results of the AMPS are indicated in the ADL motor scale and the ADL process scale. These measures reflect the relative impact of motor and process skill deficits on IADL performance [20, 21]. The cut-off value of effectiveness for the ADL motor scale was 2.0 logit, and 1.0 logit for the ADL process scale. A change of 0.3 logit indicates that there was a clinical and observational change. A change of 0.5 logit indicates that there was a statistically significant change [21]. Evaluation of the AMPS was performed by an occupational therapist certified in AMPS evaluation and not involved with the implementation of Neuro-15 at our hospital.

Analysis

To confirm the effectiveness of NEURO-15, we used the Wilcoxon signed-rank test and examined changes in performance skills in ADL and upper limb function before and after NEURO-15.

To confirm what subject characteristics were involved with changes in performance skills in ADL, we assigned subjects who had a change in the ADL motor scale of 0.3 logit or more (clinical and observational change) into the changed group, and those who did not show such changes into the unchanged group.

We then examined if the significant difference was found in changes in upper limb evaluation and subject characteristics (age, gender, time from stroke onset, BRS, and paralysis in the dominant hand) between those who improved and not improved on the AMPS using the Mann-Whitney U test, Fisher’s exact probability test, or Student’s t-test.

For changes in upper limb evaluation, we subtracted the values before and after the implementation so that positive numbers indicated improvement (for the WMFT log performance time, the amount of change = value after implementation − value before implementation). All statistical analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL).

Results

Changes before and after implementation of NEURO-15 (Table 3)

The ADL motor scale of the AMPS increased significantly ($p < 0.001$). Figure 3 shows individual changes. The ADL motor scale index of the AMPS indicated that two subjects were within the range of questionable to mild clumsiness and/or increased physical effort (1.7–1.9 logit) and 18 subjects were within the range of mild to moderate clumsiness and/or increased physical effort or fatigue (0.5–1.6 logit) before implementation of NEURO-15. After NEURO-15, six subjects were within the range of questionable to mild clumsiness and/or increased physical effort (1.7–1.9 logit) and 14 subjects were within the range of mild to moderate clumsiness and/or increased physical effort or fatigue (0.5–1.6 logit).

The ADL process scale of the AMPS increased significantly ($p = 0.011$). Data are presented in Fig. 3. Before the implementation of NEURO-15, two subjects were within the range of efficient (1.3–2.1 logit), 16 subjects were within the range of questionable inefficiency/disorganization (1.0–1.2 logit), and two subjects were within the range of questionable to mild inefficiency/disorganization (0.7–0.9 logit). After NEURO-15 implementation, two subjects were within the range of efficient (1.3–2.1 logit), 17 subjects were within the range of questionable inefficiency/disorganization (1.0–1.2 logit), and one was within the range of questionable to mild inefficiency/disorganization (0.7–0.9 logit).

The total score of the FMA increased significantly ($p < 0.001$) and the category A, B, C, and D scores changed significantly ($p = 0.003, p = 0.034, p = 0.004$, and $p = 0.046$, respectively).

The WMFT log performance time decreased significantly ($p = 0.001$) and the FAS score increased significantly ($p = 0.001$). The total STEF score also increased significantly ($p = 0.04$). The elbow joint, wrist, and fingers in the MAS score showed a significant decrease in muscle tone ($p = 0.008, p = 0.015, p = 0.001$, respectively).

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Table 3. Changes in evaluation items before and after Neuro-15

| Evaluation of performance skills in daily living | At admission | At discharge | P-value* |
|-----------------------------------------------|-------------|-------------|----------|
| AMPS                                          |             |             |          |
| ADL motor scale                               | 1.16 ± 0.37 | 1.40 ± 0.34 | < 0.001* |
| ADL process scale                             | 1.09 ± 0.13 | 1.14 ± 0.11 | 0.011*   |
| Upper limb function evaluation score           |             |             |          |
| The FMA                                        |             |             |          |
| The total score                               | 43.90 ± 12.55 | 46.35 ± 12.21 | < 0.001* |
| category A                                    | 26.65 ± 5.76 | 27.70 ± 5.23 | 0.003*   |
| category B                                    | 5.10 ± 3.73  | 5.40 ± 3.73  | 0.034*   |
| category C                                    | 9.55 ± 3.79  | 10.40 ± 3.44 | 0.004*   |
| category D                                    | 2.65 ± 1.81  | 2.85 ± 1.81  | 0.046*   |
| The WMFT log performance time                  | 2.98 ± 1.41  | 2.74 ± 1.47  | 0.001*   |
| The FAS score                                  | 42.00 ± 14.80 | 43.85 ± 14.49 | 0.001*   |
| The total STEF score                           | 20.30 ± 31.98 | 22.75 ± 33.71 | 0.041*   |
| The MAS score                                  |             |             |          |
| elbow flexors                                  | 1.15 ± 0.76  | 0.88 ± 0.65  | 0.008*   |
| wrist flexors                                  | 1.13 ± 0.74  | 0.88 ± 0.67  | 0.015*   |
| finger flexors                                 | 1.18 ± 0.85  | 0.85 ± 0.69  | 0.001*   |

Values are number or mean±standard deviation.
AMPS, Assessment of Motor and Process Skills; FMA, Fugl-Meyer Assessment; WMFT, Wolf Motor Function test; FAS, Functional Ability Score; STEF, The Simple Test for Evaluating Hand Function; MAS, Modified Ashworth Scale.
By Wilcoxon signed-rank test.
*P values < 0.05 were considered statistically significant.

Fig. 3. Changes in ADL Motor/Process Scale.
Comparison of changes in upper limb evaluation and subject characteristics between the changed group and the unchanged group (Table 4)

The changed group in the AMPS scores tended to be those with paralysis of the dominant hand compared with the unchanged group, and whether the dominant hand was paralyzed was significantly involved with the changes in performance skills ($p = 0.035$). In the upper limb evaluation, there was no significant difference between the two groups before the implementation of NEURO-15; however, after NEURO-15 the changed group had shorter WMFT log performance times compared to the unchanged group, while the total STEF scores increased. Results of these two upper-limb function evaluations were significantly involved with changes in performance skills ($p = 0.006$ and $p = 0.039$, respectively).

Discussion

Effects of NEURO-15 on upper limb function and performance skills in daily living

For upper limb evaluation, A, B, C, D, the total FMA score, the time taken to perform tasks in the WMFT, FAS, and the STEF, and the MAS score showed significant changes before and after the implementation of NEURO-15, showing improvement in upper limb function as a result of NEURO-15. These results are similar to those found in previous studies [9, 10].

There was significant improvement in the ADL motor scale in the AMPS after the implementation of NEURO-15, and ten of 20 subjects showed a 0.3 logit or higher change indicative of an observational change. NEURO-15 aims to improve the use of upper limbs in daily living through intensive occupational therapy after increasing the plasticity of the cerebrum through low-frequency rTMS; therefore, in the AMPS, the scores of the skill items for the patients’ movements of themselves or objects when interacting with objects and the environment during performing tasks are reflected [21]. Thus, our results confirm that there were changes in the ADL motor scale. The reason that improvement was observed in the performance skills in addition to the upper limb function was because the intervention approach that values the use of upper limbs in actual daily living in response to changes in upper limb function of subjects through intensive occupational therapy was effective.

On the other hand, though there was significant improvement in the process skill items after NEURO-15, none of the subjects met the 0.3 logit change that indicates both a clinical and an observational change. Process skill items are sensitive to whether subjects can live independently at home [21]. Subjects in this study lived in the area, were not hospitalized or in a facility, and received NEURO-15 of their own volition; thus, they were able to choose the required two-week hospitalization on their own. In actuality, the mean ADL process scale of subjects before NEURO-15 was 1.09 logit, which was above the cut-off value of effectiveness (1.0 logit) [21]. Therefore, the high skill level present prior to NEURO-15 and the ceiling effect both impacted the poor change in the scores.

As such, NEURO-15 not only improved upper limb function for patients with chronic hemiparesis after stroke, but also had effects on the reacquisition of performance skills in daily living.

Significant difference in the change in upper limb function evaluation and subject characteristics between the changed group and the unchanged group

Our results showed that changes in the WMFT log performance time and the total STEF score were significantly larger in the changed group compared with the unchanged group, and were involved in upper limb function evaluation. The characteristics of upper-limb function evaluation used in this study were as follows: FMA calculates the total score by comprehensively evaluating upper limb function, while MAS is an evaluation specialized for muscle tone. The WMFT and STEF are characterized by calculating the score by measuring the time to perform specific tasks, including elements such as pinching and operating using actual objects, as well as reaching into various spaces [14, 16]. On the other hand, the ADL motor scale of the AMPS scores the quality of performance, such as physical effort and awkwardness, through the observation of specific tasks; thus, the time taken to perform these tasks are reflected in the scores. In other words, the reason that only the WMFT log performance time and the STEF showed significant differences between the two groups was because the evaluation method measured the time taken to perform specific tasks. Therefore, to improve performance skills in ADL in future interventions, actual objects should be used in intensive occupational therapy, and the speed of performance should be taken into consideration.

Compared with the unchanged group, the changed group had significantly more subjects with a paralyzed dominant hand. Subjects without paralysis in the non-dominant hand, who were common in the unchanged group, probably used their dominant hand to perform tasks in daily living, and were already capable of performance skills in daily living. Therefore, compared to subjects whose dominant hand was paralyzed, the impact of improved upper limb function by NEURO-15 was difficult to observe in the ADL motor scale of the AMPS.
Table 4. Comparison of changes in upper limb evaluation and subject characteristics between the changed group and the unchanged group

| Demographic data | The changed group (n = 10) | The unchanged group (n = 10) | P-value* |
|------------------|---------------------------|-----------------------------|---------|
| Gender           |                           |                             | 0.5     |
| Males            | 5                         | 4                           |         |
| Females          | 5                         | 6                           |         |
| Handedness       |                           |                             | 0.763   |
| Right            | 9                         | 9                           |         |
| Left             | 1                         | 1                           |         |
|Affected side     |                           |                             | 0.185   |
| Right            | 7                         | 4                           |         |
| Left             | 3                         | 6                           |         |
| Side of upper limb hemiparesis |                 |                             | 0.035*  |
| Dominant hand    | 8                         | 3                           |         |
| Non dominant hand| 2                         | 7                           |         |
| Brunnstrom Stage (at admission) |             |                             | 0.300   |
| Upper limb       |                           |                             |         |
| III              | 1                         | 1                           |         |
| IV               | 2                         | 6                           |         |
| V                | 4                         | 2                           |         |
| VI               | 1                         | 1                           |         |
| Hand-fingers     |                           |                             | 0.931   |
| III              | 2                         | 2                           |         |
| IV               | 4                         | 5                           |         |
| V                | 2                         | 2                           |         |
| VI               | 2                         | 1                           |         |
| Age at admission(years) |                 |                             | 0.879   |
| 65.80 ± 7.89     |                           | 63.90 ± 9.43                |         |
| Time since stroke onset (months) |             |                             | 0.130   |
| 28.60 ± 23.98    |                           | 47.30 ± 33.19               |         |
| Upper limb function evaluation score before Neuro-15 |     |                             |         |
| The FMA          |                           |                             |         |
| The total score  | 44.90 ± 14.18             | 42.90 ± 11.36               | 0.762   |
| category A       | 26.90 ± 6.47              | 26.40 ± 5.30                | 0.820   |
| category B       | 5.40 ± 3.72               | 4.80 ± 3.91                 | 0.732   |
| category C       | 9.70 ± 4.06               | 9.40 ± 3.72                 | 0.760   |
| category D       | 3.00 ± 1.76               | 2.30 ± 0.189                | 0.415   |
| The WMFT log performance time |         |                             | 0.545   |
| 2.74 ± 1.45      |                           | 3.22 ± 1.41                 |         |
| The FAS score    | 45.00 ± 15.08             | 39 ± 14.67                  | 0.430   |
| The total STEF score |                 |                             | 0.302   |
| 23.60 ± 31.44    |                           | 17.00 ± 33.86               |         |
| The MAS score    |                           |                             | 0.558   |
| elbow flexors    | 1.05 ± 0.80               | 1.25 ± 0.75                 |         |
| wrist flexors    | 1.15 ± 0.85               | 1.10 ± 0.66                 | 0.638   |
| finger flexors   | 1.15 ± 0.88               | 1.20 ± 0.86                 | 0.968   |
| JASID            |                           |                             |         |
| amount of use    | 37.49 ± 15.66             | 47.11 ± 31.76               | 0.791   |
| quality of movement | 39.08 ± 19.46            | 39.66 ± 22.47               | 0.880   |
| Changes in upper limb function evaluation score before and after Neuro-15 |     |                             |         |
| The FMA          |                           |                             |         |
| The total score  | 3.10 ± 2.81               | 1.80 ± 1.62                 | 0.374   |
| category A       | 1.40 ± 1.51               | 0.70 ± 0.95                 | 0.259   |
| category B       | 0.40 ± 0.52               | 0.20 ± 0.63                 | 0.194   |
| category C       | 1.00 ± 1.33               | 0.70 ± 0.82                 | 0.775   |
| category D       | 0.20 ± 0.42               | 0.20 ± 0.42                 | 1.000   |
| The WMFT log performance time |         |                             | 0.006*  |
| 0.37 ± 0.27      |                           | 0.09 ± 0.21                 |         |
| The FAS score    | 2.60 ± 2.88               | 1.10 ± 1.73                 | 0.131   |
| The total STEF score |                 |                             | 0.039*  |
| 5.10 ± 4.98      |                           | -0.20 ± 3.36                |         |
| The MAS score    |                           |                             |         |
| elbow flexors    | 0.25 ± 0.49               | 0.30 ± 0.35                 | 0.461   |
| wrist flexors    | 0.25 ± 0.42               | 0.25 ± 0.35                 | 0.825   |
| finger flexors   | 0.20 ± 0.26               | 0.45 ± 0.44                 | 0.147   |

Values are number or mean ± standard deviation.
FMA, Fugl-Meyer Assessment; WMFT, Wolf Motor Function test; FAS, Functional Ability Score; STEF, The Simple Test for Evaluating Hand Function; MAS, Modified Ashworth Scale.
By the Student’s t-test or Fisher’s exact probability test or Mann–Whitney U test.
*P-values < 0.05 were considered statistically significant.
There is a possibility that subjects whose non-dominant hand was paralyzed need further strategies by which to transfer improved upper limb function to skills in daily living.

Limitations

The limitations of this study were the lack of a control group, since subjects were all voluntarily hospitalized for NEURO-15, the variation of the characteristics of subjects and the mixture of stroke patients with different levels of motor abilities and side of hemiplegia.

The effect of NEURO-15 in terms of upper limb improvement was high in subjects whose BRS was four. Since there were a small number of subjects in this study, we were unable to make comparisons based on BRS. In the future, the number of subjects should be increased in order to examine if the contribution of NEURO-15 in the reacquisition of performance skills in daily living changes depending on the degree of paralysis.

Conclusions

We were able to show the effectiveness of NEURO-15 for patients with chronic hemiparesis after stroke, not only for the improvement of upper limb function but also for the reacquisition of performance skills in daily living. We also showed that the significant difference was found in improved task performance speed and paralysis of the dominant hand between those who improved and not improved on the performance skills in ADL after NEURO-15.

Declaration of interests

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the present paper.

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