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Original Article

A neurocognitive approach for recovering upper extremity movement following subacute stroke: a randomized controlled pilot study

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Abstract. [Purpose] This study aims to describe a protocol based on neurocognitive therapeutic exercises and determine its feasibility and usefulness for upper extremity functionality when compared with a conventional protocol. [Subjects and Methods] Eight subacute stroke patients were randomly assigned to a conventional (control group) or neurocognitive (experimental group) treatment protocol. Both lasted 30 minutes, 3 times a week for 10 weeks and assessments were blinded. Outcome measures included: Motor Evaluation Scale for Upper Extremity in Stroke Patients, Motricity Index, Revised Nottingham Sensory Assessment and Kinesthetic and Visual Imagery Questionnaire. Descriptive measures and nonparametric statistical tests were used for analysis. [Results] The results indicate a more favorable clinical progression in the neurocognitive group regarding upper extremity functional capacity with achievement of the minimal detectable change. The functionality results are related with improvements on muscle strength and sensory discrimination (tactile and kinesthetic). [Conclusion] Despite not showing significant group differences between pre and post-treatment, the neurocognitive approach could be a safe and useful strategy for recovering upper extremity movement following stroke, especially regarding affected hands, with better and longer lasting results. Although this work shows this protocol's feasibility with the panel of scales proposed, larger studies are required to demonstrate its effectiveness.

Key words: Physical therapy, Stroke, Upper extremity

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INTRODUCTION

Strokes produce important physical, psychological and social consequences, in spite of advances in prevention and early care[1)]. Several studies highlight the importance of cognitive activities such as attention, memory and action observation on the nervous system plasticity[2, 3)]. The experiences and the information generated by these cognitive activities influence motor learning[4, 5)]. Hence, the importance of providing the patient with learning experiences and sensory stimuli enriched by the interaction with a therapist[6)].

After stroke, achieving patients' functionality (e.g. being able to turn a door handle) has become the focus of the therapeutic action. The emphasis of treatment has virtually always been focused on performing the task, regardless of how it was

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executed, whereas the qualitative aspects of the activity have not been considered to be important[7, 8]. Similarly, there are few qualitative outcome measures[7, 8]. Taking into account the knowledge on motor learning which highlights not only the motor processes but also the sensory and cognitive strategies[5], it is possible to direct the therapeutic performance to "recovery" instead of "compensation". This implies focusing the intervention more on the quality of execution rather than on the final result, promoting an adequate activation of the existing patterns prior to the injury[5, 9].

A therapeutic strategy that addresses these approaches is the Cognitive Therapeutic Exercise based on the neurocognitive rehabilitation theory described by the neurologist Carlo Perfetti[10, 11]. This theory connects the activation of cognitive processes with sensory-motor recovery by means of the patient learning new interaction patterns with their surroundings[10, 11]. Although its effectiveness in orthopedic rehabilitation has been recently demonstrated[12–14], there is a need for well-designed studies in neurological patients. A prior randomized clinical trial[15] in acute stroke used a protocol with an unclear and non-specific methodology and it concluded without statistically significant evidence between the two groups. Recently, significant differences were found on upper limb functions from chronic stroke patients, regarding activities of daily living and quality of life[16].

Our study has implemented a protocol based on the neurocognitive approach considering and acting on the individual's motor, sensory and cognitive characteristics. The aim was to determine its feasibility and evaluate whether subjects treated with this protocol improved qualitative upper extremity (UE) movement. We hypothesized that subjects who received the neurocognitive protocol would show greater improvements on motor, sensory and cognitive functional aspects when compared with those treated with a conventional protocol, and these positive changes would also demonstrate clinical and significant improvements on UE functionality with maintenance at follow-up.

SUBJECTS AND METHODS

Participants were recruited from the University Hospital Germans Trias i Pujol. The inclusion criteria were: diagnosis of subacute ischemic stroke (from 15 days to 3 months, middle cerebral artery territory), age between 25 and 80, Mini-Mental test ≥24, motor deficits in UE caused by stroke (Motricity Index <99) and enough trunk control to be able to sit with dorsal support. Exclusion criteria were: global aphasia, somatoagnosia or neglect, Modified Ashworth Scale >2 and carrying out other types of therapies at the same time as the study with the exception of the occupational therapy treatment applied to all participants of the study.

Each participant signed an informed consent form. The study was approved by the hospital's Clinical Investigation Ethics Committee (register number: AC-11-094) and conducted according to the Helsinki Declaration.

Following enrollment, participants were randomized consecutively for 10 months by a random number table into two groups: the control group (CG) which received conventional physical therapy and the experimental group (EG) with the neurocognitive protocol. The evaluator was a widely experienced and trained physical therapist in assessing and treating stroke patients. The study was evaluator-blinded in order to keep allocation concealment. The percentage of adherence rate of 80 and 100% required for treatment and assessments (A), respectively, as well as the percentage of retention rate of 85% were established and controlled by both therapists.

A panel of scales was applied at the beginning of the study (A1), at 5 weeks (A2), at the end of the treatment in the 10th week (A3) and at a follow-up 10 weeks later (A4). The primary outcome was the Motor Evaluation Scale for Upper Extremity in Stroke Patients (MESUPES) score to assess UE functionality. It is the only validated scale for evaluating quality of motion[8, 17]. It consists of two parts: MESUPES-arm and MESUPES-hand. MESUPES-arm comprises 8 items pertaining to shoulder and elbow performance. The result is obtained by adding together the points at each assessment (A1–2–3–4). Each item is scored from 0 (inability to adapt muscle tone to the movement) to 5 (ability to correct and complete motion without help). MESUPES-hand consists of 9 wrist and finger items scored on a 3-pointed rating scale: No movement or incorrect=0; Movement incomplete=1; Movement complete=2[8, 17]. The minimal detectable change (MDC) for the total score with 95% confidence level was calculated and resulted in a score difference of 8 to be necessary for a genuine change of function when assessed by different raters. However, the MDC obtained intra-rater was expected to be lower[17].

Additional outcomes included: The Motricity Index Test, validated for the quantitative assessment of paretic UE muscle strength. In this study it includes 3 actions: pinch grip, elbow flexion and shoulder abduction. The arm score is the result of adding together the points for the 3 arm test +1 at each assessment (A1–2–3–4)[18]. The Revised Nottingham Sensory Assessment is a standardized scale for evaluating sensory impairment in stroke patients[19]. The kinesthesia subscale is applied bilaterally on the shoulder, elbow, wrist and metacarpal-phalangeal joint at each assessment (A1–2–3–4). It is scored from 0 (absent sensation) to 3 (correct position). The light touch subscale displays the result of adding together every assessment score on the shoulder, elbow, wrist and palm. It is scored on a 3 point rating scale: Absent sensation=0; Impaired sensation=1; Normal sensation=2[19]. The Kinesthetic and Visual Imagery Questionnaire assesses the cognitive aspect of imagining a movement in its two main dimensions, visual and kinesthetic[20]. It shows the result of adding together the points of each upper extremity item at each assessment with the exception of A2 when no change was expected to be observed. Both dimensions evaluated shoulder elevation, forward shoulder flexion, elbow flexion/extension, thumb-fingers opposition on a score from 1 (no image or sensation) to 5 (image as clear as seeing or as intense as executing the action)[20].

Table 1. Hierarchy of sensory tasks with cognitive activation

Sensory task	Difficulty level (low to high)	Cognitive activity required
Kinesthetic	Joint movement discrimination	Recognition of change between presence and absence of movement: "Tell me when you feel the change"
		Recognition of the presence or absence of the movement: "Tell me when you feel that the joint X moves"
	Simple parameter joint movement discrimination	Recognition of the joint moved: "Which joint has been moved?"
		Recognition of the direction of movement of the joint X: "In which direction is it moving?"
	Complex parameter joint movement discrimination	Recognition of the distance of movement in the joint X: "How far has it moved?; In what position are you?"
		Recognition of the static position (spatial relations): "Where is your elbow in relation to your shoulder?"
		Copying spatial relations with the contralateral extremity: "Try to imitate exactly the same position with your other arm"
Tactile	Contact discrimination	Recognition of change between presence and absence of contact "Tell me when there is a change"
		Recognition of the presence or absence of contact "Tell me if you feel there is an area in contact with your palm and fingers"
	Contact location discrimination	Recognition of the contact location: "Where do you feel the contact?"
	Tactile surface discrimination	Recognition of similarities and/or differences: "Is this tactile surface the same or different from the one you felt before?"
		Recognition of touch (surface categorization) "What does this tactile surface feel like?; What surface do you think it is?"

The values obtained with MESUPES at A1 allowed the blinded evaluator to determine the level of motor involvement required by every participant (passive, active-assisted or active). The evaluator also recommended sensory and cognitive difficulties of the exercises, but those recommendations were only followed by the physical therapist in the EG treatment.

In both groups the intervention consisted of passive, active-assisted and active mobilizations with freedom of directions. Proprioceptive joint information was provided on the shoulder, elbow, wrist and fingers segments in addition to tactile information, using different textured surfaces (rough, fine, etc.), on palms and fingers[21, 22]. Both groups performed a 30-minute treatment with 3 individual sessions/week for 10 weeks[23, 24]. Fifteen minutes were dedicated to shoulder, elbow and wrist and 15 minutes to the affected hand. The participant was positioned in a supine position for the first part and in a sitting position for the second one[8].

During UE mobilizations and the contact with different surfaces, EG participants received the proposal of sensory discrimination tasks organized in a hierarchy (from lower to higher difficulty)[12, 13, 22, 25, 26] (Table 1). Resolution of these tasks involved cognitive activation of learning strategies such as observation, motor imagery, imitation, etc[12, 13, 25–27]. Every task was proposed as a problem to be resolved with closed eyes[13, 22, 25, 26]. The physical therapist began with the most suitable task for each participant and continued with the following one after the satisfactory completion of the first task[5, 12, 13]. In addition, the physical therapist could constantly adapt the protocol to the individual's level based on daily observation but always under the protocol guidelines, designed by an experienced physical therapist and based on the neurocognitive theory[12, 13].

No discrimination tasks were established in the CG although mobilizations and different surfaces were proposed[28, 29]. Hence, CG participants received the same type of information (propioceptive and tactile) but they were not asked to resolve any problem nor to be aware of their body sensations.

Individual characteristics and therapy adherence were expressed as mean ± standard deviation (SD). The therapy adherence rate (%) was also reported. Outcome measure data were reported as score differences between the post and pre-study (A4–A1) for each participant, the A1 and A4 median (Md) for each group as well as between each assessment (Md of A2–A1, A3–A2 and A4–A3). Nonparametric statistical tests were employed. The Pearson χ^2 test and Mann-Whitney U Test were used to compare demographics and clinical characteristics between groups. The Wilcoxon signed rank test allowed pre-post clinical evolution from the beginning to the end of the study to be determined in both groups and the Mann-Whitney U Test was used to compare the changes between groups on A1 and A4. A significance level of 0.05 has been used in all analyses but considered only in an exploratory sense. Descriptive and inferential analyses were performed using SPSS version 21.0.

Table 2. Change of functionality, muscle strength, sensory discrimination and motor imagery ability

Outcome measures		CG (n=4)	EG (n=4)
MESUPES-arm	Pre	18 (12, 29.5)	32.5 (29, 35.5)
	Post	22 (11, 34.5)	38 (36, 40)
	Δ	4	5.5
MESUPES-hand	Pre	2 (0.5, 4.5)	8.5 (8, 12.5)
	Post	6.5 (0, 15.5)	17.5 (15, 18)
	Δ	4.5	9
MI	Pre	39.5 (26.5, 54.5)	67 (58.5, 73)
	Post	51 (32, 76)	77 (77, 85)
	Δ	11.5	10
RNSA-light touch	Pre	8 (6, 8)	4 (3.5, 5.5)
	Post	8 (6, 8)	6.5 (5, 8)
	Δ	0	2.5
RNSA-kinesthesia	Pre	8.5 (8, 10.5)	10 (8.5, 10.5)
	Post	11 (10, 12)	12 (11, 12)
	Δ	2.5	2
KVIQ-visual	Pre	17 (14, 19.5)	13.5 (10.5, 16.5)
	Post	19.5 (19, 20)	20 (14.5, 20)
	Δ	2.5	6.5
KVIQ-kinesthesia	Pre	18 (17, 19.5)	18 (15, 20)
	Post	19.5 (17.5, 20)	18.5 (14, 20)
	Δ	1.5	0.5

All data are expressed as medians with interquartile range: Md (min, max)
CG: control group; EG: experimental group; MESUPES: Motor Evaluation Scale for Upper Extremity in Stroke Patients; MI: Motricity Index test; RNSA: Revised Nottingham Sensory Assessment; KVIQ: Kinesthetic and Visual Imagery Questionnaire
Tested by Wilcoxon signed rank test. Significance level of 0.05

RESULTS

Seven subjects with involvement of the right middle cerebral artery and one of the left were finally considered for analysis. One subject withdrew after A2 because of personal reasons and was discarded (retention rate=89%). The average age was 53.4 ± 9.6 years old, seven males and one woman, all of whom were right-handed. Time from stroke onset to treatment was 43.5 ± 23 days. No statistically significant differences between groups were found relating to gender (p=1) and injured hemisphere (p=1) nor age (p=0.89) and time from stroke onset to treatment (p=0.89). All the participants attended at least 80% of the treatment sessions and all four assessments. The average attendance was 25.9 ± 1.5 sessions. This represents an adherence intervention rate of 95.8% in the 10-week treatment period and an assessment rate of 100% in the 20-week study period.

Although not statistically significant, there were more relevant pre-post study improvements in the EG on MESUPES arm and hand subscales. These changes appeared earlier and lasted throughout the study in the EG. Despite random assignment, significant differences between groups were found at A1 with lower hand values in the CG (p=0.03). In terms of the minimal detectable change (MDC), all the participants of the EG and 2 of the CG (Participant 1 and 4) reached pre-post clinical changes. The secondary outcome measures showed neither statistically significant differences (p>0.05) between groups nor pre-post study changes for each group (Table 2). In particular, muscle strength improvements were found mainly in the first 5 weeks for both groups, the same as the kinesthetic results in the CG. The kinesthetic improvements in the EG were reached at the end of the treatment period as well as the maximum visual image results for both groups.

Primary and secondary outcome results of each participant in both groups are shown in Table 3.

DISCUSSION

This study aims to show the influence of motor, sensory and cognitive aspects on UE recovery in subacute stroke patients through the comparison between a neurocognitive protocol and a conventional treatment. The combined use of a panel of scales is also proposed as it allows the different components involved in motor control to be segregated and assessed.

Table 3. Primary and secondary outcome results of each participant

Outcome measures	CG	A1	A2	A3	A4	A4−A1	EG	A1	A2	A3	A4	A4−A1
MESUPES-arm	P.1	37	38	38	39	2	P.5	36	40	40	40	4
	P.2	14	10	10	8	−6	P.6	35	38	40	40	5
	P.3	10	13	15	14	4	P.7	28	30	33	36	8
	P.4	22	28	28	30	8	P.8	30	30	34	36	6
MESUPES-hand	P.1	6	13	17	18	12	P.5	8	16	17	18	10
	P.2	1	0	0	0	−1	P.6	16	17	17	18	2
	P.3	0	0	0	0	0	P.7	9	11	14	13	4
	P.4	3	6	15	13	10	P.8	8	11	17	17	9
MI	P.1	64	77	77	85	21	P.5	73	93	93	93	20
	P.2	34	29	34	29	−5	P.6	73	77	77	77	4
	P.3	19	24	29	35	16	P.7	56	73	77	77	21
	P.4	45	67	67	67	22	P.8	61	73	77	77	16
RNSA-light touch	P.1	8	8	8	8	0	P.5	7	8	8	8	1
	P.2	4	4	6	4	0	P.6	4	4	4	8	4
	P.3	8	8	8	8	0	P.7	4	4	4	5	1
	P.4	8	8	8	8	0	P.8	3	5	6	5	2
RNSA-kinesthesia	P.1	12	12	12	12	0	P.5	10	9	12	10	0
	P.2	9	10	9	10	1	P.6	11	10	12	12	1
	P.3	8	10	11	12	4	P.7	10	12	12	12	2
	P.4	8	11	11	10	2	P.8	7	9	11	12	5
KVIQ-visual	P.1	19		20	20	1	P.5	11		12	9	−2
	P.2	15		19	19	4	P.6	10		20	20	10
	P.3	20		20	20	0	P.7	16		12	20	4
	P.4	13		20	19	6	P.8	17		20	20	3
KVIQ-kinesthesia	P.1	20		20	20	0	P.5	14		12	11	−3
	P.2	17		20	20	3	P.6	20		20	17	−3
	P.3	19		20	19	0	P.7	16		16	20	4
	P.4	17		20	16	−1	P.8	20		20	20	0

A: assessment; CG: control group; EG: experimental group; P: participant; MESUPES: Motor Evaluation Scale for Upper Extremity in Stroke Patients; MI: Motricity Index test; RNSA: Revised Nottingham Sensory Assessment; KVIQ: Kinesthetic and Visual Imagery Questionnaire

In particular, MESUPES has allowed us to determine the individual's initial and successive states in terms of movement quality concerning functional tasks. The preliminary results of both groups suggest the use of MESUPES to obtain stratified sampling in larger studies. Thus, by obtaining more accurate information, the adaptation of the protocol to the characteristics of each individual is facilitated. The high adherence of participants in treatment and assessments sessions could be explained by both these factors.

Although the results were not statistically significant, due partially to the small sample studied, they are of important clinical relevance. Firstly, the neurocognitive protocol would seem to be feasible. Furthermore, it resulted in a considerable improvement in the functional autonomy of the UE. In particular, all the EG participants and 2 of the CG showed the score differences (MDC) needed to obtain a clinical change.

The MESUPES scale shows improvements in both groups indicating that neurocognitive and conventional treatments have been useful to UE functionality (Table 2); but also demonstrating that the neurocognitive one (EG) promotes more benefits in all segments (shoulder, elbow, wrist and hand). This group presented superior pre-post changes on arm and hand subscales. In previous studies by Lang et al.[30–32], a higher recovery of the proximal segments is questioned and lack of differences between proximal and distal joints is reported. Our pilot study highlights a greater distal recovery, where the changes for the hands were higher, and occurred earlier in the EG, as a probable consequence of giving greater importance to their treatment. This is consistent with Perfetti's concept of the hand[10, 11], considered as an essential element for the interaction with the objects inside the action, in which the movements of the more proximal segments are involved and acquire their significance. To do so, it should be noted that the exercises proposed for the hands included kinesthetic and tactile information due to their importance concerning hand functionality[25, 26]. The evolution of both groups supports the importance of starting treatment as soon as possible[33–35] and maintaining it for at least 10 weeks. With exception of some studies on chronic stroke, there is little evidence on the effectiveness of rehabilitation beyond this period, because no further treatments are usually maintained 3 months after the stroke[36]. In the present study, these months coincide with the period between A3 and A4, in which there was an overall stabilization of the evolution of UE functionality in the CG, while improvements in the EG were still observed. In addition, the improvements from A1 to A4 may indicate the importance of both motor learning strategies through the discrimination tasks[5, 37] and also the need to extend the treatment beyond this period of time for a better recovery[38]. In concordance with previous studies[34, 35] that show the correlation between the individual's initial state and the prognosis, we have also found that subjects with mild or moderate severity have a better functional outcome reached in a

shorter time compared to those with higher severity, despite the fact that these subjects are also expected to show an evident improvement at the end of the rehabilitation.

Earlier and superior improvements in muscle strength were found in the EG. These gains obtained mainly in the first 5 weeks for both groups did not correlate with increased functionality throughout the 10 weeks of treatment. This is evidenced by the MESUPES scale for all segments in the EG and for the hand in the CG. This would indicate that although muscle strength, assessed by the Motricity Index, is gained at the beginning in all segments, more time is needed to translate its gains into functionality improvement through training[28]. Moreover, it would indicate that favorable progression in UE movement depends mainly on parameters such as accuracy, fluidity, coordination or correlation between joints[7, 32, 39, 40]. All of these are qualitative aspects in which sensory discrimination has an important role[25, 26].

There are still few studies about the effects of passive movement in brain areas during the processing of tactile and kinesthetic information; but Van de Winckel et al.[25, 26] have already observed that, under both normal and stroke conditions, passive sensory discrimination causes the activation of parietal, pre-motor and motor areas in a similar way as active exploration. There are different studies about sensory treatment protocols on stroke patients for recovering sensory impairments[21, 22]. On the other hand, our pilot study aims for movement recovery by sensory processing tasks. Despite the need for more homogeneous research into the impact of sensory impairments on motor and functional UE recovery[41], a direct relationship between those aspects would seem to exist[41, 42]. The importance of maintaining the treatment during at least 10 weeks is also supported by sensory results. Tactile and kinesthetic values in the EG were modified throughout treatment. The light touch trend of improving after the treatment period could be an indicator of the learning factor which is highlighted in the neurocognitive protocol. In the EG, kinesthetic maximum values were obtained at the end of 10 weeks, unlike the CG where improvements were mainly in the first 5 weeks. Considering that kinesthesic median values at A1 in both groups were high, there was not a great deal of margin for improvement (Table 2). These results lead us to highlight the role of tactile and kinesthetic discrimination in improving UE functionality.

Finally, the cognitive element assessed has been the ability to imagine the UE movement. As in some studies[20, 43], the values of healthy UE were higher in its two dimensions (visual and kinesthetic). These results suggest that motor and sensory deficits affect the capacity to imagine the body part involved, despite still being in the subacute phase (15 days to 3 months), but this capability changes within a short period of time (days or a few weeks). In the present study, it is mainly altered for the visual dimension (Table 2). Both groups evolved favorably and similarly over the 10 weeks of treatment, until almost reaching the maximum score of the visual image. We can hypothesize that, unlike the kinesthetic image, this component is altered in early stages (acute and subacute). Conversely, the constant arrival of pathological information as well as the probable difficulty in remembering the correct movement sensations would subsequently cause a kinesthetic image disorder. The recovery of motor memory needs a better and stable representation of the primary motor area achieved with guided therapeutic exercises[44]. A potential limitation in the study is that other cognitive elements also activated in the discriminatory tasks, such as memory or attention, were not evaluated. Some studies[45, 46] have demonstrated the facilitation of tactile processing in the primary sensory area through attention.

Other limitations of this study include the lack of neuroimaging techniques to gather further data and a small sample size that resulted in unequal comparison groups with respect to MESUPES outcomes despite random assignment. This study used a blinded evaluator to decrease the likelihood of biased assessment measures.

In general, our results support the protocol feasibility and the use of a panel of scales in order to obtain more accurate evidence of the neurocognitive approach effectiveness by means of a larger study. Despite the fact that some clinical trials have been recently published about neurocognitive treatment using a similar approach, their results are not easily comparable to ours, because Chanubol et al.[15] and Lee et al.[16] performed protocols without establishing clearly either the selection criteria of exercises level or their progression. Sensory and cognition assessments were not applied and the other assessments were only performed before and after treatment.

Despite the lack of statistical significance, this pilot study indicates that upper extremity movement deficits improve when exercises with motor, sensory and cognitive components are performed following a neurocognitive approach. A careful selection of the appropriate difficulty for each individual as well as the guidance of a therapist in the cognitive and sensory processes allow greater and prolonged improvements over time on the upper extremity, especially for the hand function. The neurocognitive approach is a safe, useful and easily applicable way to work with stroke patients in any rehabilitation center. Although further research is necessary, the feasibility of the proposed protocol facilitates the carrying out of a clinical trial to consolidate evidence of these findings.

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