RESEARCH ARTICLE

# Effects of mental imagery technique in addition to conventional physical therapy to improve hand functions in chronic stroke patients

Iqra Mubeen, Ashfaq Ahmad, Waqar Afzal


## Abstract

**Objective:** To observe the effect of mental imagery and conventional physical therapy for the treatment of hand function in chronic stroke patients.

**Methods:** The study was conducted at Rana and Alvi welfare society. A sample of 50 stroke patients was selected and divided in two groups; group A (experimental) and group B (control). Inclusion and exclusion criteria were established and patients meeting inclusion criteria were included in the study. A *p*-value of <0.05 was considered significant. Group A was treated with conventional physical therapy combined with mental imagery whereas Group B was treated with conventional physical therapy alone. Wolf motor function test and action research arm test was used as outcome measures.

**Results:** Group A consisted of 17 (68%) females and 8 (32%) males and group B comprised of 11 (44%) females and 14 (56%) males. Mean age of group A and B were 59.68±2.37 and 58.52±2.46 years respectively. Mean duration (in months) of stroke for group A was 16.32±3.77 (minimum and maximum duration 13 and 23 months respectively). The stroke mean duration of group B was 16.00±2.34 (minimum and maximum duration 13 and 20 months respectively). Both groups did not show significant difference at 5th week ($p$=0.721) whereas a significant difference was observed at 10th week ($p$<0.001).

**Conclusion:** It was concluded that mental imagery technique in combination with conventional physical therapy is significantly effective to improve hand function among chronic stroke patients in comparison to conventional physical therapy alone.


**Keywords:** Conventional physical therapy, mental imagery, repeated task practice, stroke.(JPMA 71: .1944; 2021)

**DOI: https://doi.org/10.47391/JPMA.998**

## Introduction

Mental imagery is a training method in which an individual mentally performs a physical task by using his imagination skills only and not performing it physically. The purpose of the training is to enhance motor skill performance. Multiple current studies have suggested augmented recovery of motor function by using mental imagery combined with physical practice.[1] Practicing any skill in imagination or physically activates the similar areas of brain.[2] International comparative data on stroke prevalence reveals a high stroke prevalence among developing countries in comparison to developed countries. There is hence more need to direct efforts towards planning new interventions for stroke patients, so that disease burden on country may be reduced.[3] There has been an active debate on the functions of mental imagery for years,[4] the evidence of its effectiveness in hand recovery comes from different lines of research: sports literature, neurophysiologic evidence, health psychology research[5] and space sciences.[6] Implementation of this intervention might result in more functional improvement and enhanced quality of life of stroke patients. If healthy outcome proved, it would be valuable addition to new and existing evidence on this debate, which could serve community by becoming a tool for early and rapid recovery of patients globally. Mental imagery once learnt could be performed without any supervision; hence, addition of this treatment would not add any further financial burden on patients.

University Institute of Physical Therapy, The University of Lahore.

**Correspondence:** Iqra Mubeen. e-mail: iqra.awan28@gmail.com

## Methods

The study was a quasi-experimental research. A sample size of 50 patients was calculated using: power=0.8 and significance level=0.05. Sample was selected through purposive sampling technique. Patients were divided in two groups (25 in each group). The pre-diagnosed cases of ischaemic stroke were selected from physiotherapy OPD of Rana and Alvi welfare hospital Lahore from 10th May 2018 to 18th August 2019. Inclusion criteria for study was as follows, i) patients having minimum 100 active flexion on affected wrist and at least two digits, ii) stroke duration more than 12 months, iii) a score more than 70 on modified mini mental state examination scale (to briefly assess attention, concentration, orientation to time and place, long-term and short-term memory, language ability, constructional praxis, abstract thinking, and list-generating fluency, this scale also provides a brief cognitive assessment of the patient) iv) age between 55 to 75, v) male and female genders, vi) patients in initial learning stage, vii) a score less than 2 on modified Ashworth spasticity scale (for elbow, wrist, hand and fingers). Modified Ashworth scale measures resistance during

passive soft tissue stretching. Its score ranges from 0-4, 0= normal tone or no increase of muscle tone, 1= slight increase in muscle tone manifested by a catch and release or minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension, 1+= slight increase in muscle tone manifested by a catch followed by a minimal resistance throughout the remainder (less than half) of the ROM, 2=more marked increase in muscle tone through most of the ROM but affected part(s) easily moved, 3= considerable increase in muscle tone passive movement difficult, 4= affected part(s) rigid in flexion or extension. The intra-rater reliability of the scale is 0.84 and interrater reliability is 0.847.[7] Exclusion criteria for the study were as follows; i) patients with stroke of parietal lobe, as parietal lobe injury limits imaginary abilities, ii) patients with any comorbidity, previous surgery, on medication having serious hallucinations, congenital anomaly. Outcome measures of the study were Wolf motor function test and Action Research Arm Test. WMFT is a test that is specifically designed for evaluation of physical limitations primarily in post stroke rehabilitation studies. The test comprises of 17 subsets, involving basic functional movements;1) Forearm to table (side), 2) Forearm to box (side) 3) Extend elbow (side), 4) Extend elbow, 5) Hand to table, 6) Hand to box, 7) Weight to box in lbs. 8) Reach and retrieve, 9) Lift can, 10) Lift pencil, 11) Lift paper clip 12) Stack checkers ,13) Flip cards14) Grip strength in kg, 15) Turn the key in lock, 16) Fold towel, and 17) Lift basket. Every subset is scored on from 0-5 (0=No movement, 5= completely normal movement). The total score of test ranges between 0-75. Mental imagery and repetitive task practice of current study focuses on functional limitations, hence, WMFT was used as an outcome measure. The inter-rater reliability of the test is 0.97 or more for performance time and 0.88 or more for functional ability. The test-retest reliability of the test is 0.90 for performance time and 0.95 for functional ability.[8] ARAT is a test used to evaluate upper limb functional recovery after brain injury. It is further divided into four subsets i.e. Grasp, Grip, Pinch and Gross Movement. The total score of the test ranges 0-57, (10=poor, 10-56= moderate and 57= good recovery). The intra-class correlation coefficient (ICQ) of the test for the total score is 0.98 which indicates a very high inter-rater reliability. ICCs are also very high in each of the subscales.[9] Patients were divided in 2 groups, Group A was treated by using mental imagery of the following tasks; i) approaching for and holding a cup (weeks 1&2), ii) swapping a page (weeks 3&4), iii) appropriate use of pen (weeks 5&6), iv) appropriate use of spoon/fork (weeks 7&8), v) using comb/hair brush (weeks 9&10), for 30 minutes/day three days a week for ten weeks combined with repetitive practice for half hour a day for 3 days in a week for 10 weeks. Patients were guided to practice the task by keeping in view complete scenario of movement and to feel it as they are doing it personally (during session of mental imagery). These activities were chosen because a) these are few of those activities that most of stroke patients desire to regain after stroke attacks b) these activities might be graded according to subject's abilities to be easier or more difficult c) in addition to this some authors have mentioned that mental imagery should be practiced on those tasks only that subjects had previously participated as according to Mulder performance of newly learned task is not that much improved in comparison to the task that participant been practicing before stroke.[10] Group B was treated with conventional physical therapy. The conventional physical therapy plan included the repetitive practice of the same task specific functional movements i.e. i) approaching for and holding a cup (weeks 1&2), ii) swapping a page (weeks 3&4), iii) appropriate use of pen (weeks 5&6), iv) appropriate use of spoon/fork (weeks 7&8), v) using comb/hair brush( weeks 9&10), for half hour three days a week for 10 weeks. Previously most of the studies on mental imagery for rehabilitation of stroke included treatment duration of 2-6 weeks,[11] however, a little extended duration of treatment i.e. 10 weeks was used in current study. Measurements were taken at three levels i.e. baseline (at start of the treatment) at 5th week (mid treatment) and at 10th week (end treatment). There was 20% drop out in group A and 16% drop out in group B. SPSS 21 was used to statistically analyse the results. Normality of the data was tested by using Shapiro wilk test. Independent sample T test and Repeated measure ANOVA was used to check effectiveness between groups and within group, respectively. Ethical approval was gained from the Ethical Committee of University of Lahore before study. Written informed consent was taken from all the patients. All information and collected data was kept confidential. Participants remained anonymous throughout the study. The subjects were informed that there are no disadvantages or risks of the procedure of the study. They were also informed that they were free to withdraw at any time during the process of study.

## Results

The data was gathered from both genders male and female. Group A consisted of 17(68%) females and 8 (32%) of males and groups B comprised of 11 (44%) females and 14 (56%) males. Mean ages of both groups were approximately similar, mean age of group A and group B were 59.68±2.37 and 58.52±2.46 Years respectively. Patients with stroke duration>12 months were included in the study. Mean duration (in months) of stroke for group A was 16.32±3.77. The mean stroke duration of group B was 16.00 ±2.34 (Table 1). Grip strength, in kg, was measured at

three levels baseline, 5th week and 10th week, baseline grip strength for group A was 20.44±5.25, for group B was 20.10±6.28. At 5th week, grip strength of group A and B improved to 22.28±5.01 and 21.22±6.20, respectively. At 10th week, grip strength of group A and B improved to 26.48±5.34 and 24.37±6.19, respectively (Table 1).

Mean values for Wolf motor function test were evaluated at three levels, at baseline, mid-treatment and post-treatment. Baseline WMFT mean score for group A was 38.2±2.69 and for group B was 40.96±2.92. The mean values improved and at 10th week measurement, mean WMFT for group A was 69.96±1.69 (a gain of 31.76 points) and for group B was 57.9±4.69 (a gain of 16.94 points). Greater score of WMFT in group A indicated more improvement. The results indicated that score of WMFT and hence hand function was improved in both groups but group A showed more improvement (Table 1). ARAT was taken as another measure to evaluate hand function. Mean values for ARAT were also evaluated at three levels i.e. baseline, mid-treatment and post-treatment. The baseline mean ARAT value for group A was 5.00±1.19 and for group B was 4.64±1.28, respectively. The 10th week mean ARAT value for group A was 49.6±4.30 and for group B 38.2±4.06 (Table 1). The results demonstrated improvement in both groups, however, effect of MIT + conventional therapy given to the groups A dominated treatment given to group B (conventional therapy alone). Independent sample T-test was applied to evaluate effectiveness of treatment between the groups. P-value of WMFT at 5th week measurement was ($p$=0.721) indicating that initially at 5th week measurement both groups weren't significantly different, however, both groups were significantly different at 10th week of treatment $p$<0.001 (Table 2). Similar pattern

**Table-1:** Mean values of results.

| | Group A Mean | Group B Mean | Group A SD | Group B SD | Group A Std. Error Mean | Group B Std. Error Mean |
|---|---|---|---|---|---|---|
| Age | 59.68 | 58.52 | 2.37 | 2.46 | - | - |
| Gender | Female 17 Male 8 | Female 11 Male 14 | - | - | - | - |
| Stroke duration (in months) | 16.32 | 16.00 | 3.7 | 2.34 | - | - |
| WMFT-Baseline | 38.32 | 40.96 | 2.69 | 2.92 | .53 | .58 |
| WMFT- 5th Week | 44.92 | 45.28 | 4.03 | 2.97 | .80 | .59 |
| WMFT-10th week | 69.96 | 57.96 | 1.69 | 4.69 | .33 | .93 |
| ARAT-Baseline | 5.00 | 4.64 | 1.19 | 1.28 | .23 | .25 |
| ARAT- 5th Week | 29.88 | 30.04 | 4.47 | 5.47 | .89 | 1.09 |
| ARAT-10th week | 49.60 | 38.20 | 4.30 | 4.06 | .86 | 1.41 |
| Grip Strength baseline | 20.4440 | 20.10 | 5.25 | 6.29 | 1.05 | 1.26 |
| Grip Strength 5th week | 22.2840 | 21.22 | 5.02 | 6.21 | 1.00 | 1.24 |
| Grip Strength 10th week | 26.4880 | 24.38 | 5.35 | 6.19 | 1.07 | 1.23 |

ARAT= action Research arm test; WMFT= wolf motor function test; SD=Standard Deviation.

**Table-2:** Within group comparison.

| Multivariate Tests[a] | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Group** | **Effect** | | **Value** | **F** | **Hypothesis df** | **Error df** | **Sig.** |
| Group A | WMFT | Pillai's Trace | 0.991 | 1204.662[b] | 2.000 | 23.000 | 0.000 |
| | | Wilks' Lambda | 0.009 | 1204.662[b] | 2.000 | 23.000 | 0.000 |
| | | Hotelling's Trace | 104.753 | 1204.662[b] | 2.000 | 23.000 | 0.000 |
| | | Roy's Largest Root | 104.753 | 1204.662[b] | 2.000 | 23.000 | 0.000 |
| Group B | WMFT | Pillai's Trace | 0.978 | 511.892[b] | 2.000 | 23.000 | 0.000 |
| | | Wilks' Lambda | 0.022 | 511.892[b] | 2.000 | 23.000 | 0.000 |
| | | Hotelling's Trace | 44.512 | 511.892[b] | 2.000 | 23.000 | 0.000 |
| | | Roy's Largest Root | 44.512 | 511.892[b] | 2.000 | 23.000 | 0.000 |
| Group A | ARAT | Pillai's Trace | 0.960 | 277.528[b] | 2.000 | 23.000 | 0.000 |
| | | Wilks' Lambda | 0.040 | 277.528[b] | 2.000 | 23.000 | 0.000 |
| | | Hotelling's Trace | 24.133 | 277.528[b] | 2.000 | 23.000 | 0.000 |
| | | Roy's Largest Root | 24.133 | 277.528[b] | 2.000 | 23.000 | 0.000 |
| Group B | ARAT | Pillai's Trace | 0.786 | 42.139[b] | 2.000 | 23.000 | 0.000 |
| | | Wilks' Lambda | 0.214 | 42.139[b] | 2.000 | 23.000 | 0.000 |
| | | Hotelling's Trace | 3.664 | 42.139[b] | 2.000 | 23.000 | 0.000 |
| | | Roy's Largest Root | 3.664 | 42.139[b] | 2.000 | 23.000 | 0.000 |

[a]= Design: Intercept; Within Subjects Design: ARAT; [b]= Exact statistic

**Table-3:** Between group comparison.

| | Levene's Test for Equality of Variances | t-test for Equality of Means | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | T | Df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| WMFT-Baseline | EVA | 0.345 | .560 | 3.322 | 48 | 0.002 | 2.64000 | 0.79467 | 4.23779 | 1.04221 |
| | EVNA | | | 3.322 | 47.680 | 0.002 | 2.64000 | 0.79467 | 4.23807 | 1.04193 |
| WMFT- 5th Week | EVA | 4.094 | .049 | 0.359 | 48 | 0.721 | 0.36000 | 1.00240 | 2.37545 | 1.65545 |
| | EVNA | | | 0.359 | 44.199 | 0.721 | 0.36000 | 1.00240 | 2.37994 | 1.65994 |
| WMFT-10th week | EVA | 11.934 | 0.001 | 12.021 | 48 | 0.000 | 12.00000 | 0.99827 | 9.99285 | 14.00715 |
| | EVNA | | | 12.021 | 30.153 | 0.000 | 12.00000 | 0.99827 | 9.96170 | 14.03830 |
| ARAT-Baseline | EVA | 0.667 | 0.418 | 1.027 | 48 | 0.310 | 0.36000 | 0.35062 | 0.34497 | 1.06497 |
| | EVNA | | | 1.027 | 47.709 | 0.310 | 0.36000 | 0.35062 | 0.34508 | 1.06508 |
| ARAT- 5th Week | EVA | 0.647 | 0.425 | 0.113 | 48 | 0.910 | 0.16000 | 1.41398 | 3.00299 | 2.68299 |
| | EVNA | | | 0.113 | 46.177 | 0.910 | 0.16000 | 1.41398 | 3.00589 | 2.68589 |
| ARAT-10th week | EVA | 12.159 | 0.001 | 6.891 | 48 | 0.000 | 11.40000 | 1.65429 | 8.07383 | 14.72617 |
| | EVNA | | | 6.891 | 39.641 | 0.000 | 11.40000 | 1.65429 | 8.05562 | 14.74438 |

EVA= equal variances assumed, EVNA=equal variances not assumed.

was observed on the scores of ARAT. Measurements taken on ARAT at 5th week were not significantly different ($p$=0.910) however 10th week measurements indicated a significant improvement in hand function of stroke patients ($p$<0.001) (Table 2). Within group effectiveness was analyzed by Repeated Measure ANOVA. The test was applied on score of WMFT and ARAT (baseline, mid-treatment and post-treatment). The results of ANOVA indicated that hand function was significantly improved in both group A (mental imagery + conventional physical therapy) and group B (conventional physical therapy alone) ($p$<0.001) (Table 3).

## Discussion

Mental imagery is a therapeutic intervention that involves mental rehearsal of a physical task by using internal stimuli to provoke motor signals in absence of overt actions.[11] Mental rehearsal of a task activates the similar regions of the brain as activated by physical performance of the same task. It further enhances and speeds up the acquisition of physical task and alterations in motor function. There is enough literature supporting the neurophysiological basis of mental imagery. Stippich stated that when a person moves different body parts (tongue, foot/hand) a specific activation could be seen at precentral gyrus. The activation is more prominent at somatotropic region.[12] In current study, mental imagery technique was used to improve hand function of stroke patients. Mental imagery technique was found to be effective in improving hand function. Ehrsson stated that primary motor areas activates during the imagination of any body part. The activation is concerned with the part of body moved as he observed activation of somatotropic area on movement of tongue and digits of upper and lower limb.[13] Similarly hand improvement was observed among stroke patients following mental imagery of five ADLs i.e. approaching for and holding a cup, swapping paper of a book, holding pen, holding spoon, and combing hair. An increase of 31.7 points (from 38.2 to 69.9 points) on WMFT after administration of mental imagery indicates significant treatment effects. The WMFT gains achieved in current study were much higher (31.7 points) than the gains achieved in other similar studies. For example a similar study conducted by Kim in 2015 documented an improvement of only 5 points. The extended duration of the current study justifies this incremented improvement as previously most of the studies treated patients for 4 weeks only[14] whereas in current study treatment was given for 10 consecutive weeks.

Celnik et al demonstrated that ADLs performance ability of patients with CNS injury improves after task observation exercises, for example watching a clip on opening and closing door of a freezer.[15] Mental imagery training rather than task observation was used in current study. The results of current study agreed to the study conducted by Celnik et al.[15] Mental imagery tasks of the current study were the tasks of ADLs that were frequently performed by all the participants before stroke episode (autonomous stage of learning). The results of this study indicated that rehabilitation with mental imagery technique combined with physical training improves functional recovery of hand in stroke patients.

The results of treatment given to group B i.e. conventional physical therapy alone showed improvements too. The results were alike the study conducted by Thomas in 2017 which showed that repetitive task-oriented approach can retrieve upper limb function,[16] an improvement of 16.9 points was found on WMFT after treating patients with physical practice of routine tasks for 30 minutes

5days/week for 10 weeks. ARAT was used as another measure to evaluate the outcome of mental imagery and conventional physical therapy. Both groups presented improvement in ARAT score, however, ARAT improvement was significantly higher in mental imagery group in comparison to group B. P value less than 0.05 indicated significant differences between both groups.

Malouin et al. reported the importance of familiarizing the task before incorporating it in treatment.[17] It was observed that participants treated with mental imagery showed less improvement during first 5 weeks of treatment and the treatment effects were more profound during the last 5 weeks of treatment. One of the suspected reasons behind this observation is the time taken by patients to familiarize with technique. Although the tasks selected were very familiar to patients and were repeatedly performed by patients before stroke, but the technique, to imagine a task for treatment purpose was relatively new for patients. Hence, it might have taken sometime by them to accommodate to imagery technique, thereby, adding to the delayed response.

Machado suggested that it is vital to mentally rehearse a task before executing it physically.[18] Current study agreed with their findings. Mental imagery is a complementary training method that might enhance functional performance; however, inevitably it cannot substitute physical movements. The significance of physical performance of a task remains there. It is only after evaluating level of injury and neuronal condition of the patient, that decision of administrating mental imagery alone to be considered. Mental imagery might assist patient to keep neuronal networks alive when neuronal decline does not permit sound physical movements.[19,20] In patients with neurological deficits, it not only improves gross movement performance but also improves cortical reorganization,[19] this improved activation remains helpful in further motor function gains.

Current study has limitation in measuring brain activity while administrating mental imagery and hence the actual time of imagery practiced by each patient cannot be mentioned with full certainty. Measuring quality of life and stress level of patients might have added to the available literature but current study lacks in any such measurements. Furthermore, correlation of effectiveness of mental imagery with gender and age of the participants was not investigated.

While administrating mental imagery one problem was to teach patients about imagination and strength of imagination and thereby no significant effects of MI were observed in first half of treatment. Patients with parietal lobe injury lack spatial sense and navigation i.e. proprioception and cannot imagine things. Hence such patients cannot have a benefit with mental imagery. The technique without enough knowledge of nervous system seems bogus and ambiguous and hence many patients and their attendants, despite agreeing for treatment, exhibited concerns regarding the efficacy of treatment and improvement of their patient.

## Conclusion

It was concluded that mental imagery technique in combination with conventional physical therapy is significantly effective to improve hand function among chronic stroke patients in comparison to conventional physical therapy alone. Mental imagery technique appears to be a promising technique to improve hand function at chronic stage of patients when the reversal of dysfunction becomes difficult with many other techniques.

**Disclaimer:** none.

**Conflict of interest:** none.

**Funding disclosure:** the study was self-financed and has no funding sources to declare.

## References

1. Christakou A, Vasileiadis G, Kapreli E. Motor imagery as a method of maintaining performance in pianists during forced non-practice: a single case study. Physiother Theory Pract 2021; 37: 540-8.
2. Ramos-Murguialday A, Curado MR, Broetz D, Yilmaz Ö, Brasil FL, Liberati G, et al. Brain-Machine Interface in Chronic Stroke: Randomized Trial Long-Term Follow-up. Neurorehabil Neural Repair 2019; 33: 188-98.
3. Khan MI, Khan JI, Ahmed SI, Ali S. The epidemiology of stroke In a developing country (Pakistan). J Neurol Stroke 2018; 8: 00275.
4. Pearson J, Naselaris T, Holmes EA, Kosslyn SM. Mental imagery: functional mechanisms and clinical applications. Trends Cogn Sci 2015; 19: 590-602.
5. Chaturvedi A. Role of Practice and Mental Imagery on Hand function improvement in stroke survivors. J Neurol Neurosci. 2017, 8: 2.
6. Guillot A, Debarnot U. Benefits of motor imagery for human space flight: A brief review of current knowledge and future applications. Front Physiol 2019; 10: 396.
7. Compagnat M, Daviet JC, Batcho C, Vuillerme N, Salle JY, David R, et al. Oxygen Cost During Walking in Individuals With Stroke: Hemiparesis Versus Cerebellar Ataxia. Neurorehabil Neural Repair 2020; 34: 289-98.
8. Eaves DL, Riach M, Holmes PS, Wright DJ. Motor imagery during action observation: a brief review of evidence, theory and future research opportunities. Front Neurosci 2016; 10: 514.
9. Cervera MA, Soekadar SR, Ushiba J, Millán JDR, Liu M, Birbaumer N, et al. Brain-computer interfaces for post-stroke motor rehabilitation: a meta-analysis. Ann Clin Transl Neurol 2018; 5: 651-63.
10. Al Kasab S, Lynn MJ, Turan TN, Derdeyn CP, Fiorella D, Lane BF, et al; SAMMPRIS Investigators. Impact of the New American Heart Association/American Stroke Association Definition of Stroke on the Results of the Stenting and Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis Trial. J Stroke

Cerebrovasc Dis 2017; 26: 108-15.

11. Kilteni K, Andersson BJ, Houborg C, Ehrsson HH. Motor imagery involves predicting the sensory consequences of the imagined movement. Nature Communications 2018; 9(1): 1-9.
12. Stippich C, Ochmann H, Sartor K. Somatotopic mapping of the human primary sensorimotor cortex during motor imagery and motor execution by functional magnetic resonance imaging. Neurosci Lett 2002; 331: 50-4.
13. Lega C, Chelazzi L, Cattaneo L. Two Distinct Systems Represent Contralateral and Ipsilateral Sensorimotor Processes in the Human Premotor Cortex: A Dense TMS Mapping Study. Cereb Cortex 2020; 30: 2250-66.
14. Kim SS, Lee BH. Motor imagery training improves upper extremity performance in stroke patients. J Phys Ther Sci 2015; 27: 2289-91.
15. Celnik P, Webster B, Glasser DM, Cohen LG. Effects of action observation on physical training after stroke. Stroke 2008; 39: 1814-20.
16. French B, Thomas LH, Coupe J, McMahon NE, Connell L, Harrison J, et al. Repetitive task training for improving functional ability after stroke. Cochrane Database Syst Rev 2016; 11: CD006073.
17. Malouin F, Jackson PL, Richards CL. Towards the integration of mental practice in rehabilitation programs. A critical review. Front Hum Neurosci 2013; 7: 576.
18. Machado S, Lattari E, Paes F, Rocha NB, Nardi AE, Arias-Carrión O, et al. Mental Practice Combined with Motor Rehabilitation to Treat Upper Limb Hemiparesis of Post-Stroke Patients: Clinical and Experimental Evidence. Clin Pract Epidemiol Ment Health 2016; 12: 9-13.
19. Nilsen DM, Gillen G, DiRusso T, Gordon AM. Effect of imagery perspective on occupational performance after stroke: A randomized controlled trial. Am J Occup Ther 2012; 66: 320-9.
20. Israely S, Leisman G, Carmeli E. Neuromuscular synergies in motor control in normal and poststroke individuals. Rev Neurosci 2018; 29: 593-612.