Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2023 Jul 26; 11(B):678-683.
https://doi.org/10.3889/oamjms.2023.11656
eISSN: 1857-9655
Category: *B - Clinical Sciences*
Section: *Rehabilitation*

The Influence of Giving Sensomotoric Stimulation to Improve Functional Ability in Patients with Stroke

Dewi Suci Mahayati*, Wina Widiatul Hikmah, Utami Gaswi, Vira Aisyah Mercury

Department of Neurorestoration, National Brain Centre Hospital, Prof. Dr. Mahar Mardjono (RSPON), Jakarta, Indonesia

Edited by: Sinisa Stojanoski
Citation: Mahayati DS, Hikmah WW, Gaswi U, Mercury VA. The Influence of Giving Sensomotoric Stimulation to Improve Functional Ability in Patients with Stroke. Open Access Maced J Med Sci. 2023 Jul 26; 11(B):678-683. https://doi.org/10.3889/oamjms.2023.11656
Keywords: Senso-motoric stimulation; Motor skill; Functional ability
***Correspondence:** Dewi Suci Mahayati, Department of Neurorestoration, National Brain Centre Hospital. Prof. Dr. dr. Mahar Mardjono Jakarta (RSPON), Jakarta, Indonesia. E-mail: chiquita.suci@gmail.com
Received: 17-Apr-2023
Revised: 08-May-2023
Accepted: 19-Jul-2023

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Sensory stimulation can help individuals regain sensitivity by paying attention to sensory input and its relationship to the activity to be carried out. Sensory stimulation combined with functional exercise is the main determinant of functional improvement in stroke. The study of the intensity and duration of therapy has not been widely carried out.

AIM: The purpose of this study was to evaluate the influence of sensorimotor stimulation given intensively to improve functional abilities in patients with stroke and to ensure that there was no deterioration in their medical condition as a result of initial therapy.

MATERIALS AND METHODS: This research method uses a pre-experimental design with a one-group pre-posttest involving 30 patients meeting predefined inclusion criteria in a one-group pre- and post-test design. The program consists of 16 sessions of sensomotoric stimulation and functional activity training in the physiotherapy gymnasium and daily sessions of ADL at home over 6 weeks. The efficacy of the program was evaluated by a stroke rehabilitation assessment of movement and a functional independence measure.

RESULTS: A significant difference was observed in both motor skill ($p = 0.00$) and functional ability ($p = 0.00$) obtained on the 6th week of assessment. In a comparison of the benefits of therapy in two gender groups ($p = 0.96$ and 0.20), age groups ($p = 0.55$ and 0.86), and stroke severity ($p = 0.50$ and 0.64). The result showed there is no significant difference in the benefits of therapy applied to all of these groups.

CONCLUSION: Sensomotoric stimulation given from the 1st day of stroke and continued intensively has been found to have a better impact on motor skills and functional ability.

Introduction

Stroke is classically characterized as a neurologic deficit associated with acute focal injury to the central nervous system (CNS) by vascular causes, including cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage, and is a leading cause of disability and death worldwide. Stroke sufferers usually experience motor and sensory disturbances, cognitive and perceptive deficits, and emotional disturbances [1]. Immediately after a stroke, the focus of treatment changes from medical management and pain management to an exercise plan to regain effective functional activity in daily life. Thus, stroke has an important impact on their quality of life [2].

Stroke remains a serious problem faced by almost all countries in the world [3]. Although stroke has gone through significant development in the last 20 years, it is still the number one cause of disability in the world [4] and responsible for the third largest number of deaths in the world [5].

Rehabilitation environments can be direct facilitators of rehabilitation goals if they are set up for health, fitness, mental and physical stimulation, and learning. In general, patients with good sensory function tend to have better rehabilitation outcomes than those who do not. Currently, many exercises have been developed that involve their cognitive and daily activities and allow patients to participate actively. In this program, the nervous system can select the sensory input needed for the movement activities to be carried out [6].

Recovery for stroke patients is often only aimed at improving existing disorders such as muscle weakness and sensory loss. When muscle and sensory strength have increased but are not followed by an increase in functional ability. In this study, sensoromotor stimulation is expected to not only restore motor skills but also improve functional abilities [7].

Several research results on the use of rehabilitation time show that only a small part of the patient's day is spent on exercise. Research conducted by Jeon and Hwang (2018) concluded that task-specific exercises from motor learn programs in the early phase of rehabilitation can help learning of motor control and restore activity and movement patterns [8]. Research on stroke is mostly conducted to see the effect of an

intervention technique, not to increase the frequency of therapy in an acute or subacute period.

Sensomotor stimulation can help individuals regain sensitivity by paying attention to sensory input and its relationship to the activity to be carried out. For example, applying pressure and weight to the soles of the feet while standing and sitting, while standing and reaching forward, or while sitting to stand will help to increase awareness of the paretic extremity [9].

The purpose of this study was to evaluate the influence of sensorimotor stimulation given intensively to improve functional abilities in patients with stroke.

Research Methods

The study was followed by 30 patients who met the inclusion criteria and were registered at the National Brain Center Hospital. Prof. Dr. Mahar Mardjono Jakarta (RSPON). The study was conducted from September 2021 to September 2022.

The inclusion criteria included; (1) ischemic stroke patients diagnosed by CT Scan; (2) patients with a first stroke or second stroke without any neurological deficits experienced during the first stroke; (3) patients aged 25–70 years; (4) patients who do not suffer from aphasia; and (5) patients without severe cognitive impairment with a MMSE value greater than 21.

Exclusion criteria were conditions that affected the patient's physical condition at the onset of the acute period: (1) Hypertension more than 160/100 mmHg until 3 days of hospitalization; (2) patients with Knee osteoarthritis; (3) patients with cardio respiration disease, In this study, the authors will prove that intensive sensory motor stimulation is an effective method to improve functional abilities in stroke patients. Therefore, in order to prove the research results, the authors use the quasi-experimental design method.

Physiotherapy intervention

Acute phase

During the acute phase of treatment at RSPON, research subjects underwent an early mobilization protocol within the first 24 h of stroke. In addition, sensory motor stimulation was given based on the Bobath Method [10]. The length of stay for ischemic stroke patients is 4–7 days in the acute phase of stroke, depending on the patient's condition [11]. The protocol for physiotherapy intervention is shown in Table 1.

Intervention is carried out step by step, depending on the patient's condition. If the patient's blood pressure is high ≥180 mmHg or low ≤30 mm Hg, and there is a fever with a temperature of more than 39°C, then the exercise is stopped. If this condition lasts more than 2 days, the subject is removed from the study. Step-by-step mobilization is given according to the patient's condition, and no increase in functional ability is made if the patient has not been able to reach the previous step.

Intervention in the sub-acute phase is given for 5 weeks with the following doses shown in Table 2.

Physiotherapy interventions given to patients are sensomotor stimulation based on the Bobath Concept and step exercises depending on the functional abilities that can be performed by the patients. Therefore, the main goal of intervention from sensomotor stimulation with the Bobath Concept is to normalize movement patterns and postural control (postural tone) by facilitating motion in all the main joints of each part of the patient's body, such as the neck, shoulders, hands, hips, knees, and ankle. The latest concept from Bobath uses a "problem-solving method" based on the results of assessment and treatment of patients with functional disorders of movement and postural control due to lesions in the CNS. The functional exercises provided are based on the results of identification and analysis of problems in the movement components and disturbances during functional activities. In addition, it is important to add stimulation of visual, verbal, and tactile input because afferent input will affect motor skills [12].

As in the acute phase, increased functional ability exercises are given step by step depending on the functional abilities that can be performed by the patients, as shown in Table 3.

Each subject is trained starting in Stage I. The training stages are increased if the subject has performed the expected target functional abilities.

Outcome measurement

All research subjects measured demographic data and disease characteristics. The results of the intervention were assessed before the subject followed the first physiotherapy session (pre-intervention), every weekend for 5 weeks, and at the end of the physiotherapy session after 6 weeks (post-intervention).

Motoric ability was measured using the stroke rehabilitation assessment of movement (STREAM), with a maximum value of 70 [13]. STREAM is used to assess motor skills in stroke patients. Motor skills assessed using STREAM include movement patterns and movement quality. Assessment is given for movement in the upper and lower extremities and performed in each body position: supine, sitting, and standing.

Functional ability is measured using the functional independence measure (FIM). FIM consists of 18 assessment points that describe physical, psychological, and social functioning. FIM is used to assess the level of disability and its effects on the rehabilitation process or medical treatment [14].

Differences in the values of motor skills and functional abilities measured during the pre- and

post-intervention were statistically tested using the Wilcoxon Signed-Rank Test, Mann-Withney test, and Kruskal-Wallis test. The significance level is determined at 5%. Statistical analysis using SPSS.

Results of the Study

Subject characteristics

This study was followed by 30 subjects who were undergoing treatment at RSPON during the period October 2021–October 2022. The characteristics of the study subjects were in accordance with those listed in Table 4. Most of the subjects were <60 years old, and they were female. As many as 50% based on NIHSS scores had moderate strokes, the other half had mild strokes, and only 3.67% had severe strokes. Areas of the brain affected include most of the left hemisphere of the brain.

Table 1: Physiotherapy interventions in the acute phase of inpatient care (week I)

Time	Physiotherapy Intervention
Length of physiotherapy	15–30 min
Physiotherapy frequency	1 time a day
The day I	• The patient's position is supine lying with Head Up 30° • Positioning the patient, affected extremity is positioned against gravity, support by pillow. • Moving the patient to the left and right side body • Provide movement stimulation to the intrinsic muscles in the metacarpal and metatarsal areas • Facilitate movement of the upper extremities by moving the shoulders, elbows and wrists in a forward reach • Facilitate movement of the lower extremities by moving the hips, knees, ankles and knees as when walking • Movement facilitation is also carried out by providing stimulation to the muscle belly and Golgi Tendon Organ.
Day II	• The patient's position is supine lying with Head Up 90° • Positioning the patient, affected extremity is positioned against gravity, support by pillow. • Moving the patient to the left and right side body • Provide movement stimulation to the intrinsic muscles in the metacarpal and metatarsal areas • Facilitate movement of the upper extremities by moving the shoulders, elbows and wrists in a forward reach • Facilitate movement of the lower extremities by moving the hips, knees, ankles and knees as when walking • Movement facilitation is also carried out by providing stimulation to the muscle belly and Golgi Tendon Organ.
Day III	• Positioning the patient, affected extremity is positioned against gravity, support by pillow. • Teach patients to moving from supine to sitting, and sitting on the edge of the bed. When sitting on the edge of bed, both upper extremity can be support with table • Provide movement stimulation to the intrinsic muscles in the metacarpal and metatarsal areas • Facilitate movement of the upper extremities by moving the shoulders, elbows and wrists in a forward reach • Facilitate movement of the lower extremities by moving the hips, knees, ankles and knees as when walking • Movement facilitation is also carried out by providing stimulation to the muscle belly and Golgi Tendon Organ.
Days IV–VII	• Positioning the patient, affected extremity is positioned against gravity, support by pillow. • Teach patient to moving from sit to standing and vice versa, balance standing and walking if possible. • Facilitate movement of the upper extremities by moving the shoulders, elbows and wrists in a forward reach • Facilitate movement of the lower extremities by moving the hips, knees, ankles and knees as when walking • Movement facilitation is also carried out by providing stimulation to the muscle belly and Golgi Tendon Organ.

Table 2: Dosage of physiotherapy intervention sub-acute phase (week II–VI)

Time	Physiotherapy dosage
Weeks II and III	×3/week
Weeks IV and V	×2/week
Week VI	×1/week

Based on Table 5, the FIM assessment was obtained with a mean pre-test value of 46.9 and a mean post-test value of 109.17, with a mean difference of 67.27. This shows that the provision of sensory-motor therapy can increase functional independence in ischemic stroke patients at RSPON. With these differences in scores on the pre-test and post-test, it can be concluded that there are changes before and after the sensomotor stimulation.

Based on Table 6, the STREAM assessment was obtained with a pre-test mean value of 11.77 and a post-test mean value of 56.37, with a mean difference of 44.6. This shows that the adduction of sensory motor stimulation can improve motor function in ischemic stroke patients at RSPON. With these differences in scores on the pre-test and post-test, it can be concluded that there are changes before and after the sensomotor stimulation.

Normality test

The results of the normality test for the FIM and STREAM assessments indicated that each value obtained a result of $p < 0.05$, so it can be concluded that the data is not normally distributed. Seeing the normality test results for the two groups above, the researchers used a nonparametric statistical test, namely the Wilcoxon Signed-Rank Test to determine whether there was a significant effect of sensory motor therapy on changes in the level of functional independence and motor function in ischemic stroke patients, the Mann-Withney Test to test Differences in independent sample T for 2 groups (difference in scores on the Pre-test and post-test) in the sex group (male and female), and Kruskal-Wallis tested differences in independent sample T (difference in scores on the pre-test and post-test) for >2 groups in age group and stroke severity.

Statistic test

The results of the Wilcoxon signed-rank test (Table 7) obtained a value of $p = 0.000$ ($p < 0.05$). This means that the hypothesis is accepted with the conclusion that there is a significant effect of sensory motor therapy on increasing functional independence and motor function in ischemic stroke patients at RSPON.

The results of the Mann-Withney test (Table 8) obtained $p = 0.9656$ and 0.2040 ($p > 0.05$). This means that there is no significant difference between the effects of sensomotor therapy and changes in the

Table 3: Physiotherapy interventions of functional exercise in the sub-acute phase (week II–VI)

Time	Physiotherapy intervention	Functional ability targets
Week II	a. Intrinsic stimulation of the upper and lower affecting extremity, and postural muscles b. Providing stimulation to the muscle belly and Golgi Tendon Organ to facilitate movement c. Practice sitting on the edge of the bed with support. d. Practice sitting on the edge of the bed without support. e. Movement facilitation of upper extremity (reaching, grasping, peaching exercises)	a. Sit in balance without support ± 15 min b. Improved functional ability of the upper extremities
Week III and IV	a. Intrinsic stimulation of the upper and lower affecting extremity and postural muscles b. Providing stimulation to the muscle belly and Golgi Tendon Organ to facilitate movement c. Sit to stand exercise. d. Standing to sitting exercise. e. Knee stabilization correction of paretic extremity f. Postural control correction g. Weight shifting exercise. h. Balanced standing exercise. i. Movement facilitation of paretic upper extremity (reaching, grasping, peaching exercises)	a. Sitting to standing and standing to sitting without assistance b. Standing on balance without assistance c. Improved functional ability of the upper extremities
Week V and VI	a. Intrinsic stimulation of the upper and lower paretic extremity and postural muscles b. Providing stimulation to the muscle belly and Golgi Tendon Organ to facilitate movement c. Postural control correction d. Weight shifting exercise. e. Single leg standing exercise. f. Step exercise g. Gait pattern correction h. Movement facilitation of the paretic upper extremity (reaching, grasping, peaching exercises)	a. Standing on balance without assistance b. Walk without assistance. c. Improved functional ability of the upper extremities

level of functional independence and motor function in both male and female ischemic stroke patients, and the effectiveness of sensory motor therapy is not significantly different if it is given to men compared to women.

Table 4: Subject characteristics

Characteristics	Amount	Percentage
Age, mean ± SD	56.23 ± 9.87	
Age		
<60 years	20	66.67
≥60 years	10	33.33
Sex		
Man	11	36.67
Woman	19	63.33
Stroke severity (NIHSS)		
Mild	14	46.67
Medium moderate	15	50.00
Severe moderation	1	3.33
Stroke location		
Left hemisphere	18	60.00
Right hemisphere	12	40.00

The Kruskal-Wallis test results (Table 9) obtained p = 0.5503 and 0.8572 (p > 0.05). This means that there is no significant difference between sensomotor therapy and increasing functional independence and motor function in certain age groups of ischemic stroke patients, and the effectiveness of providing sensory motor therapy is not significantly different if it is given to both late adult, early elderly, late elderly, and elderly age groups.

Table 5: Description of the mean, median, minimum, maximum, and standard deviation (SD) values of the FIM

Variable	FIM value		
	Pre-test	Post-test	Difference
Mean	46.9	109.17	62.27
Median	42	113	59
Minimum	24	58	20
Maximum	85	126	93
SD	14.27	19.85	18.79

The Kruskal-Wallis test results (Table 10) obtained p = 0.4955 and 0.6415 (p > 0.05). This means that there is no significant difference between sensomotor therapy and increasing functional independence and motor function at the level of ischemic severity, and the effectiveness of giving sensory motor therapy is not significantly different if it is given at a certain level of stroke severity, whether mild, mild-moderate severe, or severe.

Table 6: Description of the mean value, median value, minimum, maximum, and SD for STREAM values

Variable	STREAM value		
	Pre test	Post-test	Difference
Mean	11.77	56.37	44.6
Median	5	62.5	42
Minimum	0	12	9
Maximum	39	78	70
Standard deviation	13.66	16.11	14.33

SD: Standard deviation

Discussion

In this study, the authors focused on providing sensory motor stimulation to increase functional abilities in stroke patients from the acute to the sub-acute phases. Sensory motor stimulation is provided with the Bobath Concept, which emphasizes two main aspects to optimize motor recovery in stroke patients: the integration of postural control and task performance; selective movement control to produce good movement coordination; and the contribution of sensory input to motor control and motor learning [15].

Table 7: Wilcoxon signed-rank results

Variable	FIM value		
	Pre-test	Post-test	p-values
Means	46.9	109.17	0.0000*
SD	14.27	19.85	
	STREAM value		
Means	11.77	56.37	0.0000*
SD	13.66	16.11	

In post-stroke conditions, the area affected by the infarction will experience functional disturbances in the form of abnormal muscle tone (low tones), impaired postural control, impaired sensory function, decreased motor ability, impaired balance, and impaired coordination, which results in decreased mobility and independence in daily activities. The restoration of

function is carried out using the principle of neuroplasticity. Neuroplasticity is the process of transferring the function of damaged neurons to other surrounding neurons with modification of neural circuits. This process is facilitated by the presence of astrocytes, which will make synapses integrate, so a new pathway is born to process new information or memories. The process of plasticity occurs because of the adaptation to new abilities that are carried out continuously and repeatedly [16].

Table 8: Differences in independent sample t (difference in scores on the pre-test and post-test) in sex groups (men and women)

Gender	FIM value	
	The mean difference between the pre-test and post test	p-value
Woman	61.54	0.9656
Man	62.68	
	STREAM value	
Woman	47.73	0.2040
Man	42.79	

Plasticity in the nervous system optimizes neural networks during ontogeny, phylogenesis, physiological learning, and brain injury. In the context of brain injury, neuroplasticity will shape cortical remapping. Loss of function due to brain damage can be reversed when the damaged cortex is remapped to other parts of the cortex [17]. The corticospinal tract plays a key role in motor control [18], and the changes in plasticity in the corticospinal tract are important mechanisms for the acquisition of skilled movement [19]. In humans, the initial phase of mastering motor skills is accompanied by improvement *in* corticospinal excitability (CSE). The increase in CSE is more likely to the acquisition of new motor skills and not related to the performance of the tasks for which they have been trained.

Table 9: Differences in independent sample t (difference in scores on the pre-test and post-test) in the age group

Age group	FIM value	
	The mean difference between the pre-test and post test	p-values
36–45 years (late adult)	67.4	0.5503
46–55 years (elderly early)	61.7	
56–65 years (late elderly)	64.1	
>65 years (elderly)	54.6	
	STREAM value	
36–45 years (late adult)	46.4	0.8572
46–55 years (early elderly)	41.8	
56–65 years (late elderly)	47.3	
>65 years (elderly)	43	

The initial sensory-motor stimulation that has been given is to position the patient's body, especially the paretic side, against gravity to stimulate decreased muscle tone and improve postural control. Task performance and selective movement exercises are given if the subject has achieved good postural control. This is because if it is given when good postural control has not been performed, then selective movement and task performance will be seen as compensation. Compensatory movement itself can distract from the improvement of balance and movement coordination, which should be possible for optimal functional recovery.

Table 10: Differences in independent sample T (difference in scores on the pre-test and post-test) in the stroke severity group

Severity of stroke	FIM value	
	The mean difference between the pre-test and post test	p-values
Mild: 1–4	64.06	0.4955
Mild–Moderate Severe: 5–14	61	
Severe: 15–24	47	
	STREAM value	
Mild: 1–4	46	0.6415
Mild–Moderate Severe: 5–14	42.8	
Severe: 15–24	42	

Sensomotor stimulation given during the study showed an increase in motor skills, followed by an increase in functional abilities. Stimulation of the intrinsic muscles in the metacarpal and metatarsal areas provides sensory information to the affected brain area and provides stimulation feedback to the extremity muscles to move.

Furthermore, facilitation of movement is given by stimulating proprioception in the muscles, namely in the muscle belly and golgi tendon organs, so that the right muscles will contract according to the stimulation given.

Stimulation is given in the form of functional movement and gradual mobilization from sitting to walking. This combination of interventions within 6 weeks of the onset of the 1st day of stroke can improve the functional abilities of stroke patients.

According to statistical test results, this study can be applied to all age groups, various levels of stroke severity, and both women and men. The weakness of this study is the lack of restrictions on subject selection and inclusion criteria on the location of infarction and cognitive scores. The variety of infarct locations makes the range of the highest and lowest enhancement values very different. This is understandable considering that each part of the brain has a different function, so the disorders experienced by patients will be different. In addition, the patient's cognitive level also influences the recovery process because, to achieve plasticity, motor control, and motor learning, it requires a fairly good understanding of the patient.

For this reason, the authors suggest that further research can be carried out by making more specific inclusion criteria by considering the location or area of infarction, cognitive level, and age of the patient. In addition to seeing the effectiveness of therapeutic doses, research can also be carried out by comparing several therapeutic doses.

The direct benefit of this research for the subjects was that within 6 weeks, most of them could return to their activities independently. As for institutions like the National Brain Center Hospital Prof. Dr. Mahar Mardjono Jakarta (RSPON), they can use research results as recommendations for post-stroke patient rehabilitation programs. Recommendations in the form of physiotherapy services are given from the 1st day of the stroke and given every day during the treatment phase,

and the dose is reduced until the 6th week post-stroke. Physiotherapy method with sensory motor stimulation based on the Bobath Concept, task performance, sufficient repetition, and gradual mobilization according to the patient's functional abilities.

Conclusion

Senso motoric stimulation given intensively have a better impact on motor skill and functional ability, so further early and appropriate rehabilitation program is needed for the recovery of stroke patients.

References

1. De Diego C, Puig S, Navarro X. A sensorimotor stimulation program for rehabilitation of chronic stroke patients. Restor Neurol Neurosci. 2013;31(4):361-71. https://doi.org/10.3233/rnn-120250
   PMid:23524843
2. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, EXCITE Investigators, *et al*. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: The EXCITE randomized clinical trial. JAMA. 2006;296(17):2095-104. https://doi.org/10.1001/jama.296.17.2095
   PMid:17077374
3. Alhamid IJ, Norma N, Lopulalan O. Analysis of risk factors for stroke. Nurs Arts. 2018;12(2):100-9. https://doi.org/10.36741/jna.v12i2.82
4. Sangha N, Ishida K. Acute stroke. Semin Neurol. 2021;41(1):3. https://doi.org/10.1055/s-0041-1722922
   PMid:33618375
5. Peisker T, Koznar B, Stetkarova I, Widimsky P. Acute stroke therapy: A review. Trends Cardiovasc Med. 2017;27(1):59-66. https://doi.org/10.1016/j.tcm.2016.06.009
   PMid:27471112
6. Carr J, Shepherd R. Neurological Rehabilitation Optimizing Motor Performance. London, United Kingdom: Churchill Livingstone; 2011. p. 259.
7. Levin MF, Demers M. Motor learning in neurological rehabilitation. Disabil Rehabil. 2021;43(24):3445-53. https://doi.org/10.1080/09638288.2020.1752317
   PMid:32320305
8. Jeon HJ, Hwang BY. Effect of bilateral lower limb strengthening exercise on balance and walking in hemiparetic patients after stroke: A randomized controlled trial. J Phys Ther Sci. 2018;30(2):277-81. https://doi.org/10.1589/jpts.30.277
   PMid:29545693
9. De Diego C, Puig S, Navarro X. A sensorimotor stimulation program for rehabilitation of chronic stroke patients. Restor Neurol Neurosci. 2013;31(4):361-71. https://doi.org/10.3233/RNN-120250
   PMid:23524843
10. Bernhardt J, English C, Johnson L, Cumming TB. Early mobilization after stroke: Early adoption but limited evidence. Stroke. 2015;46(4):1141-6. https://doi.org/10.1161/strokeaha.114.007434
    PMid:25690544
11. Bernhardt J, Hayward KS, Kwakkel G, Ward NS, Wolf SL, Borschmann K, *et al*. Agreed definitions and a shared vision for new standards in stroke recovery research: The stroke recovery and rehabilitation roundtable taskforce. Neurorehabil Neural Repair. 2017;31(9):793-9. https://doi.org/10.1177/1545968317732668
    PMid:28934920
12. International Bobath Instructors Training Association (IBITA). Theoretical Assumptions of Clinical Practice. IBITA Annual General Meeting, Sept 2006. Available from: https://www.ibita.org [Last accessed on 2021 Aug 19].
13. Salter K, Million J, Zettler L, Moses M, McClure A, Mays R, *et al*. Outcome measures in stroke rehabilitation. In: Evidence-based Review of Stroke Rehabilitation. Ch. 21. 2012. p. 46-8. Available from: https://www.ebrsr.com/uploads/chapter-21-outcome-assessment-srebr-15_1.pdf [Last accessed on 2021 Aug 05].
14. Naghdi S, Ansari NN, Raji P, Shamili A, Amini M, Hasson S. Cross-cultural validation of the Persian version of the Functional Independence Measure for patients with stroke. Disabil Rehabil. 2016;38(3):289-98. https://doi.org/10.3109/09638288.2015.1036173
    PMid:25885666
15. Graham JV, Eustace C, Brock K, Swain E, Irwin-Carruthers S. The Bobath concept in contemporary clinical practice. Top Stroke Rehabil. 2009;16(1):57-68. https://doi.org/10.1310/tsr1601-57
    PMid:19443348
16. Graham JV, Eustace C, Brock K, Swain E, Irwin-Carruthers S. The Bobath concept in contemporary clinical practice. Top Stroke Rehabil. 2009;16(1):57-68. https://doi.org/10.1310/tsr1601-57
    PMid:19443348
17. Wittenberg GF. Experience, cortical remapping, and recovery in brain disease. Neurobiol Dis. 2010;37(2):252-8. https://doi.org/10.1016/j.nbd.2009.09.007
    PMid:19770044
18. Lemon RN. Descending pathways in motor control. Annu Rev Neurosci. 2008;31:195-218. https://doi.org/10.1146/annurev.neuro.31.060407.125547
    PMid:18558853
19. Nielsen JB, Cohen LG. The Olympic brain. Does corticospinal plasticity play a role in acquisition of skills required for high-performance sports? J Physiol. 2008;586(1):65-70. https://doi.org/10.1113/jphysiol.2007.142661
    PMid:17717010