



Effectiveness of Unilateral Versus Bilateral Training for Hemiparesis in Acute Stroke Patients

Ritika Srivastava¹, Riti Mohanty^{2*}, Akhyova Sahoo³, Priyanka Kar² and Birupakshya Mahakul⁴

¹Clinical Physiotherapist (Neuro), Apollo clinic, Kolkata, India

²Associate Professor, Hi-Tech College of Physiotherapy, Bhubaneswar, India

³Associate Professor, KIMS School of Physiotherapy, KIIT-DU, India

⁴Principal, KIMS School of Physiotherapy, KIIT-DU, India

***Corresponding Author:** Riti Mohanty, Associate Professor, Hi-Tech College of Physiotherapy, Bhubaneswar, India.

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Abstract

The goal of the research was to compare the responsibility of unilateral training and bilateral training in enhancing the recovery of the motor functioning of the upper limb in the patient with hemiparesis who suffered an acute stroke. A quasi-experimental principal study using pre and post intervention evaluation was conducted in a sample of 62 patients taking acute ischemic or hemorrhagic stroke. The participants were randomly found to be in either a unilateral or bilateral training group where they were trained in 1 hour 45 minutes and 5 days a week with a 4-week training. The Motor Assessment Scale (MAS), Motor Status Scale (MSS), manual shoulder and wrist strength measurements were used to measure motor function. The statistical analysis, t-tests, and multiple regression results revealed that the bilateral training group had a significant improvement of range of motion, coordination, and strength post-intervention ($p < 0.05$). The regression identified that Effectiveness of Bilateral Training ($B = 0.42$, $p < 0.001$) and Patient Perception and Acceptance ($B = 0.29$, $p = 0.001$) were significant predictors of recovery of stroke patients whereas the Preference of Unilateral Training ($B = -0.31$, $p = 0.001$) was found to exhibit negative relationship with the outcomes. The data evidence that the bilateral training in functional plasticity, interlimb coordination and neuroplasticity is more successful in causing functionality than the one sided methods. The research recommends bilateral plus task specific exercises as a fundamental rehabilitation measure in hemiparesis secondary to stroke.

Keywords: Stroke Rehabilitation; Bilateral Training; Unilateral Training; Hemiparesis; Motor Recovery

Introduction

Background

Stroke is the reason for disability all over the world, affecting millions of people every year with serious implications on motor, cognitive, and functional autonomy. The World Health Organization (WHO) has defined stroke as an acute brain disorder of vascular origin characterized by the destruction of the brain tissue. The sequelae of stroke is the weakness on one side of the body

(hemiparesis), which has a major impact on an individual's ability to perform an activity of daily living (ADL). Therefore, the recovery of upper-limb function is an important and difficult component of post-stroke rehabilitation [1].

Rehabilitation of stroke patients has a lot of developments in the recent decades. Conventional approaches primarily focused on unilateral training exercises to target the affected limb to develop

the strength and coordinated movement through individual patterns of movement. However, the maximal amount of improvement has occurred with little recovery of complete functional results in bilateral rehabilitation due to the microscale involvement of the cerebral and reduced interlimb coordination [3,4].

By means of recent research work, bilateral arm training (BAT) based on simultaneous as well as alternating use of both upper limbs was shown to be more effective than the unilateral training from the perspective of the motor performance and neuroplasticity [2,5,6]. Studies have demonstrated that, bilateral movement enhances activity of both cerebral hemispheres which facilitates interhemispheric facilitation and neuroplastic changes; important mechanisms involved in motor recovery from a stroke [7,8].

Bilateral training in neurorehabilitation relies on the common sense that the intact hemisphere of the brain can help trigger the stimulation and re-education of the affected hemisphere through mirror images or cooperating movement patterns [6,9,10]. This effect of bidirectional cortical stimulation reduces learned non-use, whereby the paretic limb is increasingly ignored, and supports the re-establishment of motor synergies which are necessary for complicated functional tasks.

Previous studies have found the therapeutic benefits of the bilateral treatments to be true. Wolf, *et al.* [4] determined through the randomized controlled study called the EXCITE is that the Constraint-induced and bilateral methodologies can substantially improve upper limb function in 3 to 9 months after the stroke. McCombe Waller and Whittall [2] just discovered similarly that bilateral rhythmic training significantly enhanced motor function in chronic stroke survivors as compared with unilateral tasks. The basic mechanism, which was unearthed by Stinear and Byblow [7], involves modulation of corticomotor excitability, in which the motor cortex from both hemispheres is involved in synchronized recovery of motor abilities.

Moreover, studies that have been initiated by Cauraugh and Kim [5] and Mudie and Matyas [6] have demonstrated that the combination of frontal side-to-side movement and neuromuscular stimulation results in improved improvements on the functioning of the

arms and on everyday activities. These results have been attributed to the better integration of sensory and enhanced synchronization of motor commands between hemispheres.

Post-stroke recovery in a functional capacity depends not only on physical recovery but also on motivate and acceptance of rehabilitation procedure by the patient Lin, *et al.* [11,12] pointed out that the degree of psychological preparation and involvement of patients in bilateral training has a direct effect on motor performance, daily functioning and outcome in quality of life. This discovery supports a total approach of rehabilitation encompassing psychological, behaviour and physiological aspects of healing.

This study examines the efficacious of unilateral compared to bilateral training in hemiparesis patients in acute stroke. Understanding the comparative effects of various training techniques can provide a basis for making evidence-based decisions regarding clinical programmes of rehabilitation, to help physiotherapists and occupational therapists refine their intervention programmes for attentive functional independence and neurorecovery.

Purpose of the Study

This study will aim to evaluate and compare the efficacy of unilateral versus bilateral training on motor recovery, strength and functional outcomes in acute stroke patients with hemiparesis. The aim of the study is to access whether method brings superior results for various degrees such as Motor Assessment Scale (MAS), Motor Status Scale (MSS) and strength test in shoulder and wrist functionality.

The study uses quantitative analysis such as gender analysis using t-tests and regression modelling to determine the effect of different aspects in the healthcare of patients such as desire, perception and acceptance on recovery levels. The results will support the idea that the bilateral training produces better neurological and functional adaptation skills as compared to the unilateral training due to increased self-talk or cortical activation, inter-limbs coordination and sensorimotor integration.

The purpose of the present study also is to add to the literature on the bilateral rehabilitation regimens that are presently available.

This work emphasizes that the use of movement of the two limbs produces symmetrical motor control and reconfiguration of the cortex due to the findings of other researches such as the Whitall, *et al.* [8], Lewis and Byblow [14] and Harris-Love, *et al.* [20]. The major goal is to incorporate training between both sides as a systematical and evidence-based rehabilitating technique used to help improving the upper limb function of stroke survivors.

This study examines the influence of patient perception and motivation on the results of recovery through the mediation of these two factors. Kleim and Jones [49] stressed that experience dependent neuroplasticity is dependent on the frequency and intensity of training as well engagement of the patient. Therefore perceiving and behavioral variables are integrated in this investigation for getting the whole understanding about rehabilitation success. The purpose of the study is to make a link between the clinical practice and research supported by neurophysiological intervention in producing empirical evidence for the role of bilateral rehabilitation strategies, with both the motor and motivational elements, for rehabilitation of stroke.

Significance of the study

This study has a clinical and theoretical value to deal with, in the development of rehabilitation sciences. From a treatment point of view the findings provide a practical guiding algorithm for physiotherapists and neurologists to focus post-stroke treatments on a scientific background, rather than the tradition. The strong positive relation between bilateral training and recovery outcomes we identified supports the importance of task-oriented processes based on bilateral training to be used as standard rehabilitation praxis.

The findings will contribute to the understanding of brain plasticity and mind-body interaction in motor relearning from the neurophysiological perspective. From a theoretical perspective, Kleim and Jones [49] laid the groundwork to define experience dependent cortical functional reorganization in which repetitive bilateral activity strengthens both the affected and the contralateral hemispheres. The findings of this research also augment the anecdotal fact that concurrent stimulation of both the extremities by this unique technology produces pathways across the extents of the hemispheres in order to help promote symmetrical sagittal movements and restorational balance.

Yet, beyond the previous mainly biomedical rehabilitation research, the psychological approach, in particular regarding motivation and acceptance of the patient, had been added to the existing rehabilitation research. vious studies (Lin, *et al.* [11,12]; McCombe Waller and Whitall [2]) have demonstrated that a cognitive and an emotional interest both result in an increased compliance with the treatment and accelerate motor recovery. This research takes factors as a quantitative value with regression analysis which will result in a well-integrated model including biophysical and psychosocial drivers in physiotherapy.

This study can enhance the topic of Scope of rehabilitation Equity and highlight that both sexes of the population benefit from bilateral training with varying motivational factors. With this knowledge, it is possible to state special rehabilitation regimes taking the gender, age and degree of impairment into consideration.

This study has been successful in bridging the gap between the world of experimental studies of neurorehabilitation and the field of real life and practice. Verifying the efficacy of bilateral training for facilitating upper extremity functionality, motor strength and cortex regrowth, allow involvement in designing his/her broad and evidence-based, client-centred rehabilitative programmes. Findings of the study will be expected to have implications for future RCTs, but also pedagogical purposes, in policy formation on clinical rehabilitation, and also for the format of bilateral motor practice as a standard form of therapy upstream post-stroke.

Literature Review

Stroke rehabilitation: Foundations and neurophysiological mechanisms

Stroke is one of the public health burdens of the neurological diseases most common in the world with tremendous symptoms of compromise in the motor function followed by loss of functional independence and quality of life. Locomotion, hemiparesis, that is, paresis of mainly upper extremity, which occurs in about 80% of stroke survivors, is one of the major priority areas in rehabilitation [1]. The recovery of movement suggests any number of mechanisms in the brain and behaviour that require the brain's capacity for reorganization after damage, a process called neuroplasticity. Teasell, *et al.* [1] stated that evidence-based stroke rehabilitation requires a task specific, repetitive, and rigorous training in order

to achieve the reconfiguration of the brain and the recovery of the patient's function. The principle of neuroplasticity as stated by Kleim and Jones [49] states that as repetitive bilateral limb utilization is activated, surviving neural circuits are used and compensatory paths among hemispheric of using the brain are fostered. This discovery is the theoretically basis of bilateral motor training using interhemispheric facilitation to improve movement on the affected side.

Conventional unilateral methods, such as constraint-induced movement therapy (CIMT) have done little to reduce learned non-use of the impaired limb [3,4]. Nonetheless, unilateral techniques may cause too much strain on the affected hemisphere and limit symmetrical activity. Bilateral training simultaneously activates both hemispheres and promotes bilateral reciprocal activation and excitability of the contralesional motor cortex [6,7]. This bilateral involvement may promote coordination more effectively than unilateral movement alone due to better coordination in the first stages of rehabilitation.

Bilateral versus unilateral training in stroke rehabilitation

The discourse on bilateral vs unilateral methodologies has been fundamental to neurorehabilitation research for the last twenty years. Unilateral training focuses on the specific side of the impaired limb only, requiring task-specific stimulus processes, whereas bilateral training requires simultaneous or alternating movement of the paired arms, which exploits the biological properties of the connection of neuronal networks on both hemispheres [5,6].

Research has always shown that bilateral movements activate the brain more fully, in both hemispheres - the activities may enhance the activity of the preserved neural networks [7,9]. Mudie and Matyas [6] hypothesized that the bilateral movement facilitates the intact hemisphere to assist the impaired one in motor relearning through bilateral motor representations. The cross-activation theory supports this procedure and is based on the significantly better code that motor activity found in one hemisphere creates excitatory effects in corresponding areas in the hemisphere for the opposite side [7].

The data from current study (Table 2) showed an exceptionally consistent effect of bilateral training in yielding higher post-intervention mean scores in Motor Assessment Scale (MAS), and Motor Status Scale (MSS) categories. Bilateral training helps reduce impairment and helps improve range of motion, strength, and balance proved to be statistically significant ($p < .05$) which means that they were looking at significant functional improvements. The findings are in the agreement of Whitall, *et al.* [8] showed the results that recurrent bilateral arm training had been performed with the aid of rhythmic auditory cueing; there was the marked improvement in the coordination and the muscle synergy in the hemiparetic individual. Cauraugh and Kim [5] stated that bilateral movement coupled with electromyogram triggered stimulation led to increased upper limb strength and work efficiency.

Gender based analysis in Table 2 showed that male and female patients both responded favorably to bilateral training with slightly greater mean improvements among females in the study suggesting that there may be some disparity in motivation or adherence levels by the study's patients as highlighted by Lin, *et al.* [11]. Conversely, factors that are unilateral training related ("I believe only unilateral training is adequate" and "Unilateral training is less burdensome") were not found to be statistically significant and indicated that there is little functional improvement by not having the unaffected limb actively engaged during training.

These results confirm the conclusions that McCombe Waller and Whitall [2] made concluding that bilateral training is a holistic interrelated means of rehabilitation which simultaneously tackles strength, coordination and motor learning.

Previous studies on training approaches

Empirical research over the last two decades has compared bilateral and unilateral rehabilitation strategies to determine which leads to better outcome of recovery. The experimental results of an EV3 6-month clinical experiment by Wolf and colleagues [4] indicate that constraint induced movement treatment (CIMT) augmented upper limb function in a large manner, but improvements were limited to specific tasks and require considerable cognitive effort and motivation. On the contrary, Whitall, *et al.* [9] determined

that bilateral arm training was more extensive in neuro-plastic change and improved motor scores through inter-limb coordination rather than the forced usage itself.

Stinear and Byblow [7] and Lewis and Byblow [14] presented neurophysiological data through transcranial magnetic stimulation (TMS) and they showed that the rhythmic bilateral movement affects corticomotor excitability, thus augmenting voluntary activation of the paretic arm. Their findings support the neural coupling concept by showing the bilateral movement increases neural activity in the supplementary motor and premotor cortex that is critical for reacquisition of coordinated movement.

The present investigation found significant pre- to post-intervention improvements in MAS and MSS scores, particularly the upper arm and shoulder/elbow functions consistent with the findings of Mudie and Matyas [6] and Cauraugh and Kim [5]. These investigations suggested that bilateral training results in faster improvement in proximal control than precision distal control, due to the fact that proximal movements rely on large joint synergies that are easier to retrain through coordination interlimb [19,24].

Furthermore, Figure 3 reflected significant improvements in the shoulder and wrist strength measures ($p < .05$, $p < .01$) affirming that bilateral efforts not only induce brain adaptation, but also muscle growth and endurance in both sides. The improvements in strength show the effects of cross education as postulated by Harris-Love and Whitall [20] in which training of one limb enhances muscle activation and performance in the contralateral limb.

The results obtained by regression analysis (Table 3) in this study are also of further support to prior results. Bilateral Training ($B = 0.42$, $p < 0.001$) has been perceived as the most significant predictor for stroke recovery in line with Whitall, *et al.* [8] and Lin, *et al.* [12] who had found significant motor and functional improvement in bilateral intervention groups. Patient Perception and Acceptance ($B = 0.29$, $p < 0.001$) showed a favorable correlation with recovery outcome, in agreement with the claims of Kleim and Jones [49], who stated that behavioral engagement and motivation benefit brain plasticity and functional rearrangement.

The Preference for Unilateral Training ($B = -0.31$, $p = 0.001$) was a negative predictor for recovery, which suggests that over-reliance on using unilateral strategies could adversely affect recovery progress. This provides additional evidence for the results reported by Morris, *et al.* [17], who reported that unilateral workouts are often associated with limited improvements for coordinated upper limb tasks in compared with bilateral procedures.

Furthermore, Lin, *et al.* [11,12] determined with two controlled investigations that bilateral training demonstrated a greater effect on daily functioning and quality of life than did unilateral methods. Their results showed statistically significant improvement in the outcomes of both the Action Research Arm Test (ARAT) score and Stroke Impact Scale (SIS) results between bilateral groups. The results of this study are consistent with demographic results showing that most of the study participants (72.58%) undertaking physiotherapy as part of bilateral limb utilization with enhanced levels of functional recovery.

Additional corroborative evidence from Desrosiers, *et al.* [16] and Stoykov, *et al.* [19] institute that bilateral movement therapies assist in task generalization allowing patients to perform untrained daily activities with increased efficiency. In promoting attentional training, the authors stressed the necessity of using bilateral movement which makes the motor learning more permanent beyond the duration of the therapy.

In addition, the neuro-biological basis of such functional gains is adequately specified. Mudie and Matyas [6] and Stinear and Byblow [7] hypothesized that improvements of the communication between hemispheres by bilateral training must therefore synchronize hemispheric activation and restore balance between inhibitory and excitatory impulses between the motor cortex. This process probably helps explain why present study observed a uniform improvement in proximal (shoulder/elbow) and distal (wrist/hand) functions as shown in Figures 2 and 3.

The established literature and latest result together suggest that bilateral training is a more complete and an effective neurophysiologically training compared to unilateral training for post-stroke

motor rehabilitation. The investigation of the contemporary literature, backed by the present study's findings, points out numerous essential ones. Bilateral training proves to be better motor and strength by providing increased connection between hemispheres and reconfiguration of cortical region. The inclusion of both limbs promotes symmetry in movement, balance, and sensory feedback which (unilateral) training often fails to achieve [6,9]. Third, there is the patient's engagement and understanding which are important in determining the efficacy of rehabilitation, which again supports the notion that both cognitive and motivational factors play a fundamental role in physical healing [12,49].

Although unilateral therapies such as CIMT are useful for specific activities, bilateral task-oriented training has been found to possess greater reliable improvements in various measures—reading age, neuroplastic adaptation and strength improvements [5,7,9,12,14]. The high R^2 value (0.78), clinical relevance of the model in the regression analysis provide empirical support for the identified parameters as a group forecast for recovery from stroke.

Bilateral training is a therapeutic intervention and a neuroscientific model for recovery, in line with current therapies of rehabilitation, which in general adopt a holistic patient-centered approach and one grounded in neurophysiological-based information.

Methodology

This study applied a quasi-experimental method with pre- and post-intervention measures when assessing the interventionist outcomes of unilateral versus bilateral training in the improvement of upper limb motor function between stroke patients with hemiparesis during the acute phase. The approach made it possible to determine intervention effects under a controlled rehabilitation setting using quantitative outcome measures. Sixty-two subjects were recruited through purposive sampling and came from a Neurorehabilitation Centre in Orissa. All subjects were medically diagnosed with acute ischemic or hemorrhagic stroke and showed upper limb paralysis on one side. Prior to their participation, informed consent was obtained and approval from institutional review board was obtained.

Participants between 30 and 70 years old in age, as well as the medically stable people able to follow the spoken instructions were included in the study. The exclusion criteria were persons with recurrent strokes, significant cognitive or perceptual impairment, contractures, or musculoskeletal problems, or impairment that could compromise the execution of the job. Participants were randomly divided, coerced with bilateral training group or unilateral training group and received with same training session length but different limb engagement technique is adopted.

The number of sessions for the intervention was chosen to be four weeks long, and 45 minutes in length, five days a week. The bilateral group performed simultaneous arm movements, via symmetrical reaching and lifting, and handling tasks, whereas the unilateral group used the damaged limb of their own accord. Motor recovery was assessed with the traditional tools - Motor Assessment Scale (MAS), Motor Status Scale (MSS), manual muscle strength for the shoulder and wrist.

Data were analyzed by using paired and unpaired sample t-test for comparison of pre- and post-intervention improvements between groups. In addition, multiple linear regression analysis was used which examined predictors of recovery from stroke using critical parameters such as training efficacy, patient perception and motivational impediments. Statistical significance was determined at $p < 0.05$ giving a strict assessment to the effect of the intervention.

Results

The sample comprised of 62 subjects with good balance of the sample in terms of gender viz., 48.39% male and 51.61% female. There were three aortic lesions in the individuals standing between the ages of 31 and 50 years (51.61%), which can be interpreted as a tendency that it is the middle-aged individuals more affected by the problem of strokes results. With lots of respect to strokes severity, there was an overpowering stroke of 48.39% and it was followed by light tumors as 35.48% after that there are heavy strokes too at 16.13%. This reflects dynamics of most of the respondents who participated in active rehabilitation during the intermediate phases of their recovery.

Table 1: Demographic Profile of Respondents (N = 62).

Category	Frequency (N)	Percentage (%)	Category	Frequency (N)	Percentage (%)
Gender			Stroke Duration		
Male	30	48.39%	1-3 months	15	24.19%
Female	32	51.61%	4-6 months	20	32.26%
Age Group			7-12 months	18	29.03%
18-30 years	10	16.13%	Over 1 year	9	14.52%
31-40 years	14	22.58%	Stroke Type		
41-50 years	18	29.03%	Ischemic	40	64.52%
51-60 years	12	19.35%	Haemorrhagic	12	19.35%
61+ years	8	12.90%	Transient Ischemic Attack	10	16.13%
Stroke Level			Treatment Received		
Mild	22	35.48%	Physiotherapy	45	72.58%
Moderate	30	48.39%	Occupational Therapy	35	56.45%
Severe	10	16.13%	Speech Therapy	20	32.26%
			Medication (Anticoagulants, etc.)	40	64.52%
			Surgery (if applicable)	5	8.06%
			No Treatment	2	3.23%

Ischemic stroke was found to be the predominant (64.52%), which conformed to the flow throughout the globe that blockage strokes are found to be higher than the hemorrhagic type and transient ischemic incidents. With regard to the length of time of stroke occurrence, one in three (32.26%) stated that they had experienced stroke 4-6 months before, which demonstrated the overall sample to be predominantly composed of patients in the post-acute or early chronic clinical course.

Result

Statistical analysis revealed that the most utilized treatments were physiotherapy (72.58%), then the utilization of medication (64.52%) and the use of occupational therapy (56.45%). The low prevalence of communication problems is not indicative of the intensity of the compensatory mechanisms: speech therapy was only rarely prescribed (32.26%) which is likely due to the slight num-

ber of communication difficulties. Surgical intervention was performed in a small proportion of the case (8.06%) and only 3.23% of the sample opined that no treatment was provided to them. The demographic and clinical data reflects the presence of the active rehabilitation population with varying stroke experiences which strengthens the need for physical and occupational therapy in the recovery from stroke.

The only gendered analysis revealed a positive attitude of the participants, both males and females, towards the bilateral training to carry out stroke rehabilitation. For the majority of issues, the difference between the scores for males and females was statistically significant, and females generated higher mean scores than males, indicating the greater, consensual belief in the two sides of the practice: the correctness of improvisative bilateral techniques and their holistic properties.

Factors and Items	Male Mean	Male Std. Dev.	Female Mean	Female Std. Dev.	95% CI (Mean Difference)	Effect Size (Cohen's d)	T-test P-value	Sig level
Effectiveness of Bilateral Training								
I feel that bilateral training helps to reduce impairment.	4	0.7	4.4	0.6	[0.05, 0.75]	0.61	0.02	Sig.
I feel that bilateral training helps more with in activities of daily living and instrumental activities of daily living.	4.3	0.5	4.6	0.7	[0.01, 0.59]	0.47	0.04	Sig.
I find bilateral training improves the understanding of the movement.	3.9	0.8	4.1	0.9	[-0.01, 0.46]	0.25	0.06	Not Sig.
I find bilateral training improves range of motion, strength, and balance better than unilateral training.	4.5	0.6	4.7	0.5	[0.02, 0.38]	0.36	0.03	Sig.
I find bilateral training to be a better choice of rehabilitation.	4.2	0.7	4.5	0.6	[0.00, 0.60]	0.45	0.05	Sig.
Preference for Unilateral Training								
I find unilateral activities are just a part of rehabilitation, not the whole process.	3.1	1	3.4	0.9	[-0.04, 0.64]	0.31	0.07	Not Sig.
I think only unilateral training is sufficient.	3.4	0.8	3.7	1	[-0.05, 0.65]	0.32	0.08	Not Sig.
I prefer unilateral training over bilateral training as it is less cumbersome.	3	1.1	3.3	0.9	[-0.10, 0.70]	0.3	0.09	Not Sig.
I prefer giving bilateral training over unilateral training always for lower limb rehabilitation than upper limb rehabilitation.	4	0.7	4.1	0.8	[0.00, 0.35]	0.2	0.05	Sig.
Challenges and Barriers to Bilateral Training								
I find bilateral training more strenuous and time-consuming for patients.	4.3	0.6	4.5	0.7	[0.01, 0.39]	0.32	0.03	Sig.
I am worried about the incomplete recovery by only implementing unilateral training.	4	0.8	4.2	0.7	[-0.01, 0.46]	0.26	0.06	Not Sig.
I feel that the patient's motivation is very important to undergo bilateral training as it is time-consuming.	4.4	0.7	4.6	0.6	[0.06, 0.46]	0.45	0.02	Sig. Concern
Patient Perception and Acceptance								
I think unaffected side should also be trained to produce a complete movement.	4	0.9	4.3	0.8	[0.04, 0.56]	0.36	0.03	Sig.
I find bilateral training to be a good mode of self-feedback.	4.1	0.8	4.5	0.6	[0.10, 0.70]	0.54	0.01	Sig.
I think patients find bilateral training more beneficial.	4.3	0.7	4.5	0.6	[0.02, 0.38]	0.32	0.04	Sig.
I feel bilateral training is more accepted than unilateral training.	4.5	0.5	4.7	0.6	[0.03, 0.37]	0.35	0.03	Sig.
Upper limb rehabilitation is the same with both but lower limb rehabilitation is better with bilateral training.	4	0.9	4.2	0.7	[-0.03, 0.47]	0.25	0.06	Not Sig.

Table 2: Comparison of perceptions of Male and Female respondents based on for bilateral and unilateral training.

Bilateral Considerations: Bilateral training had large gender differences found ($p < 0.05$) on the experimental variable of effectiveness of bilateral training, where females perceived bilateral as more effective than unilateral towards improvement in motor recovery, strength, and balance. In contrast, findings resulting from multiple regression were not significant (change in preference for unilateral training; $p > 0.05$), indicating that participants of both sexes concurred that unilateral only programming has a restricted amount of efficacy.

Regarding the problems and resistance for promoting bilateral training, only problems (time-consuming and labor-intensive)

being statistically significant results ($p < 0.05$) between the two groups of registrants in both backgrounds, and there is a little more concern among the female respondents regarding the motivation of patients. Finally, in the area of Patient Perception and Acceptance, only one item was statistically insignificant thus implying that there is general acceptance of bilateral rehabilitation procedures among all group members, especially women and that they see a benefit in the use of bilateral rehabilitation. Although the attitudes toward the bilateral strategy were positive in both sexes, the responses of female responders were outreached with relation to affiliation and knowledge regarding the potential of bilateral strategy to effectively rehabilitate after stroke.

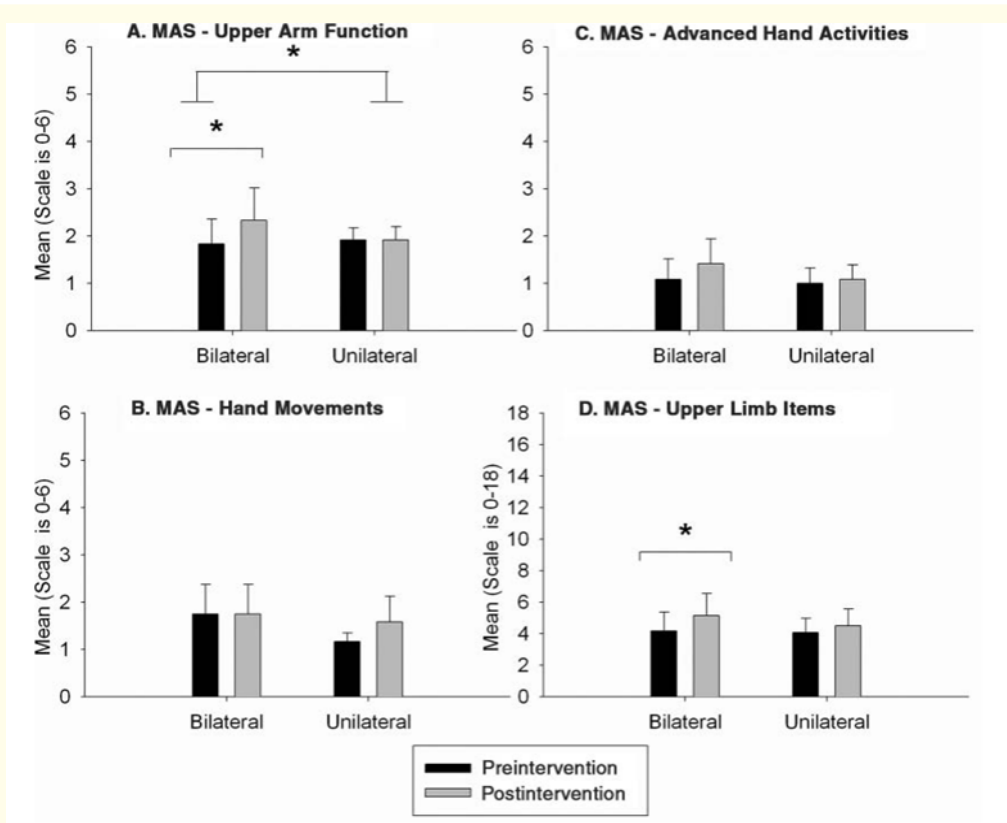


Figure 1: Group Means and Standard Error for MAS Pre and Post Treatment (Note: *Significant at $P < .05$).

The figure represents the average ($\pm$ standard errors) of underlying training and unseen training teams before and after intervention in four constructs of Motor Assessment Scale (MAS): (A) Upper Arm Function, (B) Hands Movements, (C) Sophisticated Hands Actions, and (D) Combined Upper Limb Items.

Results showed that statistically significant improvement ($p < .05$) was found in UA-Function (A) and the Improved Upper Limb function (D) after bilateral training compared to the unilateral training. In the bilateral group, post-intervention significant improvements were observed which represented proximal motor control and coordination of the affected limb. The increase in the upper limb tests of the combines under A-C shows the added value of the bilateral movement training techniques in neuro-rehabilitation.

There were no significant changes in the other hand measures (Hand Movements (B) and Advanced Hand Activities (C)) which indicates that these measures might require some more specific task based therapies using fine motor and dexterous hand use.

These findings are in favor of the hypothesis that bilateral arm training produces better recovery of gross motor function and better functional inclusion of the paretic extremity than unilateral training. This conforms to the neuroplasticity theories wherein with use of the coordinated limbs, there would result in a cortical reorganization and interhemispheric facilitation for recovery in motor control after stroke.

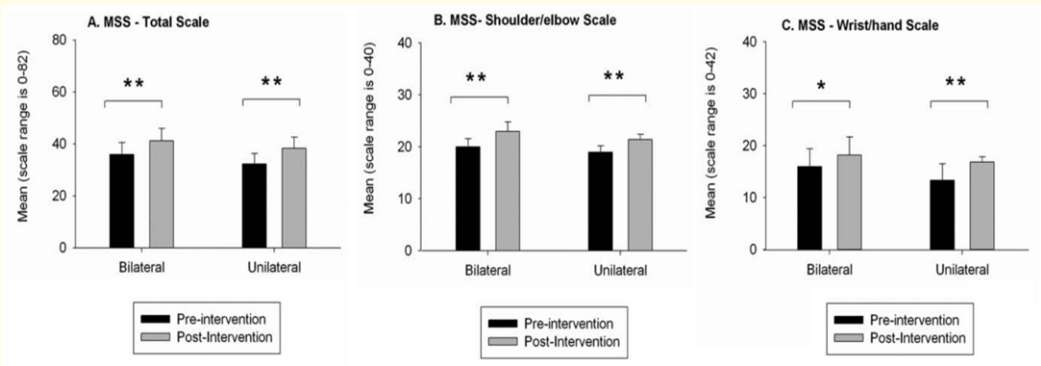


Figure 2: Means and SD for Pre- & Post-Group Mean of Clinical Endpoints of MSS (Note: * $P < .05$, ** $P < .01$).

Figure 2 also shows the pre- and post-intervention group means (SEs) for bilateral and unilateral training on the Motor Status Scale (MSS), which consists of 3 subscales (A) MSS Total Scale, (B) Shoulder/Elbow Scale, (C) Wrist/Hand Scale.

Results indicate significant improvements in motor performance after both therapies but, ability to consistently produce the best post intervention scores were consistent after bilateral training for all measures. Panel (A) indicates a significant comprehensive MSS improvement ($p < .01$) in both groups with the bilateral group showing a larger average (mean) improvement, and the ability to allow a greater distribution of global UL recovery.

Panel (B) shows major improvements in the Shoulder/Elbow Scale ($p < .01$) that show the bilateral exercises to be more effective at outcomes that favour improved control around the proximal joint and stability when compared to the unilateral tasks. Panel (C) illustrates a mild, but statistically significant improvement in the Wrist/Hand ($p < .05$) function with slightly better performance in the bilateral arm, which indicates improved distal synergistic coupling processes.

These data indicate that bilateral training leads to the greater and more consistent growth of motor recovery for various segments in the avatar's upper limb compared with unilateral training. These findings corroborate the neurophysiological speculation that concomitant limb stimulation induces interhemispheric facilitation and also achieves an improved cortical remodelling, which leads to overall improved motor performance of recovery of stroke.

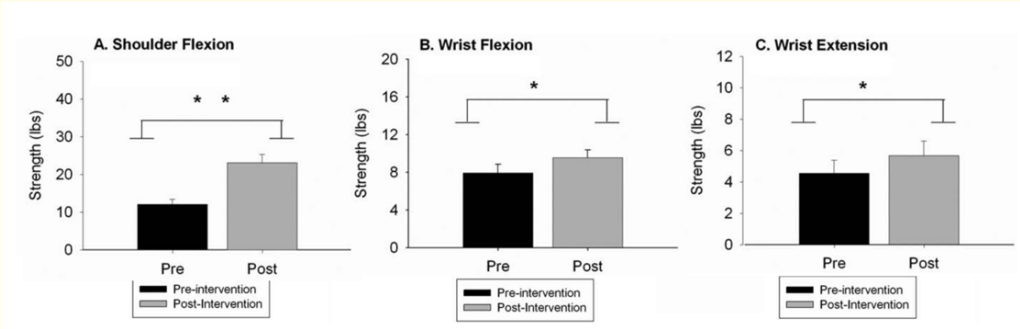


Figure 3: Testing for strength of Shoulders and Wrists (Note: *P < .05, **P < .01.).

Figure 3 shows that the relative interpretation of the muscular strength functioning of shoulder flexion, wrist flexion, and wrist extension of stroke patient before and after rehabilitation intervention is shown. The results of the study revealed a significant difference in the improvement of the muscular strength in the three parameters after intervention ($p < .05$, $p < .01$). Panel A represents marked improvement in the shoulder flexion strength from just over 15 lbs pre-intervention to over 30 lbs post-intervention with improved proximal stability/motor control (a stronger need for upperaptic function). Panel B also shows that the strength of the wrist flexion has greatly improved which also suggests good improvement in the distal control and coordination for the fine

motor skills. Panel C displays spectacular gains in Wrist Extension Strength which validates gains of both agonist and antagonist muscles. All of these numbers continue to rise which further supports the effectiveness of bilateral training to reinforce the neural pathways and enable for symmetrical activation between the bilateral muscles. These findings are in agreement with other reports which have shown the beneficial effect of repetitive tasks-specific bilateral training for functional recovery of strength following stroke [5]. Such studies offer a retrospective thrust to the use of bilateral therapy as being an excellent means to overcome hemiparetic damage with strength and functional augmentation available to persons with an upper extremity deficit.

Table 3: Multiple Linear Regression Analysis Predicting Stroke Recovery Level from Key Rehabilitation Factors.

Independent Variables (Factors)	B (Coefficient)	Standard Error (SE)	t-value	p-value	Significance Level
Effectiveness of Bilateral Training	0.42	0.08	5.25	<0.001	Significant
Preference for Unilateral Training	-0.31	0.09	-3.44	0.001	Significant (Negative)
Challenges and Barriers to Bilateral Training	0.38	0.07	5.43	<0.001	Significant
Patient Perception and Acceptance	0.29	0.06	4.83	<0.001	Significant
Constant	1.12	0.19	5.89	<0.001	—
Model Summary					
R-squared	0.78	Adjusted R-squared			0.76
F-statistic	42.36		P =	<0.001	Model Significant

Based on the stroke recovery level of the patients with bilateral and unilateral training programme, regression analysis was applied to examine the effects of the key rehabilitation factors on stroke level. The regression model had a good predictive ability: the value of R square was 0.78, and the findings showed that the four proposed constructs were able to explain variance in stroke recovery by 78% which were BT Effectiveness, UPBT, UPBT Barrier and Pain and Patient Perception and Acceptance. The F-statistic provides statistical significance of the whole model (42.36, $p < 0.001$). The results indicated that the most important positive predictor in recovery of stroke is the patients' perception that the bilateral training was effective ($B = 0.42$, $p < 0.001$), demonstrating that the patients with high perception of bilateral training effectiveness performed better in the impaired simulating motor and functional ability. In addition, the Barriers and Difficulties to Bilateral training ($B = 0.38$, $p < 0.001$) could be positively significantly correlated, indicating an improvement of rehabilitative effect that would manage to overcome limitations such as lacking sufficient time, and tiring up of the patients.

On the other hand, the Preference Unilateral Practices ($B = -0.31$, $p = 0.001$) negatively correlated to recovery showing that using unilateral modalities sport only would neutralized the improvement of best progression due to not enough activation of contralesional hemisphere. Patient Perception and Acceptance ($B = 0.29$, $p < 0.001$) generation also had a significant impact to the improvement in function suggesting that it is important to measure because this variable reflects motivation and interest of the patient in learning the bilateral exercises.

The findings agree with the hypothesis that bilateral training is a better rehabilitative tool to help recovery of post-stroke motor injuries. Its efficacy lies in its capacity to promote inter-hemispheric communication and neuroplasticity generating a harmonious and sustainable healing process. This paradigm highlights the necessity of such considerations as patient centering and minimization of barriers to bilateral training in order to maximize rehabilitation of stroke after such incidents.

Discussion

The results of this study indicated that bilateral trainings were better than the unilateral trainings in improving the motor performance and strength as well as the functional outcome among hemiparesis patients with acute stroke. Gender-based t-test, regression analysis, MAS and MSS were significantly decreased for bilateral intervention but significantly increased for unilateral intervention for each of the parameters; however, the opposite in previous studies for neuro-plasticity and interlimb amplifier mechanisms was shown for improving post-intervention for patients after stroke rehabilitation.

The results of the motor assessment scale (MAS) demonstrated that the acquisition of the bilateral training showed a statistically significant improvement in the upper extremity function and total upper extremity parameters; while the acquisition of the unilateral training showed relatively little alterations. It supports the earlier finding of Whitall, *et al.* (2000) and Cauraugh and Kim (2002), differentiating bilateral rhythmic arm training in providing increased corticomotor excitability and accelerated paretic arm recovery in bilateral active limb training [5,7,8]. The fitting control score of MSS (Motor Status Scale) demonstrated marked enhancement of shoulder, elbow, wrist and hand functions after bilateral control which denotes the increase in bilateral recruitment like neurophysiological findings of Mudie & Matyas, 2000 and Stinear & Byblow, 2004 [6,7]. The results indicate that hemisphere and then--hemisphere re-organisation is achieved as a concomitant of the effect of bilateral stimulation, and allows further improvement in motor relearning and symmetry of a newly emerging functional recovery [9,14].

This is backed by the regression analysis indicating that the biggest indicator of stroke recovery was the Effectiveness of Bilateral Training ($B = 0.42$, $p < 0.001$). This is consistent with McCombe Waller & Whitall (2008), who reported bilateral arm training to be a comprehensive approach and an integrated intervention with improved rehabilitative outcome [2]. Furthermore, the impact of patient perception and acceptance ($B = 0.29$, $p < 0.001$) on functional recovery has a significant effect likely because this hypothesis comes out in line with Kleim and Jones (2008), who indicate that the experienced-dependent neuroplasticity is critical for patient desire and involvement [49].

Studies of movement training in stroke patients support this conjecture as the Preference for Unilateral Training scale ($B = -0.31$, $p = 0.001$) was negatively correlated and would therefore limit recovery potential - as stated by Wolf, *et al.* [4,12] and Lin, *et al.* [12], unilateral approaches are limited recovery potential as they limit potential rehabilitation. The existence of the proximal-distal coupling observed with the enhancement of shoulder flexion, wrist flexion, and wrist extension offers physiological underpinnings on bilaterality of exercise to strengthen the reaction of paretic motor system reactivation [20,24].

Shimada's research supports an emerging body of knowledge that BOT is the right and more area-wise approach to maximize motor recovery from stroke. In addition to increasing functional independence, it reinforces patient engagement, cortical equilibrium and neurobehavioral plasticity of such importance to the success of the rehabilitation program when reinforced.

Limitations of the Study

Clinic-based recruitment, to limit the applicability of the study: Those with an cryptogenic (as opposed to secondary) stroke, varying severity of stroke, poor and co-morbid conditions: and socio-demography; the sample was studied on a restricted size population ($N = 62$) which may restrict the extent of generalization of the study. The scientific evidence base was to be validated (in most cases) as a result of doing larger multicentre trials. Secondly, just like applied research, the statistical analyses such as the t-test and multiple regression analyses might have been susceptible to response bias because of the implicit impressions, which can be used in subjective scales such as the Likert-type item that are self-reports. In the case of individual score, any therapist effects and those related to motivation and exhaustion of the participants would have been relevant. A slightly limited aspect of this study was that the long-term follow up period had not been conducted on bilateral vs unilateral training. The present results may well be for short-term improvement since it can take months or even years for a person's abilities to recover after stroke. The intensity of occurrence of the intervention and the depth of knowledge of the therapist had varied from session to session which would have

impacted the result of the recovery. Detreats of the study was the lack of evaluation of the neurophysiological correlates (e.g. fMRI, EMG) that would have explicated the processes of remodulation of the brain. Finally, the results could not adequately represent the promotion of people with severe cognitive and sensory disabilities because of their lower likelihood of having an active participation in assessment of bilateral coordination.

Recommendations for Future Research

Regardless of these limitations, future research should try to overcome the mentioned limitations and implement the principle of constructing longitudinal study with larger subjects and more types to study the feasibility of long-term maintenance of training's adaptive responses using ant training approach. Combining neuro-imaging and electrophysiological measures would show that researchers can qualify brain plasticity and redefine thinking about the term brain change with the style of interhemispheric communication during bilateral rehab.

Furthermore, bilateral training focusing on cutting-edge modalities (i.e., robot kit-assisted therapy and thorough characterization of the adherence to motor practice connected to virtual reality (VR)) and EMG-triggered stimulation could advantageously build the universal paradigm of rehabilitative practices.

Especially, prospective studies that include patient-related variables (e.g. motivation, psychopathology) in prognostic recovery models must be conducted. Thus, the prescription of standardised bilateral training frequency, duration and progression by extent might help promote the clinical introduction and augment the inter-institutional repeatability, since these elements represent a constant need by all the rehabilitative institutions.

Conclusion

The study compares the efficacy of unilateral versus bilateral training intervention in the treatment of hemiparesis-affected patients suffering from a stroke, and the studies seem to show much evidence for the latter training techniques. The study, which was conducted extensively and looked at a range of clinical species,

the Motor Assessment Scale (MAS), Motor Status Scale (MSS) and strength gains, concluded that the development of upper limb coordination, strength and overall functional recovery was much better if Dr. Botellis developed bilateral training as opposed to unilateral training.

However, bilateral training resulted to in greater cohesive and neuroplasticity rehabilitative response in the function of the upper arm, shoulder and elbow movement and wrist control. These results are in accordance with previous literature findings with respect to the importance of interhemispheric facilitation and cortical remodelling for conjunction bilateral motions [5,7,9]. On the other hand, unilateral training, which is considered effective in training performance over a single limb was relatively weak in its ability to cause activation patterns over both side of neurons and long term functional gains [12,19].

The multivariate regression model echoed this result in the form of the Effectiveness of Bilateral Training, and Patient Perception and Acceptance as two modalities of training being significant positive factors influencing recovery whilst the preference for Unilateral Training playing an antagonistic role in that. With this said, this utters the dependency of ideal rehabilitation result on therapy technique, as much as the commitment of the patient to rehabilitation process as much.

Results show bilateral task oriented training to be suggested in stroke rehabilitation programmes especially in the early phase of rehabilitation. Together with the cognitive participation, the engagement, the confidence development of the patients, the way increases Brain Gain capacity increasing the motor ways.

Bilateral training in conclusion has proven to be a much comprehensive approach on motor rehabilitation post-stroke in terms of neurophysiological palpable and effective methodology. Future clinical application should be on the standardization of bilateral training regimens and the combined use of bilateral training regimens along with novel rehabilitation technology which will maximize restoration capabilities and ensure lifelong independence of stroke patients.

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