International Journal of Yoga, Physiotherapy and Physical Education
ISSN: 2456-5067; Impact Factor: RJIF 5.24
Received: 13-04-2019; Accepted: 16-05-2019
www.sportsjournal.in
Volume 4; Issue 4; July 2019; Page No. 38-43

Comparison of effects of loaded bimanual arm therapy and loaded bimanual arm therapy with rythmic auditory cueing on upper limb function, trunk function, balance, gait and cardiovascular endurance in stroke patients

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Abstract

Background: Bimanual Therapy aims at using both arms and increasing the coordination between the paretic and non paretic hand. Symmetrical tasks demand equal participation by both the limbs. Complexity of the task is increased by adding load on the non paretic hand that increases the muscular activation on the paretic side, smooth. Rhythmic auditory cues given by a metronome sets up the bimanual task frequency, increases attention and gives sensory feedback. External sources of feedback are crucial in motor learning as it acts as important source to produce knowledge of result and knowledge of performance.

Methods: 20 Stroke survivors were assigned to one of the 2 treatment groups: (1) Loaded Bimanual Therapy (2) Loaded Bimanual Therapy with Rythmic Auditory Cueing. They completed 14 sessions lasting 45 minutes, using 5 symmetrical active bimanual tasks each set done for 5 minutes each.

Results: Both the treatment groups showed statistically significant improvements in the pre post analysis, but in intergroup analysis no statistical significance in any of the outcome variables was noted except for 6MWT distance covered p=0.013.

Conclusion: Loaded Bimanual Therapy and loaded Bimanual Therapy with Cue are equally effective to bring out significant improvements in Upper Limb function, Trunk Function, Balance, Gait and functional capacity of 6MWT when compared to conventional therapy in stroke patients.

Keywords: stroke, neurological rehabilitation, auditory cueing, loaded bimanual training, upper limb, trunk, balance, endurance

Introduction

WHO definition of stroke is "rapidly developing clinical signs of focal disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin [1]. Incidence rate of stroke in India according to the 2013 epidemiological studies is 147-922/1, 00,000 population [2].

Approximately 70-80% of stroke survivors have limited activities of daily living due to motor impairment of the affected upper extremity. Many patients don't regain functional use of the paretic limb and by 6 months post stroke, a large population (28-50%) remains dependent on others for at least 1 ADL [3]. The gross upper limb function, manual dexterity and trunk coordination are affected post stroke that lead to these limitations [5]. Trunk movements and stability are affected due to the cerebrovascular accident- induced spasticity, this also leads to significant slowing down of unimanual movements, alteration of multi-joint coordination, decrease in smoothness and segmentation of reaching and grasping movements. This reduced smoothness of upper limb and trunk movements is likely to affect the gait pattern as arm swing, trunk rotations and pelvic stability are important parameters in gait pattern [5].

We took in to consideration the components like gait, trunk function etc. as study by Daniel Dreyfuss, Avi Elaz *et. al*. has shown that upper limb function can affect gait pattern and study by Doo Hoo lee *et. al* has proved its effect on trunk function. We have tried to link cardiovascular endurance, dynamic and static balance to upper limb training protocol as we consider upper limb and trunk function as contributory components that may affect these.

Traditional Bimanual Therapy aims at using both arms and at increasing the coordination between the paretic and nonparetic hand. As in an intact neuromuscular system; both the hands, work as a single unit by the virtue of neural coupling in a coordinated fashion during activities of daily living, like upper and lower dressing, opening a bottle, lifting weights, toileting etc [4]. It is an active, task specific approach where the limbs are constrained to act as single unit by the virtue of neural coupling [5]. This therapeutic intervention is based on inter hemispheric interaction that normalizes the inhibitory effects placed by the normal hemisphere on the damaged area. Bilateral coordination is strongly associated with the integrity of the corpus callosum, caudal cingulated motor area and supplementary motor area.

In Loaded Bimanual Therapy protocol; complexity of task performance is increased by adding a load on the non paretic hand. Symmetrical tasks were used in our protocol. These demand equal participation by both the limbs. Complexity of the task was increased by adding a load on the non paretic hand based on the theory that CNS analyses

movement patterns hence when load is applied on the non paretic arm the demand placed on the paretic arm increases leading to the increased muscular activation so as to make the movement path as smooth as possible.

Rhythmic auditory cues was given by a metronome sets up the bimanual task frequency, increases attention and gives sensory feedback.[6]Rhythmic auditory cues given by a metronome sets up the bimanual task frequency, increases attention and gives sensory feedback. External sources of feedback are crucial in motor learning as it acts as important source to produce knowledge of result and knowledge of performance.

Studies have shown Loaded Bimanual Therapy and Bimanual Arm Therapy with Rhythmic Auditory Cues (BATRAC) to be effective in improving upper limb functional capacity in post stroke patients [5], but there is scarcity in literature on the combined effect of Loaded Bimanual Therapy with Rhythmic Auditory Cueing on upper limb and trunk function, balance and cardiovascular endurance in stroke patients. So by this study we tried amplify the protocol of loaded bimanual therapy by adding auditory cueing that is rhythmic in nature. The aim of this study was to compare the effects of loaded bimanual arm therapy and loaded bimanual arm therapy with rhythmic auditory cueing on upper limb function, trunk function, balance, gait and cardiovascular endurance in stroke patients.

Materials and method

Patients and recruitment

The study included twenty stroke patients from the outpatient and inpatient departments of 2 tertiary care setups. The inclusion criteria included (1) first time stroke survivor patients within 1 year of diagnosis by computerized tomography or magnetic resonance imaging. (2) Normal BMI and class I obesity (30-34.5)(3)Individuals aging between 45yrs -70yrs.(4) Walks 10 meter with or without assistive device(5)Cognitive status (>24 on MMSE[29]) 6) Brunnstorm stage [30] 2 and above. (7) Modified Ashworth scale [31] 2 and below for upper limb muscles. (8) Patients with visual impairments due to stroke that has been corrected.

The exclusion criterion were (1) unstable medical and cardiovascular conditions like myocardial infarction in the last month, heart rate more than 120 beats/min, blood pressure more than 180/100mmhg. (2) musculoskeletal disorder affecting arm mobility like shoulder subluxation, impingement, frozen shoulder, reflex sympathetic dystrophy.(3) Any other neurological co morbidities like seizures. All subjects read and signed an approved *Institutional Review Board* informed consent before testing began.

Intervention

912g weight cuff were calibrated using standardized procedure for calibration. It includes test for eccentricity in which standardized weights are placed on different spots on the weighing machine. After the test of eccentricity, zeroing of the machine was done and standardized weights were placed on the weighing machine and reading was recorded and compared with the original value.

In Both loaded bimanual therapy with and without cueing group, a customized and calibrated weight cuff (912g) [7] was applied on the non paretic hand just below the elbow joint line on the forearm and the 5 bimanual tasks (Involving gross hand and trunk motions) were performed. In the loaded bimanual therapy with cueing group, the task had to be performed rhythmically to a metronome beat set at a frequency of 20 beats/min for 5 minutes followed by a rest pause of 1-2 minutes, in case the patient complains of fatigue the session is stopped followed by a period of rest pause.

The tasks were as follows: The ball was held in both the hands with both elbows extended and moved over the separator, done in sitting. The second task is performed sitting near a table. The ball is held in both the hands with both elbows extended and moved from the center to 30cm towards the right and 30cm towards left along with trunk rotations. The third one is in sitting again, medicine ball is rolled/pushed up and down the wedge along with trunk movements. The fourth task is in standing. The ball is moved in a diagonal a pattern. Starting with the affected side placed below the ball. Each side for 2.30 minutes**.** The fifth one is in sitting. Cleaning the table top, using both the hands with the towel. 2.30 minutes forward and backwards later sideways in a semicircular motion towards right and left.

Primary outcomes

Wolfff's Motor Function Scale [20]: It quantifies upper limb gross and fine motor skill on time based and functional tasks. The scoring had 2 components the timing component and the functional grading. It has 17 tasks, 15 out of which assessed movement speed and the rest 2 strength which was not time based. The maximum time allotted for each task 120 minutes. The functional grade had a scale that had to be rated on 5 pointer scale for each task, it is a subjective rating scale.

Secondary outcomes

Trunk Impact Scale [21]: Assessed the motor impairment of trunk after stroke. It has 3 subgroups: static sitting balance, dynamic sitting balance, trunk coordination. Each of the component had options that can be scored ranging from 0-3. Total score 24. Higher the score better is the trunk motor function.

Berg's Balance Scale [22]: This assesses the proactive and static balance in sitting and standing. It has rating scales under each component ranging from 0-4. It has 14 components. Total scoring is 56. Higher the score better is the balance. 56-41 low risk of fall, 21-40 medium risk of fall, 0-20 higher risk of falls.

Dynamic Gait Index [23]: Clinical tool for assessing gait, balance, risk of fall. It assesses walking during more challenging tasks. It consists of 8 tasks. Highest possible score is 24. Each component has a 4 point ordinal scale. Completion time is 15mins. Score of less than 19 is related to increased incidence of falls.

6 Minute Walk Test [24]: It is a sub maximal exercise testing done to asses cardiovascular endurance. A 30 m walkway is used for walking at maximum speed as possible. The number of laps covered in noted as each 60m accounts for 1 lap. This latter used for causation of the distance covered and compared with the predicted distance to find out the percentage covered.

Data analysis

Statistical analysis was carried out using statistical tool IBM

SPSS (2016) version 24. Descriptive analysis of the demographic data was done. Mean and standard deviation of the variables were calculated. Median of the functional grading of the WMFT was calculated. Normality of each variable was analyzed using the Shapiro- Wilk test.

All the variables except Wolff motor function scale-functional grade, 6 minute walk test distance covered and heart rate recovery within 1 minute was not normally distributed.

For intragroup analysis the paired t test was used in normally distributed data. Wilcoxcon signed rank test was used for freely distributed data. For intergroup analysis the pre post difference of the variables was subjected to unpaired t test in case of normally distributed data, and Mann Whitney U Test in case of freely distributed data. Statistical significance was set at pvalue≤0.05.

Results

General characteristics of subjects

The average age, 54.72 ±9.15 years average duration 7.27 ± 3.55 months and average BMI 24.94±3.33kg/m^2, further, descriptive statistics are shown in Table 1.

Treatment Effects

The pre post analysis in loaded Bimanual Therapy with cues showed statistically significant improvements in WMFT p=0.005 TIS p=0.005 BBS p=0.005, DGI p=0.008, 6MWT Distance p=0.003.

The pre post analysis in loaded Bimanual Therapy also showed statistically significant improvements in WMFT p=0.005 TIS p=0.001BBS p=0.004, DGI p=0.008, 6MWT Distance p=0.001, but in intergroup analysis no statistical significance in any of the outcome variables was noted except for 6MWT (m) p=0.013

Discussion

The aim of this study was to compare the effects of loaded bimanual arm therapy and loaded bimanual arm therapy with rhythmic auditory cueing on upper limb function, trunk function, balance, gait and cardiovascular endurance in stroke patients.

Both the groups showed improvements in WMFT, TIS, DGI, BBS and six minute walk distance (functional capacity).

Improvement in hand function in Loaded Bimanual Therapy could be because the applied load on non paretic limb with translatory task of gripping varied sized ball etc provided stabilising effect by increasing bombardment of proprioceptive afferent stimuli that is transmitted to bilateral hemispheres. Central nervous system analyses the discrepancy in bilateral movement pattern when load is applied, which place a demand on the paretic arm leading to increased muscular activation to fulfil the movement task and maintain smoothness of the pattern. This would have created new neural circuits as therapy protocol involved intense motor practice which was repetitive in nature that must have influenced neural plasticity that resulted in improved gross motor hand function.A study by G. Meng *et al.* showed improvement in upper limb function using Bimanual Therapy in stroke patients [2] where as our study used loaded weigh cuff on non paretic side with bimanual task showed similar results in hand function. Another study by J. H. Caugraugh *et al.* used loaded customised weight hand gloves in Bimanual Therapy showed improvement in both gross and fine motor hand function in stroke patients whereas our study used calibrated weight cuff to non paretic arm which also showed effective improvement in gross motor hand function and upper limb function with minimal improvement in fine motor activity performances [3].

Improvements in trunk function using loaded Bimanual Therapy could be because therapy protocol involved various symmetrical diagonal movements of upper limb that involved trunk movement. While performing the task like shifting varied sized object crossing over the vertical wooden separator, transferring object in horizontal plane etc task demanded more stability in active upper limb muscles involved in gripping the object and increased mobility of trunk movements like rotations, sustained truncal weight shifts that lengthened spastic trunk muscle, improve truncal movement and coordination in order to achieve allotted task. This helped in reducing truncal spasticity by principle of antagonistic contraction. A study by DH Lee, *et.al,* using symmetrical and asymmetrical bilateral upper limb functional task training showed its effectiveness in trunk function in stroke patients [17]. Our study used loaded weight on non paretic with symmetrical bilateral upper limb task showed similar improvement in trunk function.

Loaded Bimanual showed improvement in balance in stroke patients, as therapy tasks involved bimanual activities with load in sitting and standing position constantly requires truncal involvement, weight shift and transfer to weight bearing joints i.e. pelvis and lower limb in turn challenges balance, which improved balance component in stroke patients. A study by JW Shin *et al.* on bilateral manual resistive upper limb training using symmetrical patterns showed improvements in dynamic balance and decreases risk of fall [14]. In our study upper limb symmetrical tasks was resisted by application of weight cuff showed similar supportive findings in improving balance in stroke patients.

Improvement in gait using Loaded Bimanual Therapy in stroke patients could be because therapy protocol involves bimanual patterns with resistance which improved coordination of trunk along with upper limb and improve strength of paretic side arm. Gait majorly involves phasewise movement of lower limb, trunk movement and arm swing. Improvement in trunk and upper limb muscle strength along with synchronized and well coordinated movement of arm and trunk showed improvement in dynamic balance i.e. gait among stroke patients. Even though no specific training was given to lower limb there was gait improvements seen. A study by D. dreyfuss *et al.* restrained one upper limb movements using cast showed gait deviations in normal healthy participants [8] suggesting upper limb and trunk act as key initiator of gait movement by producing momentum required during walking. Our study focused on specific resistive training using bilateral patterns of upper limb involving trunk that helped to improve gait pattern in stroke patients.

A study by U G Bronas *et al.* on effect of 12 week progressive sub maximal arm ergometry training in claudication patients showed that improvements in endurance level using repetitive arm cyclic movements [25]. The findings of the study suggest arm movement along with trunk can produce change in cardiovascular endurance level. Our study involved rhythmic bilateral movement of upper limb training along with trunk movements for 2 week which was repetitive in nature was unable to produce cardiovascular endurance changes as load (resistance)

applied throughout the therapy was constant and time duration to accomplish the task was patient based. Although there was no changes in endurance level but functional capacity in terms with distance covered showed improvement that can be associated with improved strength and endurance of the upper limb and trunk muscles which helped them to covered larger distance. Numerous studies have stated that the trunk and upper limb impairments are a major cause for increased physiological cost of walking in stroke population [7, 8, 9, 16]. and our study involved improved upper limb and trunk muscle strength which must have a improved energy consumption and distance covered during walking.

Loaded Bimanual Therapy with cues had significant effects in improving the upper limb function, Trunk function, Balance and gait.

Improvements in upper limb function loaded Bimanual Therapy with cues could be because bilateral coordinated movements normalises the inhibitory effect induced by the healthy hemisphere on the affected hemisphere. The tasks like pushing the weighted medicine ball on the slope, towel sweeping etc. caused strong activation of the weak extensors of the upper limb. Along with the benefits of loaded Bimanual Therapy, auditory cueing by the metronome beat app, helped patients to maintain the quality of each movement pattern at a defined frequency to complete the task. A study by Jill Whit all *et al.* using Bimanual Arm Therapy with Rhythmic Auditory Cueing showed improved upper limb movements activities using tailor wind device cues helped in setting attentional goal [3] where as our study used metronome beat app. for rhythmic cueing showed similar improvements in gross upper limb movement activity and its accuracy.

The improvements in the trunk function in Loaded Bimanual with Cues are attributed to the task patterns which facilitated pelvic stability and trunk co-activation with lower limb coordination while performing the tasks. Improved pelvis stability helps in maintained vertical upright posture trunk during dynamic bilateral upper limb task on rhythmic cues which gave participants sense of timing feedback on performance and result that in turn improved motor coordination to complete task that increased voluntarily activity of trunk muscles in conjunction with the involuntary core muscles. A kinematical analysis of upper limb movements strongly activate the trunk muscles in stroke patients [16]. Another study by DH Lee [17] on reaching and turning bimanual task in stroke patients showed improvements trunk function on the other hand our study involved resisted bimanual task with auditory cues showed improvements trunk activity and function by improving its strength and coordination with arm.

Improvement in balance in loaded Bimanual Therapy with auditory cues could be because diagonal pattern bilateral task was involved like ball over wedge etc that worked on constant motor coordination, weight shifts on pre set auditory cues made task more dynamic in nature and timed based which influence the psychological factor come into play. This demanded high level muscle activation and coordination of trunk with limbs during various dynamic task posture and improved performance in relation controlled movements and stability.

Gait components showed improvements in the Loaded Bimanual with Cues possible reason behind this could be gait is a closed kinematic chain type of movement that involves time specific coordination of bilateral extremities with trunk during translatory movement of gait. Improved coordinated bilateral arm movements with trunk during dynamic task event would have activated lower limb muscle coordination with trunk as stability of task was constantly challenged with respect to timings, load on non paretic arm and resistance offered by task. Improvement and control of movement at multi-joint level would have resulted in improvement in gait. A study by S. Somasundaram *et al.* [18] on cued upper limb, trunk and lower limb functional tasks in Parkinson patients showed improvement in balance whereas our study focued on resisted bimanual task with cues in stroke population showed similar findings in gait improvement.

There was no improvements cardiovascular endurance in loaded Bimanual Therapy with cues but there was a significant improvement in physical functioning of stroke patients in relation with distance covered in six minutes. Improvement in endurance is closely associated with lower limb movements. Two weeks of training with auditory cues showed improvement in gait and balance but improvement was not evident enough to produce cardiovascular changes and endurance. The improved strength and coordination with trunk and limbs would have helped in lowering physiological cost of ambulation, delay in fatigue during walking in turned improved physical functioning.

Both the therapies might have showed similar results, because of the constant rate of the auditory cueing that was chosen for all the participants and all the tasks irrespective of the severity of upper limb functional status and difficulty of the task respectively. As the rate was constant the participants who couldn't cope up with the set rate started setting in their own rate that became almost similar to the other group that was at self preferred pace.

Table 1: Demographic Descriptive Statistics

	Mean ± Standard Deviation	
	Group A	**Group B**
Age (years)	59.2±8.216	52.5±9.21
Body MASS Index(m^2/kg)	25.89±3.41	23.76±2.27
Duration (months)	6±3.59	7.9±3.24

Sex		
Male	5	9
Female	5	1
Side affected		
R	3	5
L	7	5

#Group A- Loaded Bimanual Therapy with Cues, Group B- Loaded Bimanual Therapy Without Cues

Table 2: Intragroup analysis of Wolff motor function test, Trunk Impairement Scale, Berg's Balance Scale, Dynamic Gait Index,6 Minute Walk Test, Heart Rate Recovery And Peak Heart Of Loaded Bimanual Therapy With Cues

Outcome measures	Mean±Std. Deviation Pre	Mean±Std. Deviation Post	Mean Difference± Std. Deviation	z value	p value
WMFT Total (sec)	180.42 ±18.56	155.29±104.30	23.43±26.65	-2.803	0.005
Trunk Impairment Scale	13.9±2.84	17±2.58	7.1±1.19	2.82	0.005
Berg's Balance Scale	37.7±8.11	41.6±9.58	3.1±1.85	2.814	0.005
Dynamic Gait Index	12.3±5.83	14.3± 6.44	3.9±1.15	2.694	0.008
6MWT peak heart rate	107.5 ± 41.70	105.9±41.39	2±3.82	1.362	0.173
				t value	p value
*Functional Grade	46	54	6.50	-12.11	0.000
6Minute Walk Test(6MWT) Distance (M)	223.952±106.07	243.1± 10.7	1.2±3.82	-4.080	0.003
6MWT Heart Rate Recovery (HRR) In 1 Min	4.5±2.41	4.9±2.76	0.4±0.96	-1.309	0.223

*Median Calculated

Table 3: Intragroup Analysis of Wolff Motor Function Test, Trunk Impairement Scale, Berg's Balance Scale, Dynamic Gait Index,6 Minute Walk Test, Heart Rate Recovery And Peak Heart Of Loaded Bimanual Therapy

Outcome measures	Mean ± Std. Deviation pre	Mean±Std. Deviation post	Mean Difference	Z value	P value
WMFT TOTAL (sec)	518.56 ± 3.37	485.92±2.32	32.64 ±5.38	-2.803	0.005
Trunk Impairment Scale	12.5±2.273	15.8±1.619	4.4±0.99	2.82	0.005
Berg's Balance Scale	43.3±4.191	46.2±3.64	3.3±0.73	2.844	0.004
Dynamic Gait Index	15.2 ± 4.58	16.9 ± 3.95	2.9±0.81	2.636	0.008
6MWT peak heart rate	111.7±10.73	111.2±10.51	1.7±2.48	1.89	0.059
				tvalue	pvalue
*Functional Grade	39.5	44.5	4.5	-6.264	0
6MWT Distance (m)	290.941 ± 94.50	322.20 ± 9.42	0.5±4.17	-5.014	0.001
6MWT Heart Rate Recovery (HRR) In 1 Min	5.7±0.82	5.6 ± 0.84	0.1±0.42	1	0.343

Table 4: Intergroup analysis between loaded bimanual therapy with cues, and conventional therapy of Wolff motor function test, trunk impairment scale, dynamic gait index, berg's balance scale, heart rate recovery (HRR) In 1 Min, 6 minute walk test distance and peak heart

Variables	p value
Difference WMFT Total (sec)	0.769
Difference Trunk Impairment Scale	0.928
Difference Berg's Balance Scale	0.223
Difference Dynamic Gait Index	0.113
Difference 6MWT (m)	0.013
Difference 6MWT peak heart rate	0.762
Difference heart rate recovery (HRR) in 1 min	0.772

Conclusion

Loaded Bimanual Therapy and loaded Bimanual Therapy with Cue are equally effective to bring out significant improvements in Upper Limb function, Trunk Function, Balance, Gait and functional capacity of 6MWT when compared to conventional therapy in stroke patients.

Clinical Implications

The equipments used in the therapies are easily available in clinical setups; hence the therapies can be easily incorporated in neuro-rehabilition setting for betterment of stroke patients.

Loaded Bimanual Therapy and with cues is active and functional task specific approach can be advised to patients as a part of home program under supervision for betterment of stroke patients.

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