Research Paper: Effect of Resisted Bimanual Therapy With Auditory Cues on Arm Function, Balance, and Endurance in Stroke Survivors: A Pilot Study

Siddharth S Mishr[1*], Susan Jose[1]

1. Department of Neuro Physiotherapy, MGM College of Physiotherapy, Maharashtra University of Health Sciences, MGM Super-Speciality Hospital, Vashi Navi Mumbai, India.

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ABSTRACT

Objectives: Upper limb motor impairment causes limited activities of daily living in stroke survivors. Bimanual therapy is based on Bimanual movement that facilitates cortical balancing by simultaneous movement of paretic and non-paretic arms while performing a task. Studies aimed at exploring the effects of resisted Bimanual therapy with rhythmic auditory cues on arm function, balance, and endurance in stroke survivors.

Methods: A pilot study was commenced after the institutional ethical committee approval. Twenty stroke survivors were randomly allocated into two treatment groups; Group A received conventional therapy along with resisted bimanual therapy with rhythmic auditory cues and group B received only conventional therapy. All patients received 14 treatment sessions within three weeks. Each session lasted for 45-60 minutes. The outcome measures used to assess hand function, trunk function, balance, gait, and endurance were Wolf Motor Function (WMFT), Trunk Impact Scale (TIS), Berg's Balance Scale (BBS), Dynamic Gait Index (DGI), and Six Minute Walk Test (6MWT), respectively.

Results: Pre-post-analysis in resisted bimanual therapy with rhythmic auditory cues showed statistically significant difference in WMFT (P=0.005), TIS (P=0.005), BBS (P=0.005), DGI (P=0.008), and 6MWT (P=0.003). Pre-post-analysis in conventional therapy showed statistically significant difference in WMFT (P=0.005), TIS (P=0.016), and BBS (P=0.014). Inter-group analysis of mean difference between resisted bimanual therapy with rhythmic auditory cues and conventional showed statistically significance difference in WMFT (P=0.037), TIS (P=0.003), BBS (P=0.0001), and DGI (P=0.004).

Discussion: Although both groups showed improvement individually in arm function, balance, and functional capacity among stroke survivors, resisted bimanual therapy with rhythmic auditory cues showed better improvement than conventional therapy in all three components: arm function, balance, and functional capacity in stroke survivors.

*** Corresponding Author:**
Siddharth S Mishra, MPT (Neuro-PT).
Address: *Department of Neuro Physiotherapy, MGM College of Physiotherapy, Maharashtra University of Health Sciences, MGM Super-Speciality Hospital, Vashi Navi Mumbai, India.*
Tel: *+91 (88) 79948943*
E-mail: *siddharth24789@gmail.com*

Highlights

- Resisted bimanual therapy with rhythmic auditory cues improves hand function, trunk function, balance, and functional capacity in stroke survivors.

- Resisted bimanual therapy with rhythmic auditory cues showed no effect on cardiovascular endurance among stroke survivors.

- In comparison, resisted bimanual therapy with rhythmic auditory cues showed better improvement than conventional therapy in all three components than conventional therapy.

- Training upper limb can improve lower limb function in post-stroke survivors.

Plain Language Summary

Stroke is one of the disabling conditions, which often grossly influences the activity of daily living and functional performance in stroke survivors. In the majority of survivors, upper limb dysfunction is commonly seen that needs a longer time to recover. Resisted bimanual therapy with rhythmic auditory cues is based on a bimanual movements task that encourages both upper limbs to use to complete the task successfully. Resistance in this therapy is given by a well-calibrated weight cuff on the non-paretic arm and rhythmic auditory cues by a metronome that is set at a defined frequency. Resisted bimanual therapy can improve upper limb function as therapy is intense, repetitive, and causes voluntary movement of paretic arm are performed on metronome pre-set frequency that modulates movement direction and speed. It is more pleasant and encouraging for patients by overcoming physical task challenges. Conventional therapy included stretching, strengthening, weight-bearing exercise, and the bimanual task was considered with the absence of added weight and auditory cues. In our study, ten stroke survivors performed resisted the bimanual movement task with rhythmic auditory cues. The finding showed improvement in arm function, balance, and functional capacity in survivors; thus, using this therapy on a routine basis can be beneficial for stroke patients.

1. Introduction

World Health Organization (WHO) defines stroke as a neurological deficit attributed to an acute focal injury of the central nervous system by vascular cause or origin [1]. According to 2013 epidemiological studies, the incidence rate of stroke in India is 147 to 922 in 1,00,000 population [2]. Activities of Daily Living (ADLs) are limited in 70%-80% of stroke survivors due to motor impairment of affected upper extremity. Major patients do not regain functional use of paretic limb and by six months post-stroke, approximately 28%-50% of stroke survivors remain dependent on a caregiver for their ADL [3] due to impairment in gross upper limb function, manual dexterity, and arm-trunk coordination post-stroke [4, 5]. Stroke induces trunk spasticity and causes muscle weakness on both sides of the trunk that induces limitation in unimanual trunk movement, postural stability and produces an alteration in movement coordination at the multiple-joint level. As a result, causes poor arm-trunk coordinator movements that is more likely to produce reduced arm swing, trunk rotational movement, and pelvic stability during gait [5]. Conventional bimanual therapy is based on a bimanual coordinated active task and specific movements where they are constrained to act as a single unit by virtue of mutual coupling [6-10]. According to a randomized controlled trial, upper limb and trunk dysfunction can influence and alter antigravity postures and proximal body stability during dynamic movements and gait among stroke survivors [11-15].

Conventional bimanual therapy is proven to be effective in producing significant improvement in upper limb function in a longer time frame [15, 16]. Application of resisted bimanual therapy with rhythmic auditory cues consists of a constant resistance that is applied on the non-paretic arm of stoke survivors while performing a bimanual movement task at a pre-defined beat frequency. There is scarcity in the literature about the use and effect of resisted bimanual therapy with rhythmic auditory cues; hence, the present study aimed to explore the effects of resisted bimanual therapy with rhythmic auditory cues on arm function, balance, and endurance in stroke survivors.

2. Materials and Methods

A pilot study was commenced after the approval from MGMUPT Institutional Ethical Review Committee (IEC) and a signed written informed consent form was obtained from all participants prior to administration of therapy. Twenty stroke survivors were included from out-patient and in-patient departments of two tertiary health care centers from the Navi-Mumbai region and were randomly allocated into two treatment groups using the lottery method (10 participants in each group). Group A received conventional therapy along with resisted bimanual therapy with rhythmic auditory cues and group B received only conventional therapy.

All participants met the following inclusion criteria: first-time stroke survivor patient within one year of diagnosis by computerized tomography or magnetic resonance imaging, the age of 45-70 years, normal BMI, class I obesity as per WHO classification, being able to walks 10 m with or without assistive device, cognitive mini mental scale examination score of 24 and above [17], grade 2 and above in the Brunnstrom voluntary control grading [18], and spastic muscle tone of upper limb Garde II and below in the Modified Ashworth scale. Exclusion criteria were any unstable medical and cardiovascular conditions, a musculoskeletal disorder affecting arm mobility, like shoulder subluxation, reflex sympathetic dystrophy, etc., and any other neurological comorbidities, like seizures and non-correctable visual impairment, caused due to post-stroke events. The principal investigator was blinded and evaluated all the outcome measures used to assess hand function, trunk function, balance, gait, and endurance by administering the Wolf Motor Function Test (WMFT), Trunk Impact Scale (TIS), Berg's Balance Scale (BBS), Dynamic Gait Index (DGI), and 6 Minute Walk Test (6MWT), respectively.

Intervention: Resisted bimanual therapy with rhythmic auditory cueing group received calibrated weight cuff of 912g [9] that was tied over the non-paretic forearm. Weight cuff of 912g was calibrated using standardized calibration procedure, eccentricity test, and test-retest reliability test. Metronome was used as an auditory cue that was rhythmic in nature with a beat frequency of 20 beats per minute [4]. Metronome was turned off during the rest phase. Therapy included conventional therapy and bimanual tasks with weight cuff and metronome. Bimanual movement task included: 1) Transfer of the ball from one side of vertical separator to another side, 2) Transfer and passing the ball to therapist from one side to other using trunk rotation in a circular manner, 3) Controlled rolling of the ball on the wedge, 4) Controlled rolling a towel (cleaning of the wall) in up to down, side to side and circular movement and 5) Movement of the ball in Proprioceptive Neuromuscular Facilitation (PNF) diagonal chopping and lifting pattern. First, the three movements were performed in a high sitting position whereas the remaining two were performed in a standing position. In the ball-based task, the ball was held in between both hands with elbow extension. If the patient was unable to hold the ball, straps were used. Conventional therapy group received weight-bearing exercise, stretching and strengthening exercise, pegboard exercise, functional object grasp exercise, and bimanual task without any added weight and auditory cue. Both groups received 15 intervention sessions within three weeks and each session lasted 45-60 minutes [2, 4].

Outcome measures: WMFT [19] was used to assess upper limb function based on time-based functional tasks. It consists of 17 tasks scaled on a five-point score for each task. TIS [20] was used to assess motor impairment in the trunk after stroke. It consists of three subgroups: static sitting balance, dynamic sitting balance, and trunk coordination. Each component has a score ranging from 0-3. The upper limit score is 24 signifies better trunk motor function. BBS [21] was used to assess proactive, balance, and risk of fall consisting of 14 components with rating scales of each component ranging from 0-4. A score from 56-41 indicates low risk, 21-40 medium risk, and 0-20 high risk of falls. DGI [22] was used to assess gait and balance. It consists of eight tasks and each component has a 4-point ordinal scale with a maximum score of 24. Also, the 6MWT [2, 23] was to assess cardiovascular endurance and distance covered.

Statistical analysis: SPSS v. 24 software was used for data analysis. The mean and standard deviation of demographic variables were calculated. Shapiro-Wilk test was used for the normality of each variable. Wolff motor function test-functional grade, 6-minute walk distance covered, and heart rate recovery within 1 minute was not normally distributed; hence, Wilcoxon signed-rank test was used. Other variables were normally distributed; thus, analysis was carried out using paired t-test for intragroup analysis. For intergroup analysis, differences between pre-test and post-test values were obtained, and a normality test was used using the Shapiro-Wilk test. For the normally distributed data, ANOVA and post hoc Tukey's LSD test was used, and for the freely distributed data, the Kruskal-Wallis test was used. Statistical significance was set at P-value ≤ 0.05.

3. Results

Twenty stroke survivors, including 13 males and 7 females were enrolled in the study with the mean age 54.72±9.15 years, mean duration of stroke was 7.27±3.55 months, mean BMI was 24.94±3.33 kg/m², and 11 patients had left side affected, whereas 9 cases had right side affected (Table 1).

The intra-group pre post comparison of resisted bimanual therapy with rhythmic auditory cues showed statistical significances in the scores of WMFT (z=-2.80, P=0.005), TIS (z=2.82, P=0.005) BBS (z=2.814, P=0.005), DGI (z=2.694, P=0.008), and 6MWT distance covered (t=-4.08, P=0.003) (Table 2).

The intra-group pre post comparison of the conventional therapy showed statistically significant improvements in only WMFT (z=-2.803, P=0.005), TIS (z=2.414, P=0.016) and BBS scores (z=2.46, P=0.014) (Table 3).

Further, post hoc test showed statistical differences in resisted bimanual with rhythmic auditory cues in WMFT (P=0.76), TIS (P=0.928), BBS (P=0.223), DGI (P=0.531), 6MWT distance (P=0.013) with respect to conventional therapy in all domains expect cardiovascular endurance (Table 4).

4. Discussion

We explored the effect of resisted bimanual therapy with rhythmic auditory cueing on arm function, balance,

Table 1. Demographic information of the participants

Variables		Mean±SD/No.	
		Group A (n=20)	Group B (n=20)
Age (y)		59.2±8.216	52.5±10.99
Body mass index (kg/m²)		25.89±3.41	25.19±4.03
Duration (mon)		6.0±3.59	7.9±3.81
Gender	Male (n=13)	5	8
	Female (n=7)	5	2
Affected side	Right (n=9)	3	6
	Left (n=11)	7	4

Group A: Resisted bimanual therapy with rhythmic auditory cues; Group B: Conventional therapy.

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Table 2. Intragroup comparison of patients receiving resisted bimanual therapy with rhythmic auditory cues

Outcome Measures	Mean±SD			Statistic Value	P
	Pre-test	Post-test	Mean Difference		
WMFT (sec)	180.42±18.56	155.29±104	23.43±26.65	z=-2.80#	0.005*
TIS (score)	13.9±2.84	17.0±2.58	7.1±1.19	z=2.82#	0.005*
BBS (score)	37.7±8.11	41.6±9.58	3.1±1.85	z=2.814#	0.005*
DGI (score)	12.3±5.83	14.3±6.44	3.9±1.15	z=2.694#	0.008*
6MWT peak heart rate (hr/min)	107.5±41.70	105.9±41.39	2.0±3.82	z=1.362#	0.173
6MWT distance covered (meter)	223.95±106.07	243.1±10.7	1.2±3.82	t=-4.08##	0.003*
6MWT heart rate recovery in 1 minute	4.5±2.41	4.9±2.76	0.4±0.96	t=-1.31##	0.223

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* P<0.05; #Wilcoxon signed rank test; ##Student t-test; WMFT: Wolff Motor Function Test; TIS, Trunk Impairment Scale; BBS, Berg's Balance Scale; DGI, Dynamic Gait Index; 6MWT, 6 Minute Walk Test

Table 3. Intragroup comparison of patients receiving conventional therapy

Outcome Measures	Mean±SD			Statistic Value	P
	Pre-test	Post-test	Mean Difference		
WMFT (sec)	273.83±82.74	265.97±81.13	7.96±5.38	-2.803#	0.005*
TIS (score)	12.7±2.45	13.8±2.34	0.6±0.99	2.414#	0.016*
BBS (score)	18.6±10.63	19.5±10.69	1.1±0.73	2.46#	0.014*
DGI (score)	39.4±9.14	40.4±9.61	0.9±0.81	-2.428#	0.150
6MWT peak heart rate (hr/min)	109.3±20.05	109.1±19.71	1.0±2.48	1.651#	0.099
6MWT distance covered (meter)	268.72±4.00	275.73±6.81	2.2±4.17	-6.960##	0.300
6MWT heart rate recovery in 1 minute	6.9±1.66	7.1±1.59	0.2±0.42	-1.500##	0.168

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* P<0.05. # Wilcoxon signed rank test; ## Student t-test.WMFT: Wolff Motor Function Test; TIS: Trunk Impairment Scale; BBS: Berg's Balance Scale; DGI: Dynamic Gait Index; 6MWT: 6 Minute Walk Test.

and endurance in stroke survivors. Both groups showed significant changes in the WMFT, TIS, DGI, BBS, and 6MWT distance but none showed any change in cardiovascular endurance using 6MWT.

Improvements in upper limb function resisted bimanual therapy with rhythmic auditory cues in participants could be because bilateral coordinated movements normalize the inhibitory effect induced by the healthy hemisphere on the affected hemisphere. Bimanual movement with resistance caused strong activation of weak upper limb extensors than conventional therapy with added resistance. The added benefits of metronome auditory cueing, helped in maintaining the quality of movement pattern at a pre-defined frequency. A similar study by Whitall et al. used bimanual arm therapy using a tailor wind device showed improvement in paretic upper limb movements activities that helped in setting a future goal in post-stroke patients [4].

Improvements in trunk function in resisted bimanual therapy with rhythmic auditory cues in participants are attributed to resisted bimanual movement task patterns that challenged more pelvic stability and trunk muscle activation than no resistance therapy. Improved pelvis stability helps in the maintenance of vertical upright trunk posture during the activity based on rhythmic cues that gave participants a sense of timing and feedback on performance and result. This improved arm-trunk motor coordination to complete the task and increased

Table 4. Intergroup comparison using post hoc test between resisted bimanual therapy

Outcome Variables	Mean Difference Between Group A and Group B	SE	P
WMFT (sec)	15.48	11.81	0.037*
TIS (score)	2.000	0.54	0.003*
BBS (score)	3.000	0.58	0.0001*
DGI (score)	1.000	0.47	0.044*
6MWT peak heart rate (hr/min)	9.56	5.67	0.229
6MWT distance covered (meter)	-3.40	1.19	0.080
6MWT heart rate recovery in 1 minute	0.20	0.28	0.488

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Group A: rhythmic auditory cues : Group B: conventional therapy. * P<0.05. WMFT: Wolff Motor Function Test; TIS: Trunk Impairment Scale; BBS: Berg's Balance Scale; DGI: Dynamic Gait Index; 6MWT: 6 Minute Walk Test; SE: Standard Error voluntary activity of trunk muscles in conjunction with the involuntary core muscles. A study on post-stroke survivors showed that kinematical analysis of upper limb movements is highly associated with and strongly activates trunk muscles and activates trunk muscles in stroke patients [15]. Another study by Lee et al. [13] showed improvement in trunk function on reaching and the turning bimanual task in stroke patients.

Balance improvements in resisted bimanual therapy with rhythmic auditory cues participants could be because resisted diagonal pattern bilateral task was more effortful, dynamic in nature, and self-competitive-based. Additional cueing during performance demanded more attention and concentration that influenced psychological factors to come into play to complete the task. Gait is a closed kinematic chain movement that involves time-based specific coordination of bilateral extremities with trunk during translator motion. Improved bilateral arm movements, trunk coordination, and pelvic stability while performing dynamic activity must have constantly challenged stability and base of support that was more intense and repetitive in nature would have activated lower limb muscle and improved trunk-lower limb coordination in terms of timings and speed. Resistance while performing activity must have made frequent and strong activation of lower limb muscles and gained control of movement at the multi-joint level that would have resulted in improvement in gait in participants subjected to resisted bimanual therapy with rhythmic auditory cues. A similar study by Ahmad et al. [14] on cued upper limb, trunk, and lower limb functional tasks showed improvement in static and dynamic balance in Parkinson's patients.

There were no improvements in cardiovascular endurance in resisted bimanual therapy with rhythmic auditory cues participants but there was a significant improvement in physical functioning of stroke patients in relation to distance covered in six minutes. Improved strength due to added resistance and coordination between trunk and limbs would have helped in lowering the physiological cost of ambulation, delay in fatigue during walking in turned improved physical functioning capacity in participants. Fourteen sessions of training must be not evident enough to produce cardiovascular endurance changes among stroke survivors [24-28].

5. Conclusion

Resisted bimanual therapy with rhythmic auditory cues showed significant improvements in upper limb function, trunk function, balance, gait, and physical functional capacity in stroke survivors than conventional therapy. Conventional and resisted bimanual therapy with rhythmic auditory cues were not effective to produce any evident cardiovascular endurance changes.

Limitation and future recommendation: More interventional sessions could have bought improvement in the cardiovascular endurance domain. Another limitation would be a small sample size, and future studies can consider long duration with a large sample size to study and explore the in-depth effect of resisted bimanual therapy with rhythmic auditory cues and residual therapy effect.

Clinical implications: The equipment used in the therapies is easily available in clinical setups; hence, therapies can be easily incorporated in normal neuro-rehabilitation settings for the betterment of stroke patients. Resisted bimanual therapy is an active and functional approach that can be advised to patients as a part of the home program under supervision for the betterment of stroke patients.

Ethical Considerations

Compliance with ethical guidelines

Institutional ethical approval was obtained by MGM University and College of Physiotherapy (MGMUPT/CT-28/2019-200088). Written signed informed consent was obtained before administration of therapy.

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Authors' contributions

Both authors equally contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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