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COMBINED EFFECTS OF AUDITORY AND VISUAL RHYTHMICAL CUEING ON LOWER LIMB SENSORIMOTOR RECOVERY AND GAIT PARAMETERS IN PATIENTS WITH HEMIPLEGIA

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ABSTRACT

Background: Post-stroke gait impairments significantly limit mobility. Auditory rhythmical cueing (ARC) has shown potential benefits, prompting the need for a trial to evaluate the effects of combined auditory and visual rhythmical cueing (AVRC) on gait and motor recovery in hemiplegic patients. This study aimed to assess the effects of AVRC on the recovery of lower limb sensorimotor function and gait parameters in hemiplegic individuals.

Methods: In this multicenter randomized clinical trial (NCT06059781), 24 patients participated. The experimental group received standard rehabilitation supplemented by auditory cues (Metronome App) and visual cues (white chalk lines), while the control group received standard rehabilitation with auditory cues only. Assessments were conducted using the Fugl-Meyer Assessment for Lower Extremities (FMA-LE) and the Dynamic Gait Index (DGI), focusing on sensorimotor function and gait. The intervention lasted four weeks, with three 45-minute sessions weekly.

Results: Both groups showed improvement, with the experimental group displaying significantly better outcomes in range of motion, pain management, movement speed, coordination (FMA-LE),

and safe ambulation (DGI). The combined cueing approach led to greater enhancements in gait parameters.
Conclusion: The combined auditory and visual cueing approach significantly improved lower limb sensorimotor recovery and gait parameters, suggesting that multimodal sensory stimulation is a beneficial addition to rehabilitation for hemiplegic patients.

Key words: Auditory rhythmical cueing, Gait parameters, Hemiplegia, Sensorimotor recovery, Visual cues.

BACKGROUND

The sudden demise of brain cells happens when the arteries supplying the brain are ruptured in the course of a stroke, leading to a lack of oxygen. (1) About two-thirds of stroke survivors are left disabled after leaving the hospital. A stroke might be a permanent problem for some people, while others recover completely. (2) Hemiplegia is one of them that stroke victims frequently experience as a consequence. As a typical post-stroke consequence, hemiplegia limits limb movement; 38% of post-stroke patients experience difficulties with rehabilitation due to spastic hemiplegia. (3) The primary characteristic of a stroke is unilateral upper and lower limb paralysis. One of the main causes of death among adult populations in developed nations is stroke. Stroke is the second or third leading cause of death in most of the nations. (4)
Stroke is not a single illness; rather, it is a result of numerous risk factors, illness processes, and disease mechanisms. (5) There are both modifiable and non-modifiable risk factors for stroke. Race/ethnicity, age, genetics and sex are among the non-modifiable factors. The modifiable factors include drinking alcohol, smoking, diabetes, dyslipidemia, atrial fibrillation, diet, metabolic syndrome, obesity and physical activity. (6)

World health organization (WHO) approximates that 15 million people have a stroke annually, leaving 5 million dead and 5 million with severe disabilities. (7) Stroke causes morbidity and mortality and is the second largest cause of death globally. (8) In middle to high-income nations, stroke stands as the second leading cause of death and the primary contributor to acquired physical disabilities worldwide. Over the last decade, the occurrence of both ischemic and hemorrhagic strokes has risen to 85-94 cases per 100,000 in these nations, reaching notably higher rates (1151-1216 per 100,000) among individuals aged 75 and older. (5) Over the past three decades, there has been a rise in the prevalence of stroke, with low-income nations reporting an annual increase of 14.3%. (9) The South Asian region is the leading contributor to stroke death worldwide, accounting for almost 40% of the burden of stroke in the developing world. (10) In Asia, the annual incidence of stroke ranged from 116 to 483/100,000. (11)

Rehabilitation exercises can increase muscular strength and limb functionality quickly, avoid muscle atrophy and joint stiffness, lower the rate of disability, and enhance patients' quality of life. (12) Over the past ten years, improvements in stroke patient care have dramatically decreased mortality; yet, one-third of the 16 million patients who suffer from stroke each year remain disabled. Therefore, there is a need for more effective stroke rehabilitation techniques. (13)
More than 80% of stroke victims experience difficulty walking and are less likely to be able to resume their jobs. (14) Rehab objectives for stroke survivors include increasing their capacity to walk in the community and participating in worthwhile activities. (15) One of the main rehabilitation objectives for stroke victims is to be able to walk again. (16) According to the patient's residual abilities, physical rehabilitation after a stroke often focuses on the sensory-motor recovery of the upper extremity, lower extremity, balancing skills and gait functions. (17) Enhanced visual and auditory cues have been recognized for their ability to support both perception and action. (18) In the creation of neuromuscular rehabilitation approaches, visual stimuli and feedback play a prominent role in the rehabilitation and treatment of patients. (19)

To enhance Temporal Gait Adaptation (TGA), prior research has explored the application of rhythmic stimulation. This method incorporates external cues, such as auditory or vibrotactile stimuli, to deliver a pulsed rhythmic pattern (e.g., metronome), promoting synchronization with the individual's walking pattern. The timing of these stimuli can be manipulated to influence and enhance temporal gait parameters, including symmetry and cadence. (20)

It has been proven that auditory stimulation with regular rhythm will motivate and activate sensorimotor cortical areas. (21) When visual and auditory cues are integrated, there is a possibility of inducing structural interference, wherein the two types of cues necessitate distinct responses. For instance, auditory cues may influence temporal gait adaptations, while visual cues may demand spatial adjustments, thereby augmenting the overall attentional demand. (22) Since 2019, the official Stroke Care Guidelines in the United States and Canada have included RAS as a neurologic music therapy (NMT) rehabilitation technique. (23)

People experiencing hemiplegia frequently face challenges in recovering lower limb sensorimotor functions and managing gait parameters, significantly impacting their mobility and overall well-being. It is crucial to explore intervention methods that can effectively tackle these issues and improve their quality of life. In this randomized controlled trial, a meticulously crafted exercise protocol will be employed to examine how the combined effects of auditory and visual rhythmical cueing influence lower limb sensorimotor recovery and gait parameters in individuals with hemiplegia. This innovative approach seeks to offer valuable insights for optimizing rehabilitation interventions tailored to this population.

METHODS

Trial Design

The research utilized a Randomized Clinical Trial framework to investigate the collective impact of auditory and visual cues on hemiplegia. Data gathering took place at Mayo Hospital Lahore, spanning a six-month duration after the approval of the synopsis. Non-probability convenient sampling technique was employed for sample selection.

Participants

The study included 24 hemiplegic patients, determined using the G power sample size calculator. (24) The focus of this study was on individuals experiencing hemiplegia in the chronic phase following a stroke. The consort diagram for this method is shown in Figure 1.

The inclusion criteria encompassed both male and female participants aged between 45 and 65 years, who were in the chronic phase of stroke, specifically six months post-stroke, and were capable of independently walking a distance of 10 meters. (21) Participants in this study included individuals with involvement of the anterior and middle cerebral arteries, as well as those in Brunnstrom's recovery stages 3 and 4. Additionally, participants had Mini-Mental State Examination (MMSE) scores exceeding 24. (21) Grade 1 and 1+ on the Modified Ashworth Scale were considered for inclusion. (25) On the contrary, patients with dementia, depression, or productive psychosis, as well as those with any visual or auditory impairments, were not included in the study's criteria for participation. (26) Patients exhibiting foot drop and recurrent transient ischemic attacks (TIAs) were not included in the study.

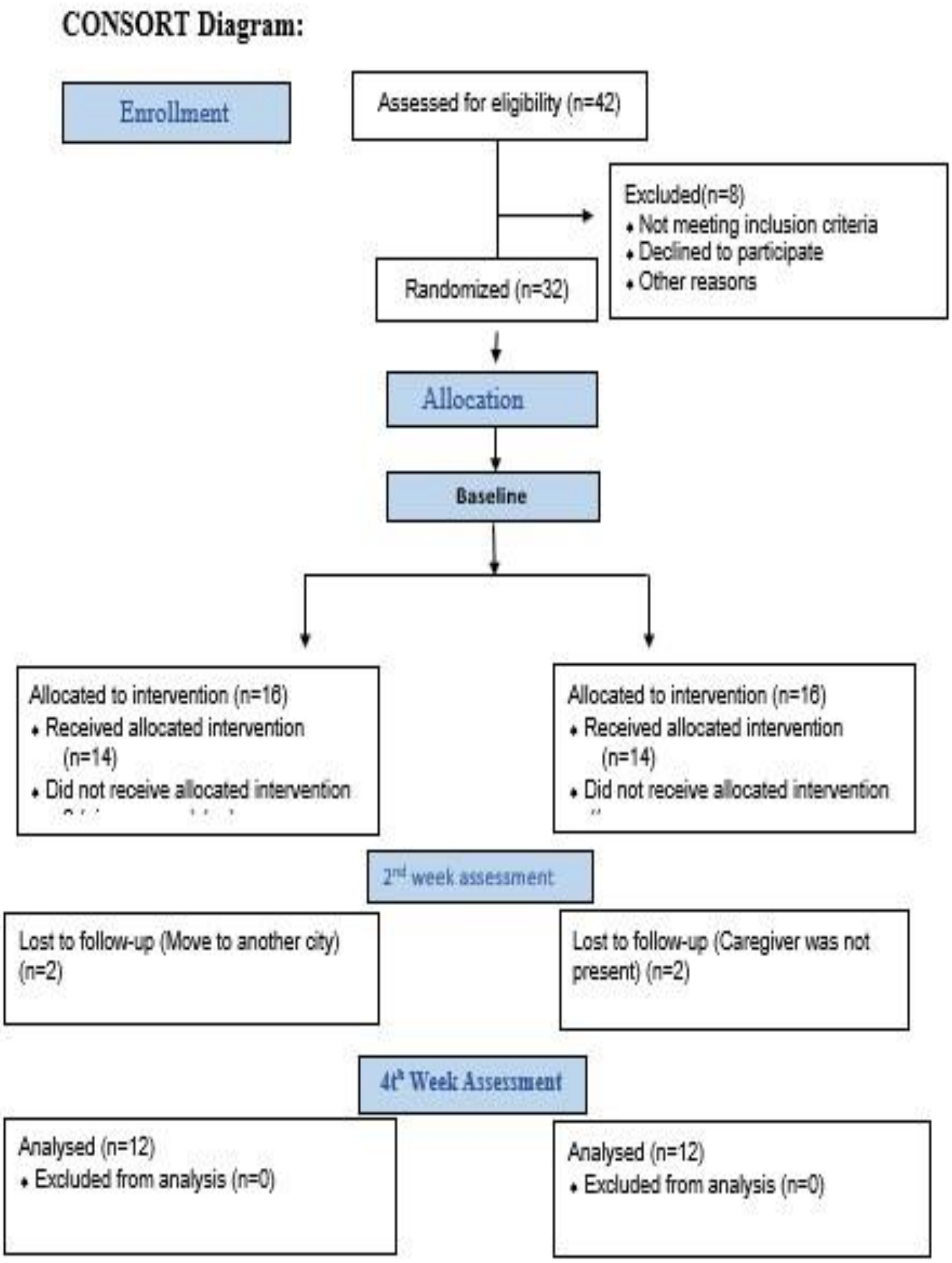

Figure 1: CONSORT Diagram

Intervention

The experimental group received both rhythmical auditory stimulation and visual cues represented in Figures 2,3 and 4, while the clinical group received only auditory stimulation as shown in Figure 4. Both groups underwent 45-minute sessions, three times a week for four weeks, alongside routine rehabilitation, which included lower extremity range of motion exercises and marching exercises. During walking exercises, the experimental group had auditory stimulation set at 110% of their walking rate and supplemented with visual cues drawn on the ground, whereas the clinical group solely underwent auditory stimulation-based walking exercises.

Figure 2: Visual cues on Floor

Figure 3: Gait training using visual cues

Figure 4 Gait training using auditory cues

Data Analysis:
The analysis of descriptive and analytical data was conducted using SPSS version 23. Quantitative data, including age, were presented in the format of mean ± SD, while qualitative data such as gender were represented as percentages (%), frequency tables, and relevant charts as applicable. The normality of the data was assessed using the Shapiro-Wilk test. To ascertain differences between the experimental and clinical groups across all clinical parameters, One Way ANOVA was employed. Additionally, within-group comparisons during the Baseline, 2nd week, and 4th week of treatment were conducted using Repeated Measure ANOVA.

RESULTS
Figure 5 outlines the demographic characteristics of the study across two groups. Within the Experimental Group, patients exhibited a mean age and standard deviation (SD) of 62.25±11.10, contrasting with 57.16±5.63 observed in the clinical group. The composition of the Experimental Group consisted of 7 (58.33%) males and 5 (41.67%) females, while the clinical group comprised 8 (66.67%) males and 4 (33.33%) females. In both groups, Ischemic stroke was predominant, accounting for 8 (66.7%) cases, while Hemorrhagic stroke constituted 4 (33.3%). Additionally, 9 patients presented with chronic artery disease, whereas 14 patients exhibited no chronic artery disease.

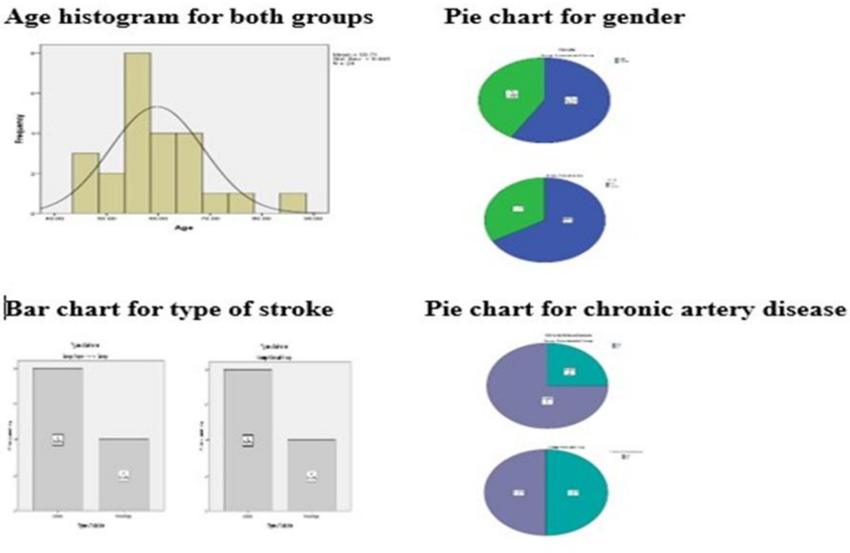

Figure 5 Demographics

Table 1 presents a comprehensive overview of the demographic characteristics. In the Experimental group, 7(58.3%) and 5(41.7%) individuals utilize their right and left hands, respectively, while in the Clinical group, the corresponding figures are 8(66.7%) and 4(33.3%), respectively. Among the 12 participants in the Experimental group, 6 suffer from diabetes, whereas in the Clinical group, 8 out of 12 participants have diabetes. Notably, in the Experimental group, only 3 out of 12 participants exhibit chronic artery disease, whereas in the Clinical group, the count rises to 6 participants with the same condition.

Table 1. Demographics and Clinical Characteristics of Participants

Characteristics	**Experimental Group (n=12)**	**Clinical Group (n=12)**
Age (years)	62.25±11.10	57.16±5.63
BMI	27.03±3.24	30.15±5.85
Gender	**Male** 7(58.33%); **Female** 5(41.67%)	**Male** 8(66.67%); **Female** 4(33.33%)
Months after Stroke	6.95±0.54	6.87±0.77
Marital Status	**Married** 11(91.7%); **Unmarried** 1(4.55%)	**Married** 10(83.3%); **Unmarried** 2(16.7%)
Hemisphere Involved	**Right** 5(41.7%); **Left** 7(58.3%)	**Right** 4(33.3%); **Left** 8(66.7%)
Lobe Involved	**Parietal** 4(33.3%); **Frontal** 4(33.3%); **Temporal** 1(8.3%); **Occipital** 3(25%)	**Parietal** 2(16.7%); **Frontal** 7(58.3%); **Temporal** 2(16.7%); **Occipital** 1(8.3%)
Type of Stroke	**Ischemic** 8(66.7%); **Hemorrhagic** 4(33.3%)	**Ischemic** 8(66.7%); **Hemorrhagic** 4(33.3%)
Smoking Status	**Never Smoked** 2(16.7%); **Former Smoker** 4(33.3%); **Current Smoker** 6(50%)	**Never Smoked** 2(16.7%); **Former Smoker** 5(41.7%); **Current Smoker** 5(41.7%)
Hypertension	**Yes** 7(58.3%); **No** 5(41.7%)	**Yes** 10(83.3%); **No** 2(16.7%)
Diabetes	**Yes** 6(50%); **No** 6(50%)	**Yes** 7(58.3%); **No** 5(41.7%)
Dominant Hand Involvement	**Right** 7(58.3%); **Left** 5(41.7%)	**Right** 8(66.7%); **Left** 4(33.3%)
Affected Side Involvement	**Right** 7(58.3%); **Left** 5(41.7%)	**Right** 8(66.7%); **Left** 4(33.3%)

Values are expressed in Mean± SD and Numbers (%); BMI = Body Mass Index

Table 2 demonstrates that between-group results were analyzed by One Way ANNOVA and within groups were by repeated measure ANNOVA test which showed the effects at baseline, 2nd week, and 4th week.

Table 2: Between-group and in-between-group comparison by One Way ANNOVA and Repeated Measure ANOVA tests

Outcome Measures		**Mean±SD Experimental group**	**Mean±SD Clinical group**	**F-value**	**P value**
Total FMA	**Baseline**	49.91±2.19	49.83±1.74	0.011	0.919
	2nd week	61.08±2.42	57.33±2.26	15.267	0.001
	4th week	80.08±2.23	66.83±3.45	124.203	0.000
	Within group P- value	<0.001***	<0.001***		
DGI	**Baseline**	11.75±1.05	11.83±0.93	0.042	0.840
	2nd week	17.08±1.08	15.00±1.65	13.350	0.001
	4th week	23.16±0.93	17.83±2.88	37.053	0.000
	Within group P-value	<0.001***	<0.001***		

Cadence	**Baseline**	48.16±3.88	50.41±4.54	1.702	0.205
	2nd week	63.75±1.42	62.67±1.49	3.302	0.083
	4th week	74.00±2.66	65.50±1.50	92.592	0.000
	Within group P-value	<0.001***	<0.001***		
Walking Speed	**Baseline**	0.59±0.07	0.61±0.09	0.497	0.488
	2nd week	0.80±0.07	0.71±0.09	7.225	0.013
	4th week	1.24±0.06	0.81±0.09	163.491	0.000
	Within group P-value	<0.001***	<0.001***		
Stride length	**Baseline**	112.91±1.31	112.33±1.23	1.262	0.273
	2nd week	124.91±1.31	124.00±1.04	3.588	0.071
	4th week	136.75±1.71	126.50±1.56	234.063	0.000
	Within group P-value	<0.001***	<0.001***		
Step length	**Biseline**	45.50±2.39	45.91±2.06	0.208	0.652
	2nd week	55.50±1.62	54.50±1.62	2.276	0.146
	4th week	65.41±2.06	56.58±1.78	125.862	0.000
	Within group P-value	<0.001***	<0.001***		
Step width	**Baseline**	15.67±0.88	15.83±0.93	0.200	0.659
	2nd week	12.00±1.27	13.83±0.93	16.036	0.001
	4th week	8.00±1.12	12.75±0.86	133.854	0.000
	Within group P- value	<0.001***	<0.001***		
Step Length Symmetry Ratio	**Baseline**	1.06±0.01	1.06±0.01	0.027	0.872
	2nd week	1.12±0.01	1.08±0.01	16.566	0.001
	4th week	1.12±0.01	1.12±0.01	56.687	0.000
	Within group P-value	<0.001***	<0.001***		
Sride Length Symmetry Ratio	**Baseline**	0.62±0.01	0.62±0.01	0.103	0.752
	2nd week	0.74±0.01	0.66±0.01	243.919	0.000
	4th week	1.03±0.01	0.82±0.01	1603.87	0.000
	Within group P-value	<0.001***	<0.001***		

Values of Mean ± Standard Deviation; FMA LE=Fugl-Meyer Assessment Lower Extremity,DGI= Dynamic Gait Index, p < 0.001*** indicates a very highly significant result within the group.

The mean scores for the experimental group of FMA L.E consistently increased and the P value decreased from 1.000, 1.035, and 0.000 over the baseline, 2nd, and 4th weeks showing significant improvements in sensorimotor recovery related to the clinical group. An increase in F value showed a more significant difference between the groups. Within group comparison by repeated measure, ANOVA showed that there were significant improvements at each time point (p<0.001).

In One Way ANOVA of DGI, P-values were 0.804, 0.005 and 0.000 which showed that there was significant improvement in 4th week. While an increase in F value was also observed. Within group comparison by repeated measure ANOVA showed (P<0.001) at each time indicating significant improvement.

In the between-group comparison for Cadence, One Way ANOVA showed that P-value is 0.205 at baseline showing that there was no significant difference between the two groups. This value decreased in the 4th week which was 0.000 and increased in F value indicating significant improvement between the two groups' results. Repeated Measure ANOVA results showed ($P<0.001$) in baseline and 2nd week, baseline and 4th week, and 2nd week and 4th week. These results showed significant improvement.

DISCUSSION:

This research was conducted to observe the improvement in sensorimotor recovery and gait parameters in hemiplegic patients by executing Auditory and Visual Rhythmical Cueing for 4 weeks, including 24 stroke patients both males and females. In each group, 12 patients were randomly assigned. According to the results, both groups improved, although the experimental group's s showed more significant improvements in the DGI, gait characteristics, and FMA-LE post-treatment scores. While DGI demonstrated improvements in safe ambulation and more significant changes in gait metrics, FMA-LE demonstrated improvements in range of motion and coordination.

The study was conducted by M. Ahmed, Ebtesam M. Fahmy (2023) on 30 male stroke patients. A control group was treated by strengthening exercises for weak upper and lower limbs, stretching exercises for lower limbs, weight bearing on the affected side and treadmill exercises for 6 weeks. The experimental group was treated by Rhythmic auditory cueing stimulation (RAS) in addition to treadmill training exercises. The final results of this study showed that there was a significant improvement in the post-treatment of the experimental group which was treated with Rhythmical auditory cueing. This study's findings were parallel with the current study as sensory stimulation of Rhythmical auditory cueing showed improvement in FMA-LE, DGI and gait parameters. (25)

Research by Xin Lil, Lu Wang (2022) in which they included 24 stroke patients with upper limb deficits. One group was treated with combined sensorimotor rhythm-based brain-computer interference (SMR-BCI) and conventional training with an audio cue, motor observation with multisensory feedback for rehabilitation of the upper limb. The other group was treated with conventional treatment only. Results of this study showed that one group which was treated with combined (SMR-BCI) and conventional had long-lasting upper limb improvement. The results of this study conflict with the present study as this study showed the results of the upper limb but the present study was related to the lower limb. (27)

The study is subject to several limitations that warrant acknowledgment. Firstly, patients exhibited poor compliance and motivation due to rapid onset fatigue, potentially impacting data reliability. Secondly, patient selection lacked preference based on dominant side involvement, failing to account for potential asymmetries. Moreover, while tasks in the experimental group were standardized, individual patient goals were not considered, possibly affecting treatment efficacy. In light of these limitations, future researchers are encouraged to expand the study scope beyond chronic stroke patients to include subacute and acute cases for a more comprehensive understanding. Additionally, while previous research predominantly explored sensory techniques on the lower limbs, there is a clear need to explore the combined application of these techniques, particularly in the context of lower limb rehabilitation.

CONCLUSION

In chronic stroke patients, the experimental group demonstrated clinically significant and statistically significant improvements in lower limb sensorimotor recovery and locomotion parameters compared to the clinical group especially improvement in lower limb motor function, cadence, step length, walking speed, step width, stride length, step length symmetry ratio and stride length symmetry ratios was seen.

LIST OF ABBREVIATION

ABBREVIATION	DESCRIPTION
TIA	Transient Ischemic Attack
NMT	Neurologic Music Therapy
ARC	Auditory Rhythmical Cueing
FMA-LE	Fugl-Meyer Assessment for Lower Extremities
DGI	Dynamic Gait Index
RAS	Rhythmical Auditory Stimulation
MMSE	Mini-Mental State Examination
SPSS	Statistical Package for the Social Sciences
AVRC	Auditory and Visual Rhythmical Cueing
WHO	World Health Organization

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CONFLICT OF INTEREST AND DISCLOUSER
The authors declare that there is no conflict of interest regarding the publication of this paper. None of the authors have any financial or personal relationships with other people or organizations that could inappropriately influence their work.
The authors report no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

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