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Efficacy of rhythmic auditory stimulation on gait parameters in hemiplegic stroke patients: a randomized controlled trial

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Abstract

Background Gait disorders which caused by stroke are one of the most common causes of functional disabilities in hemiparetic stroke patients that leads to significant impact on quality of life and financial cost. In this study, we focused on how certain gait metrics in stroke patients were affected by rhythmic auditory stimulation and treadmill training.

Results In this randomized controlled experiment, which involved 30 male stroke patients, there was a significant increase in post treatment walking speed, step cycle, step length, percent of time on each foot and ambulation index in both groups. The post treatment improvement in gait parameters was significantly higher in the study group compared to the controls.

Conclusions Combination of rhythmic auditory stimulation with treadmill training enhances the gait performance.

Keywords Stroke, Rhythmic auditory stimulation, Biodex gait trainer 2TM

Background

Epidemiological studies showed a considerable increase in the prevalence of stroke in Egypt, based on available community-based studies and compare the resulting findings to those of other regional and international studies [1].

One of the most prevalent disabilities following a stroke is hemiplegia, which greatly lowers walking efficiency. Even while the majority of stroke patients develop an independent gait, many of them fail to walk well enough to carry out all of their daily tasks [2]. Poor gait adaptation results in a decreased capacity to adjust gait to changes in task demands, whereas poor gait coordination after stroke is reflected in an altered relative timing in inter-limb coordination and higher variability in the resulting coordination pattern [3]. Stroke survivors in particular tend to modulate their walking speed more through changes in stride length than stride frequency. On the other hand, poor gait adaptation results in a decreased capacity to adapt gait to changes in task demands [4].

Treadmill Training which enables patients to follow principles of motor learning while walking. Because it allows for entire gait cycles with several repetitions and is assisted by the treadmill's constant rate of movement, treadmill training has frequently been referred to as task specific training [5]. Using an outside stimulus can have an impact on gait characteristics as well. Walking in the presence of an external cue can change step length, velocity, cadence, cycle duration, and double support time [6].

To enhance abnormal gait, acoustic cueing such as metronome beeps or other sensory cues have been used in

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rehabilitation practices. Metronomes have been shown to have immediate and carry-over effects on walking speed, cadence, stride length, and/or gait symmetry in individuals with conditions such Parkinson's disease, traumatic brain injury, and cerebrovascular accidents [7].

The current study aimed to study the effect of treadmill training and rhythmic auditory stimulation (RAS) on chronic stroke patients' gait characteristics.

Methods

This is a single blinded, randomized, controlled trial which was accepted by the Ethical Committee of faculty of physiotherapy (P.T. REC/012/00232), (Cairo University). It adhered to the Declaration of Helsinki's ethical research criteria for using human subjects as set forth by the World Medical Association (WMA). Prior to participation, a consent form was signed by each patient.

Using sealed envelopes, the patients were randomly divided into two comparable groups (A and B). Another licensed physiotherapist who conducted the examination both before and after the intervention served as the blinded part.

This study was conducted on the 30 male stroke patients, their age was ranged from was 45–60 years, the stroke onset was ranged from 6 to 24 months, the patients were all right handed, the Modified Ashworth Scale spasticity ranged from 1 to 1+, the group muscle testing grade of weakness in the paretic lower limb muscles was not less than (grade 3), and the patients were able to walk at least 10 m without the aid of any assistive device.

Patients were disqualified if they had any of the following conditions: cardiovascular issues (uncontrolled hypertension, unstable angina, significant coronary heart disease, and/or congestive heart failure); a history of recurrent strokes; hemiparesis from a neurological condition other than a stroke; obesity; and severe musculoskeletal issues affecting one or both lower limbs (deformity or contracture).

This research was done at the faculty of physical therapy's isokinetic lab and outpatient neurology clinic (Cairo University). Body mass index (BMI) was computed using height and weight data. All patients were clinically evaluated in accordance with the neurology department's standard form (Cairo University).

Biodex gait trainer 2 treadmills (TM): (No.: 601-1-M90, EN60601-1, USA) were used to measure multiple gait kinematics, including step length (m), step cycle (cycle/sec), walking speed (m/sec), time on each foot (measured as a percentage of gait cycle), and ambulation index, before and after the treatment program. In addition, the tool was utilized to treat every patient in the research and control groups.

Every patient was instructed to wear suitable clothes and suitable light shoes before assessment. The patient was standing on the treadmill holding on handrails to ensure safety. The speed of treadmill was ramp up slowly to 0.3 m/h. It was then increased gradually to a comfortable pace for the patient; then, the data recording was started. The patient was asked to walk continuously for three min, till the evaluation session ended, and the gait trainer slow down gradually until it stopped. Three successive trials were done for each patient. The mean value of each variable of spatiotemporal parameters of gait [walking speed (m/s), step cycle (cycle/s), and step length (m)] were recorded. All patients were evaluated before and at the end of the 6-week training period for both groups.

The patients were assigned into two equal groups; Group A (Control group) and group B (Study group).

Group A (Control group) was given a specially designed physical therapy program for stroke patients, consisting of strengthening exercises primarily for weak upper limb muscles (shoulder flexors, elbow extensors, and wrist extensors) and weak lower limb muscles (hip flexors and abductors, knee flexors and extensors and ankle dorsiflexors). Depending on each patient's capacity, each exercise was repeated five to ten times. Stretching activities primarily for the hip adductors, knee flexors, and ankle plantar flexors in the lower limbs. Depending on the patient's capabilities, each exercise was repeated three to five times.

Weight bearing on the affected side: the patient stood in front of wall and tried to bear weight on the affected lower limb for ten seconds and then relax. The exercise repeated from five to ten times according to the ability of each patient, balance training on balance board, Gait training between parallel bars which the patient was encouraged to cross obstacles to facilitate hip flexion, knee flexion and ankle dorsiflexion.

In addition, patients got three times weekly treadmill (TM) exercise for a total of 6 consecutive weeks (every other day). Each gait session lasted 30 min, with a 5-min break required every ten, and a 5-min warm-up. Patients could take more time to rest if necessary, but the gait session had to last a total of 20 min in order for it to be deemed successful. According to the Spendiff and colleagues protocol, patients had a 5-min warm-up session on the treadmill walking at a speed of their choosing, followed by a 1-min rest before the training session [8].

Patients used a treadmill during the training session, moving at speeds ranging from 1.2 to 1.6 m/sec at first, then increased as they advanced to the highest pace the patient could tolerate while maintaining an upright posture during the gait cycle. The patients were instructed to hang on the rails while walking if they started to feel uneasy or feel that they would fall over.

Patients in Group B (the study group) had rhythmic auditory stimulation (RAS) in addition to the same physical therapy regimen with treadmill training as in the control group. During treadmill training sessions, rhythmic regular beats were produced by a software program called Snapoh metronome and played through a portable headphone called the "LGH-301 M.V". The software program aids in ensuring temporal accuracy, tempo stability, and full frequency modulation of the stimulus in accordance with patient needs. During treadmill training, stimulation frequency was set to the highest pace that each patient could tolerate. Each patient's ability was taken into account when modulating the stimulus. The patients were told to match their stride frequency with the rhythmic auditory stimulation during TM training.

Analysis of the data: prior to study data analysis, test of normality was done. Descriptive statistics and *t* test were used to compare the mean ages, weights, heights, BMIs, and lengths of sickness between the two groups (A and B). Each group's pre- and post-treatment measurements were compared using a paired *t* test. The pre- and post-treatment measures for groups A and B were compared using an unpaired *t* test. All statistical tests had a significance threshold of *p* 0.05. The statistical software for social studies (SPSS) version 19 for Windows was used for all statistical calculations.

Results

The General characteristics of patients in both groups are presented in Table 1. There were no significant differences between both groups regarding the age, weight, height, BMI and duration of illness ($p > 0.05$).

The mean walking speed, step cycle, step length of the affected and non-affected side, percent of time on the foot of the affected and non-affected side and ambulation index (pre and post treatment) for both groups were illustrated in Table 2.

All gait measures in both groups significantly improved after treatment compared to before treatment. Pretreatment comparisons of all gait parameters showed no significant differences between the groups with $p > 0.05$.

Regarding the post-treatment comparisons between study group (B) and control group (A), there was a significant increase in post treatment walking speed in group (B) compared to group (A) with a mean difference between both groups was 0.11 m/sec and p value = 0.001. In step cycle, There was a significant increase in post treatment step cycle in group (B) compared to group (A) with a mean difference between both groups was 0.06 cycles/sec and p value = 0.01.

Table 1 Basic characteristics of patients in both groups

	Control group Mean ± SD	Study group Mean ± SD	*p* value
Age (years)	52.41 ± 5.21	52.16 ± 5.55	0.91
Weight (kg)	84.66 ± 6.12	84.25 ± 5.89	0.86
Height (cm)	168.66 ± 11.19	168.16 ± 11.45	0.91
BMI (kg/m^2)	30.15 ± 4.74	30.1 ± 3.96	0.97
Duration of illness (month)	16.66 ± 4.44	15.83 ± 3.9	0.43

p value: level of significance (< 0.05)

SD standard deviation

In step length, the mean difference between both groups was 0.04 m with a significant increase in post treatment step length of the affected side in group (B) compared to group (A) with p value = 0.03. In percent of time spent on the affected side of the foot, the mean difference between both groups was 1.5% with a significant increase in post treatment percent of time on the foot of the affected side in group (B) compared to group (A) with p value = 0.04, while in percent of time on the foot of the non-affected side, the mean difference between both groups was 1.34 with no significant difference between both groups with p value = 0.08 and in ambulation index, the mean difference between both groups was 1.92 with a significant increase in post treatment ambulation index in group (A) compared to group (B) with p value = 0.01 (Table 2).

Discussion

The findings of the current study showed that both groups (A and B) significantly improved in all gait measures after therapy especially group B. Shortened step length of the paretic side in stroke patients may be caused by decreased propulsion producing capability, which slows gait velocity and diminishes gait ability [9]. The triceps surae muscle's reduced muscle strength and lost muscle contraction timing are the root causes of this diminished propulsion. Gait ability would be improved by the restoration of this function [10, 11]. The pelvic and trunk mobility are improved by RAS implementation employing metronome beats [7]. In addition, according to Roerdink and Beek, better trunk rotation during walking results in better propulsion during standing on the paretic side, which boosts the walking speed [12].

The findings of the current study are in line with those of Thaut and colleagues, who claimed that gait velocity, cadence, step length, and symmetry were all improved in a group that used a metronome and music training as opposed to a group that just received tone reduction techniques [6]. The authors showed that using RAS to

Table 2 Comparison of gait parameters within and between control and study groups pre- and post-treatments

Gait parameters	Control group Mean ± SD	Study group Mean ± SD	Mean difference	*T* value	*p* value
1. Walking speed (m/sec)	0.72 ± 0.06	0.71 ± 0.05		0.31	0.75
	0.78 ± 0.06	0.89 ± 0.06	0.11	0.31	0.001*
Improvement (%)	8.33	25.35			
	T = 9.52	*T* = 29.8			
	p = 0.0001*	*p* = 0.0001*			
2. Step cycle (cycles/sec)	0.61 ± 0.06	0.60 ± 0.05		0.29	0.77
	0.64 ± 0.04	0.70 ± 0.05	0.06	0.29	0.01*
Improvement (%)	4.91	16.66			
	T = 3.79	*T* = 16.63			
	p = 0.003*	*p* = 0.0001*			
3. Step length of the affected side (meters)	0.36 ± 0.03	0.35 ± 0.02		0.44	0.66
	0.40 ± 0.04	0.44 ± 0.03	0.04	0.44	0.03*
Improvement (%)	11.11	25.71			
	T = 11.86	*T* = 23.68			
	p = 0.001*	*p* = 0.0001*			
4. Step length of the non-affected side (meters)	0.65 ± 0.04	0.64 ± 0.04		0.7	0.48
	0.66 ± 0.04	0.67 ± 0.04	0.01	0.62	0.53
Improvement (%)	1.53	3.68			
	T = 2.34	*T* = 2.87			
	p = 0.03*	*p* = 0.01*			
5. Percent of time on affected side (%)	42.5 ± 1.56	42.25 ± 1.05		0.45	0.65
	43.58 ± 1.72	45.08 ± 1.72	1.5	0.45	0.04*
Improvement (%)	2.54	6.69			
	T = 13	*T* = 10.47			
	p = 0.01*	*p* = 0.0001*			
6. Percent of time on non-affected side (%)	57.5 ± 1.56	57.75 ± 1.05		0.45	0.65
	56.25 ± 1.91	54.91 ± 1.72	1.34	0.45	0.08
Improvement (%)	2.17	4.91			
	T = 9.57	*T* = 10.47			
	p = 0.01*	*p* = 0.0001*			
7. Ambulation index	73.08 ± 1.72	72.66 ± 1.15		0.69	0.49
	74.16 ± 1.74	76.08 ± 1.83	1.92	0.69	0.01*
Improvement (%)	1.47	4.7			
	T = 9.57	*T* = 8.58			
	p = 0.02*	*p* = 0.0001*			

$p > 0.05$: non-significant

$p < 0.05$: significant

SD standard deviation

increase gait training during hemiparetic stroke rehabilitation is an efficient therapeutic approach. These results supported those of Pelton and colleagues, who found that training with RAS would enhance a stroke patient's gait ability and reduce step time while also enhancing gait velocity, step length, and asymmetry [13].

RAS stimulates sensorimotor synchronization and enhances neuronal plasticity, which improves motor responsiveness and function in stroke survivors and leads to improvements in gait kinematics [14]. To maximize functional recovery and promote beneficial neuroplastic changes, post-stroke patients need more than 357 steps of treatment per session, according to Lang and colleagues [15]. RAS can be used to increase steps without lengthening the course of treatment.

In addition, the regularity of RAS leads to the recruitment of more motor neurons by modifying their activity, resulting in more regular and synchronised patterns of neural activation [16].

The complete specification of the dynamics of the movement over the entire movement cycle has been demonstrated in optimization models using rhythmic cues as predictive time constraints [17]. This reduces variability, improves temporal precision, and makes it easier to choose the best movement trajectories, velocity, and acceleration parameters. Therefore, to restore motor function during brain rehabilitation, temporal-rhythmic motor signals regulate comprehensive spatiotemporal and force parameters in addition to movement speed and timing [18].

In addition, Rojo and colleagues discovered that RAS causes motor improvements in hemiparetic individuals with chronic stroke [19]. This was accompanied by a change in the motor cortical representation as well as an increase in the excitability of the corticospinal tract, which was demonstrated by an elevated motor evoked potential amplitude along the corticospinal tract. These alterations are the result of a plasticity effect that depends on training and is triggered by the development of new motor abilities. These results provided evidence that, when administered to stroke patients in the chronic phase, the audio motor coupling might boost plasticity within the impaired motor cortex (which, in turn, produces motor improvement on the affected side).

The findings of the current study are in line with those of Peterson and colleagues, who discovered that using a treadmill enhances walking speed and lengthens strides and cadences [20]. The relative paretic stance time, relative paretic swing time, and relative double support time are all reduced by treadmill training, according to the study. Through repeated practice of more symmetrical stepping over the course of 6 months, the treadmill also enhances motor learning and activates the nervous system and brain plasticity. Running on a treadmill increases step length and, to a lesser extent, cadence, which in turn improves the gait velocity [21]. This was supported by the findings of the current investigation, which showed that treadmill training improved gait metrics in both groups.

Conclusion

The results of this study allow us to draw the conclusion that rhythmic auditory stimulation, when used in conjunction with treadmill training, improves a number of gait kinematics in chronic stroke patients, including walking speed, step cycle, step length, time on each foot, and ambulation index. Therefore, it is advised to include it in the traditional physical therapy program for the rehabilitation of stroke patients with gait problems.

Abbreviations

RAS	Rhythmic auditory stimulation
WMA	World Medical Association
BMI	Body mass index
TM	Treadmills
SPSS	Statistical package for social studies

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Author contributions
GMA: research idea, manuscript reviewing; EMF: research idea, manuscript reviewing; MFI: application on the patients, data interpretation and manuscript writing; AAN: application on the patients, data interpretation and manuscript writing; HE: manuscript writing and reviewing; MMM: data interpretation and manuscript writing; MYE: data interpretation and manuscript writing. All authors read and approved the final manuscript.

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Availability of data and materials
The data sets generated and/or analyzed during the current study are not publicly available due to the current Cairo University regulations and Egyptian legislation but are available from the corresponding author on reasonable request and after institutional approval.

Declarations

Ethics approval and consent to participate
An informed written consent was taken from each patient. All data obtained from every patient were confidential and were not used outside the study. The patients have rights to withdraw from the study at any time without giving any reason. All the cost of the investigations was afforded by the researcher. Our study was approved by Faculty of Physical Therapy Ethical Committee, Cairo University, Egypt (P.T. REC/012/00232).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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