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Original Article

Physiotherapy Section

Effect of Rhythmic Auditory Stimulation and Nordic Walking on Arm Swing and Spatiotemporal Gait Parameters in Parkinson's Patients: A Quasi-experimental Study

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ABSTRACT

Introduction: Parkinson's Disease (PD) is a neurological illness characterised by impairments in movement, balance, coordination and gait caused by the absence or deficiency of dopamine and it is progressive in nature. The absence or decreased arm swing is a prodromal sign that may lead to gait impairments.

Aim: To assess and analyse the effect of Rhythmic Auditory Stimulation (RAS) on arm swing and spatiotemporal gait parameters in conjunction with Cura Swing and Nordic Walking (NW).

Materials and Methods: A quasi-experimental study was conducted at the Krupanidhi Group of Institutions, Bengaluru, Karnataka, India, which recruited 30 subjects based on specific inclusion criteria; the study duration was six months, from June 2022 to December 2022. After obtaining informed consent, participants were randomly divided into two groups, groups A and B, each consisting of 15 subjects, with interventions provided for five days each week over three weeks. The pre- and post-treatment evaluation included a 3D analysis using Kinovea and the Functional Gait Assessment (FGA). Group A, the control group, received 20 minutes of NW along with conventional physiotherapy, whilst group B received 20 minutes of RAS training through Cura Swing, followed by 20 minutes of NW.

Results: After analysing the data using an Independent t-test, the results for Kinovea post forward swing and Kinovea post backward swing for both the right and left sides revealed a substantial difference between the two groups. Additional variables such as Timed Up and Go (TUG), cadence, stride length and FGA indicated significant differences between groups, with p-values of 0.01, 0.03, 0.009 and 0.02, respectively. Based on intergroup comparison analysis using a Paired t-test, there was a significant improvement in both groups independently regarding the measures of Kinovea forward and backward swing for both the right and left arms, TUG, cadence, stride length and FGA.

Conclusion: RAS and NW programmes have shown beneficial effects on arm swing and balance. The lack of research in the literature concerning the therapeutic advantages of NW in conjunction with RAS as a holistic treatment contributes to the uniqueness of this study.

Keywords: Cadence and arm swing, Cura swing, Functional gait assessment, Kinovea

INTRODUCTION

The PD is a progressive degenerative neurological disorder affecting 1-2 individuals per 1,000, characterised by dopamine depletion [1]. This depletion leads to the degeneration of dopaminergic neurons in the substantia nigra pars compacta and the formation of Lewy bodies (cytoplasmic aggregates of alpha-synuclein) [2]. Dopamine is essential for coordinated movements and its deficiency results in motor symptoms such as tremors, bradykinesia (slowness of movement), rigidity, postural instability and gait disturbances, along with non motor symptoms like orthostatic hypotension, depression, and insomnia [3].

Bradykinesia is characterised by a progressive reduction in movement amplitude and speed, significantly affecting walking speed and arm swing frequency. Pathologically, this condition arises from abnormal basal ganglia activity, increased thalamic and primary motor cortex (M1) inhibition and nigrostriatal dopaminergic depletion [4]. These pathological changes disrupt muscle tone regulation and automatic movements such as arm swings during walking. The interconnected regions of the Central Nervous System (CNS) are responsible for synchronised arm and leg movements during gait, which help to reduce the metabolic cost of walking [5].

Gait impairment in PD progresses with the disease, manifesting as reduced arm swing, decreased step length, shuffling steps, increased double-limb support and other gait deviations. These impairments lead to a higher risk of falls, decreased independence and increased morbidity and mortality [6].

Recent research has focused on gait rehabilitation strategies such as RAS and NW. RAS, a form of Neurologic Music Therapy (NMT), employs auditory rhythmic cues to improve gait by facilitating movement planning and execution [7]. These rhythmic auditory cues activate motor neuronal spinal nuclei, enhancing walking speed and coordination. Auditory cueing is considered more effective than visual cueing for gait rehabilitation in PD. Another therapeutic approach, sonification, converts sensor-based movement data into audio signals to support motor control [8].

NW originated in Finland and involves walking with specially designed poles, promoting larger steps and arm swings, enhancing trunk stability and reducing the fear of falling. The use of poles provides visual cues for walking coordination [9]. Arm swing is crucial in the gait cycle, aiding balance, counterbalancing leg movements and propelling the body forward. Reduced arm swing is an early symptom of PD and can lead to falls, underscoring the importance of targeted arm swing training [10].

Training arm swing and gait through NW and RAS offers a holistic treatment approach, enhancing coordination, balance and posture—key components for improving the quality of life in PD patients [11].

While current evidence supports the efficacy of these methods, further research is necessary to confirm their effectiveness and investigate their combined use, highlighting a critical area for future study.

Regarding this research, the aim was to assess the effectiveness of RAS on arm swing and spatiotemporal gait parameters, evaluate the effect of the Cura Swing application on arm swing as assessed using Kinovea software and evaluate the efficacy of RAS alongside NW on spatiotemporal gait parameters. The hypothesis for the current study are as follows: the Null Hypothesis posits that there is no significant effect of arm swing training and RAS training on gait in PD, while the Alternative Hypothesis posits that there will be a significant effect of arm swing training and RAS training on gait in PD.

MATERIALS AND METHODS

This study was a quasi-experimental study conducted in the Outpatient Department (OPD) of Krupanidhi College of Physiotherapy, Bengaluru, Karnataka, India from June 2022 to December 2022. The research process commenced upon obtaining institutional ethical approval through the ethical committee (ethical clearance number: MPT/2022/PHY/007), and the participants were informed about the purpose and procedure of the research.

Inclusion criteria: Clinically diagnosed Parkinson's patients aged 50-75 years, with a Hoehn and Yahr scale score of stages 1-3 [12] and intact cognitive functions were included in the study.

Exclusion criteria: Individuals with visual or hearing impairments, atypical PD and those who had undergone orthopaedic lower limb procedures such as Total Knee Replacement (TKR) or Total Hip Replacement (THR) were excluded form the study.

Sample size: The sample size recruited was 30 subjects, apportioned into two groups of 15 each, based on the number of cases available at that time. The experimental group comprised five females and ten males, while the control group consisted of two females and thirteen males.

Outcome measures: The FGA comprises 10 items, each scored from 0 to 3, with a maximum total score of 30 points. Scores range from 0 (severe impairment) to 3 (normal function), and a score of 22 or below suggests an increased risk of falls [13]. The TUG test measures the time taken for a person to stand from a chair, walk 3 metres, turn, walk back to the chair, and sit down [14]. The recorded time is categorised as follows: less than 10 seconds indicates normal mobility, 10-19 seconds indicates mild mobility impairment, 20-29 seconds indicates moderate mobility impairment, and 30 seconds or more indicates severe mobility impairment. Longer times on the TUG test signify a greater risk of falling and mobility impairment.

Kinovea software: The video was calibrated using a known reference object to ensure precise measurements. Using frame-by-frame analysis, heel contact points were marked for successive steps. The distance between these points was measured with the distance tool, providing accurate step length data.

Procedure and intervention: The participants were informed about the purpose and procedure of the research. The subjects were selected based on the inclusion and exclusion criteria, and then they received an overview of the procedure. Written consent was obtained from all participants. They were selected based on pretreatment arm swing, balance and gait assessments using Kinovea software, the FGA and the TUG test.

The control group received 20 minutes of conventional therapy, followed by 20 minutes of NW. The experimental group underwent 20 minutes of NW and 20 minutes of RAS. Initially, the subject was asked to walk at their own pace and a video of their walking was recorded. This video was then analysed for arm swing and gait using Kinovea software.

After three weeks of treatment, assessments of arm swing, balance and gait were repeated using Kinovea software, FGA and TUG. Participants were instructed about the interventions and how they would be performed. A preanalysis was conducted based on the TUG and FGA assessments and a video analysis of gait was performed through Kinovea software. The experimental group, consisting of 15 participants, was recruited through simple random sampling.

Treatment comprised 20 minutes of arm swing training with gait training based on RAS using the Cura Swing application, followed by 20 minutes of NW. In the first half of the treatment, an iPhone containing the application was strapped to the patient's wrist and connected to wireless earphones that the patient wore. The rhythmic auditory response provided by the application trained the patient to coordinate their arm swing rhythmically with their gait. The parameters set in the application, based on its instructions, were 20 minutes at 112 beats per minute (bpm). In the second half of the treatment, the subject performed NW using Nordic walking sticks along the designated pathway. Here, adjustable Nordic sticks were provided, and their height was adjusted based on the patient's height; the patient was advised to wear sports shoes throughout the treatment.

The therapist strapped the poles to the patient's sides and initially asked the patient to walk normally while ignoring the poles. The patient was instructed to focus on stepping with the heel of their foot while placing the pole of the adjacent arm on the floor. As a next step, the patient was guided to step on their heel, which allowed the opposite pole to propel their body forward. The therapist then encouraged the patient to move their arms in conjunction with their lead foot, instructing them to choose their lead foot and move both arms simultaneously with that foot. The poles should touch the ground as they walked.

The therapist demonstrated the procedure to the patient, who lightly touched the sticks to the ground while positioning them at a 45° angle. The patient engaged their entire body and focused on their torso, allowing it to move naturally as they pushed off with the Nordic poles. The patient followed the described technique, moving their arms in sync with their lead foot, for 40 minutes per session, five days a week, for three weeks. Progression of the intervention was initiated only after the patient fully understood the procedure. The control group continued their regular conventional treatment, supplemented with NW following RAS. The duration of the treatment was five days a week for three weeks, with each session lasting 20 minutes.

STATISTICAL ANALYSIS

Statistical analysis was conducted using Independent and Paired t-tests to assess significance. These tests were performed between the groups and within the groups independently, considering a 95% confidence level and a 5% margin of error. The data were analysed using Statistical Package for the Social Sciences (SPSS) version 29.0.

RESULTS

Following three weeks, a postassessment was conducted. The results obtained from the analysis, based on Paired t-tests and Independent t-tests, exhibited a substantial difference between both the control and experimental groups, with the experimental group demonstrating more significant improvement. For the Kinovea forward and backward arm swing for both the right and left sides, the experimental group showed significance with a p-value of 0.001. The TUG test indicated a post mean of (12.32±1.33) for the control group, whereas the experimental group had a post mean of (10.84±1.72), yielding a p-value of 0.01. For cadence, the post mean for the control group was (131.33±8.79), while the experimental group recorded a post mean of (129.73±9.68), with a p-value of 0.03. The post stride length for the control group was (58.62±8.28), and for the experimental group, it was (67.72±9.37), resulting in a p-value of 0.009. For the FGA, the post score for the control group was (17.40±1.72), while the experimental group

achieved a post score of (18.13±1.99), with a p-value of 0.02. Thus, the results indicate that the training intervention may be effective in improving kinematic performance. The intervention significantly improved TUG test performance, cadence, stride length and FGA compared to the control group. Consequently, the intervention may enhance certain aspects of motor function and gait in individuals with Parkinson's disease.

[Table/Fig-1] shows that the mean age of participants in the control group was 59.53±6.63, while the mean age of participants in the experimental group was 63.67±9.36. The Whitney U Test was employed to assess the difference between the groups, yielding a U value of 83.000 and a p-value of 0.220 (p-value >0.05), indicating that the distribution of participants was homogeneous.

Group	Mean±Standard deviation	U value	Z value	p-value
Control group	59.53±6.63	83.000	-1.226	0.220
Experimental group	63.67±9.36			

[Table/Fig-1]: Comparison of age distribution between the group.

Intragroup comparison of mean values of Kinovea forward and backward arm swing for the control group, for both the right and left sides, showed significant differences overall, denoting an increase in arm swing and other variables indicative of locomotion efficiency [Table/Fig-2].

Intragroup comparison of mean values of Kinovea forward and backward arm swing for the experimental group, for both the right and left sides, also showed significant differences overall, reflecting an increase in arm swing and other variables denoting gait efficiency [Table/Fig-3].

The comparison of Kinovea forward and backward arm swing for both the right and left sides between the groups demonstrated a significant difference post-intervention, indicating an increase in arm swing and other variables associated with gait efficiency [Table/Fig-4].

	Mean			SD					
Control group	Pre	Post	Mean difference	Pre	Post	Std deviation difference	T value	p-value	Inference
Kinovea forward swing right in degrees	8.43	10.19	-1.76	2.01	1.67	0.34	12.39	0.0001	Significant
Kinovea backwards swing right in degrees	5.93	7.14	-1.21	2.26	2.03	0.23	7.94	0.0001	Significant
Kinovea forward swing left in degrees	7.41	8.30	-0.89	2.47	2.63	-0.15	4.48	0.001	Significant
Kinovea backward swing left in degrees	6.49	7.28	-0.79	2.20	2.43	-0.23	6.88	0.0001	Significant
Time up and go test in secs	13.05	12.33	0.72	1.33	1.33	-0.00	11.12	0.0001	Significant
Cadence (steps/min)	123	131.33	-8.33	10.75	8.79	1.96	9.57	0.0001	Significant
Stride length in cm	54.29	58.62	-4.33	7.23	8.29	-1.05	7.24	0.0001	Significant
Functional gait assessments	16.80	17.40	-0.6	1.56	1.72	-0.15	3.15	0.007	Significant

[Table/Fig-2]: Intragroup comparison of mean values in the control group's gait performance.

	Mean			SD					
Experimental group	Pre	Post	Mean difference	Pre	Post	SD difference	T value	p-value	Inference
Kinovea forward swing right in degrees	7.54	12.83	-5.28	0.96	0.81	0.14	28.32	0.0001	Significant
Kinovea backward swing right in degrees	6.26	11.36	-5.1	1.87	2.13	-0.26	25.97	0.0001	Significant
Kinovea forward swing Left in degrees	7.57	12.39	-4.82	0.79	1.58	-0.79	15.72	0.001	Significant
Kinovea backward swing left in degrees	5.89	10.69	-4.8	1.25	1.44	-0.18	55.1	0.0001	Significant
Time up and go test in seconds	13.26	10.84	2.42	1.45	1.72	-0.26	17.61	0.0001	Significant
Cadence (steps/min)	113.93	129.73	-15.8	10.97	9.68	1.28	13.98	0.0001	Significant
Stride length in cm	52.25	67.72	-15.47	7.11	9.37	-2.25	15.73	0.0001	Significant
Functional gait assessments	15.27	18.13	-2.86	1.94	1.99	-0.05	17.35	0.0001	Significant

[Table/Fig-3]: Intragroup comparison of mean values in the experimental group's gait performance.

Variable	Group	Mean±Std. deviation	Mean diff.	Std. deviation difference	T value	p-value	Inference
Kinovea forward swing right (pre) in degrees	Control	8.43±2.01	0.88	1.05	1.53	0.13	Non-significant
	Experimental	7.54±0.95					
Kinovea forward swing right (post) in degrees	Control	10.19±1.67	-2.64	0.85	-5.50	0.001	Significant
	Experimental	12.83±0.81					
Kinovea backward swing right (pre) in degrees	Control	5.93±2.26	-0.33	0.39	-0.43	0.67	Non-significant
	Experimental	6.26±1.87					
Kinovea backward swing right (post) in degrees	Control	7.14±2.03	-4.22	-0.09	-5.54	0.001	Significant
	Experimental	11.36±2.13					
Kinovea forward swing left (pre) in degrees	Control	7.40±2.47	-0.16	1.67	-0.24	0.80	Non-significant
	Experimental	7.57±0.79					
Kinovea forward swing left (post) in degrees	Control	8.30±2.63	-4.08	1.04	-5.51	0.001	Significant
	Experimental	12.38±1.58					
Kinovea backward swing left pre in degrees	Control	6.48±2.20	0.59	0.94	0.90	0.37	Non-significant
	Experimental	5.89±1.25					
Kinovea backward swing left (post) in degrees	Control	7.28±2.43	-3.40	0.99	-4.65	0.001	Significant
	Experimental	10.68±1.44					
Time up and go test (pre)-in seconds	Control	13.04±1.33	-0.21	-0.11	-0.41	0.68	Non-significant
	Experimental	13.25±1.45					

Time up and go test (post) in seconds	Control	12.32±1.33	1.48	-0.38	2.63	0.01	Significant
	Experimental	10.84±1.72					
Cadence (pre) (steps/min)	Control	123.00±10.75	1.60	-0.88	0.47	0.63	Non-significant
	Experimental	113.93±10.97					
Cadence (post) (steps/min)	Control	131.33±8.79	9.06	-0.21	2.28	0.03	Significant
	Experimental	129.73±9.68					
Stride length in cm (pre)	Control	54.28±7.25	2.04	0.13	0.77	0.443	Non-significant
	Experimental	52.24±7.11					
Stride length in cm (post)	Control	58.62±8.28	-9.10	-1.08	-2.81	0.009	Significant
	Experimental	67.72±9.37					
Functional gait assessment (pre)	Control	16.80±1.56	-0.73	-0.27	-1.07	0.291	Non-significant
	Experimental	15.27±1.94					
Functional gait assessment (post)	Control	17.40±1.72	1.53	-0.37	2.37	0.024	Significant
	Experimental	18.13±1.99					

[Table/Fig-4]: Comparison of the group's mean values for the gait performance.

The data presented in the above tables support the alternative hypothesis that arm swing and RAS training have a substantial effect on gait in PD. Furthermore, the null hypothesis was rejected.

DISCUSSION

In PD, significant motor dysfunctions include difficulties in initiating movement, balance and gait issues and deficits in rhythmic motion pacing. Gait impairment is particularly critical as it leads to reduced mobility and independence. The reduction of arm swing and discordance during gait in PD has been extensively studied as early symptoms, with evidence suggesting that training arm swing can improve gait stability. This study evaluated the impact of RAS combined with the Cura Swing programme and NW on arm swing and spatiotemporal gait parameters. The demographic data revealed that 66.7% of participants in group B were male, while 33.3% were female. In group A, 86.5% of participants were male, and 13.5% were female. The current study found no significant preswing kinematic differences between the control and experimental groups. However, postswing kinematics showed substantial differences, with the experimental group exhibiting more significant improvements (p-value=0.0001). These findings are consistent with those of Amini R et al., who reported that RAS significantly increased arm swing amplitude and symmetry in PD patients. Their study found that arm swing symmetry scores improved from 0.43±0.18 to 0.63±0.15, and arm swing amplitude increased from 10.4 cm to 13.2 cm post-RAS [15].

In the TUG analysis, the control group's average pre-TUG was 13.04±1.33 seconds, which improved to 12.32±1.33 seconds postintervention. The experimental group's average TUG time improved from 13.25±1.45 seconds preintervention to 10.84±1.72 seconds post-intervention, with a significant p-value of 0.01. This aligns with Santos RL and Ribeiro SM, who found that RAS significantly reduced TUG test times in PD patients, with the RAS group averaging 13.8 seconds compared to 17.6 seconds for the control group [16].

Additionally, Alizadeh S et al., found that RAS reduced cadence and increased stride length in PD patients. The present study results support this, showing a significant increase in cadence and stride length post-RAS intervention. The control group's precadence was 123.00±10.75, increasing to 131.33±8.79 postintervention, while the experimental group's precadence of 113.93±10.97 increased to 129.73±9.68, with a p-value of 0.03. The mean stride length for the RAS group was 78.7 cm, significantly longer than the control group's 70.1 cm, indicating improved gait efficiency [17].

The findings of this study regarding gait performance improvements are consistent with those of other studies. For instance, Amini R et al., reported that RAS improved FGA scores from 44.2 (control) to 55.2 (RAS group), indicating reduced gait impairment [18].

The mechanism by which RAS improves motor control involves activating motor neuronal spinal nuclei via the reticulospinal pathway. Thaut MH and Abiru M, demonstrated that RAS enhances spinal motor neuron excitability and movement synchronisation, improving gait in PD patients [19]. Additionally, Zhang J et al., suggested that RAS increases the activity of subcortical nuclei, which are crucial for coordinating muscle group activities and improving gait variability [20]. Reactive motor coordination, which is essential for adjusting movements in response to environmental changes, also benefits from RAS, providing cues that help PD patients anticipate and adjust their movements.

Moreover, NW, which activates the vestibular system and motor cortex, complements RAS by improving balance and coordination. RAS may also reduce anxiety by activating the brain's reward pathway, releasing dopamine and increasing the activity of the inhibitory pathway, which helps suppress other brain activities. This provides a rhythmic auditory stimulus that is perceived as both distracting and rewarding [21]. Overall, combining RAS with NW presents a promising intervention for improving gait and arm swing in PD, warranting further research to optimise their combined application.

Limitation(s)

The study was limited by its small sample size, and further insights could be gained by extending the protocol beyond three weeks to investigate changes in neuroplasticity and to further demonstrate the long-term effects of RAS and NW on gait. Additionally, further research is needed to determine the optimal frequency and duration of RAS and NW interventions.

CONCLUSION(S)

The present study compared the effectiveness of RAS and NW on the recovery of balance and gait functions. It can be concluded that RAS, NW and even conventional physiotherapy treatments have beneficial effects on improving gait and balance functions. However, when compared for greater effectiveness, the results were highly significant for the experimental group. Therefore, this study accepts the hypothesis. The results indicate that, in both outcome measures, the mean values obtained were significantly higher in the experimental group compared to the control group. Hence, RAS training combined with NW is much more effective in improving balance and gait than conventional physiotherapy alone. Spatiotemporal parameters showed an increase alongside an enhancement in the degree of arm swing, which contributed to the improvement of gait and balance. Thus, it is suggested that RAS and NW can be utilised as adjuncts to conventional physiotherapy or other treatment interventions to promoted balance and gait rehabilitation.

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