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Impact of rhythmic auditory stimulation on gait disturbances in individuals with progressive supranuclear palsy

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ABSTRACT: The neurological disorder known as Progressive Supranuclear Palsy, or PSP, is characterized by severe difficulties in movement and balance, which frequently result in falls and a decrease in function. Sensory cueing techniques such as Auditory Stimulation and visual stimulation that utilizes external cues to enhance motor coordination and gait performance in movement disorders. Sixty people with a diagnosis of progressive supranuclear palsy (PSP) were chosen by convenience sampling and split up into two groups: thirty in the experimental group received balance exercises and rhythmic auditory stimulation, while thirty in the control group received balance training and visual cueing. Over a six-week period, both therapies were given for 40 minutes, five days a week. Before and after the intervention, gait performance was evaluated using the 10-Meter Walk Test and the Timed Up and Go (TUG) Test. The Timed Up and Go (TUG) Test and the 10-Meter Walk Test showed statistically significant improvements in the Rhythmic Auditory Stimulation (RAS) group as compared to the visual cueing group (P-value <0.0001). By encouraging better health outcomes through non-invasive rehabilitation, this research supports good health and well-being. It also reduces inequality by ensuring that people with neurodegenerative illnesses have fair access to effective rehabilitation. In conclusion, rhythmic auditory stimulation significantly improves gait speed and motility in individuals with progressive supranuclear palsy (PSP) when paired with balance training.

Keywords: Balance; Gait disturbances; Good health and well-being; Mobility; Progressive supranuclear palsy; Reduced inequalities; Rhythmic auditory stimulation

1.0 INTRODUCTION

Atypical Parkinsonian syndrome is another name for progressive supranuclear palsy (PSP), a form of Parkinson-plus disease. Speech, swallowing, gait, balance, movement, vision, eye movements, mood, behavior, and cognition are all impacted by this rare neurological condition. Environmental variables, including pollution exposure and aging are thought to be the causes. According to recent studies, there are 5.8 to 6.5 cases of progressive supranuclear palsy for every 100,000 individuals. Previous research reported an

annual incidence rate of 0.3 to 0.4 per 100,000 for progressive supranuclear palsy. Progressive supranuclear palsy usually manifests symptoms after the age of 65. (Agarwal & Gilbert, 2025).

A neurological condition called Parkinson's causes involuntary behaviors like shaking, rigidity, and trouble balancing and coordinating. (Deepa & Khilar, 2025) Bradykinesia and a shuffling stride pattern, with shorter stride length and lower step cadence, are two of the most distinctive aspects of the gait profile in Parkinson's disease. Other changes include inadequate toe clearance and heel strike, postural instability, cognitive dysfunction, akinesia, ocular motor dysfunction, asymmetry in lower-limb stride times, and insufficient flexion at the hip, ankle, and knee. Although early detection is essential for successful intervention, the speed and accuracy of standard diagnostic techniques are frequently limited (Devi et al., 2025). Virtual reality is a type of nonpharmacologic treatment that has frequently been discussed, using sensory systems, such as visual or auditory cues, to promote locomotor activity. (Thaut et al., 1996; Grimm et al.,2019)

70–80% of the brain's dopamine-producing cells are destroyed in Parkinson's disease. (Adam et al., 2025). A biochemical change in the tau protein is the neuropathological hallmark of PSP, leading to neurodegeneration and gliosis in the brainstem, cerebellum, basal ganglia, and prefrontal cortex. Exosomal proteins and miRNAs, such as α-synuclein, Aβ, tau, CXCL12, miR-24, and miR-23b-3p, are becoming important indicators of Parkinson's disease (Sivalingam & Sureshkumar, 2025). The primary cause of morbidity and mortality is falls (Clerici et al., 2017). The rapid decrease in executive function that is characteristic of progressive supranuclear palsy is usually more noticeable than that observed in CBD. In addition, supranuclear vertical gaze palsy is frequently accompanied by personality changes, apathy, impulsivity, and perseverance (Steffen et al., 2014).
Sensory information can be enhanced by biofeedback (BF), a training method that teaches individuals to enhance their performance and well-being by utilizing signals from their own bodies. Adding artificial sensory information (sensory augmentation or substitution) that tells the brain about real body position and movements can specifically improve balance (Nicolai et al., 2010). Defects in the brainstem and higher brain regions are both responsible for falls in PSP, rather than just a local neurodegenerative disease. (Goetz et al., 2003) Apraxia can be brought on by a variety of conditions impacting the basal ganglia, such as progressive supranuclear palsy (PSP), Parkinson's disease, and Huntington's disease (Zadikoff & Lang, 2005). To improve mobility and gait performance, external (auditory) cueing is a popular and effective approach. Rhythmic music is another way to give auditory signals. Additionally, music may trigger reward-related and emotional physiological sensations of pleasure (De Dreu et al., 2012; Blood & Zatorre, 2001). The overall diagnostic accuracy for PSP is close to 80%, while clinical diagnosis is difficult. PSP is currently known as classic PSP, or Richardson syndrome (PSP-RS), in accordance with its original description. (Ali et al., 2019) The symptoms of Parkinson's disease (PD) that can be observed in both CBD and PSP include bradykinesia, rigidity, loss of facial expression, difficulty turning in bed or getting out of a chair, lack of arm swing, and shorter strides. The characteristic of PSP is abnormal eye movements, which start with impairment of downgaze and progress to issues with upgaze and horizontal gaze. Typically, the oculocephalic reflexes are remarkably preserved. (Dickson, 1999) Two clinically distinct tauopathies, progressive supranuclear palsy (PSP) and corticobasal degeneration (CBD), have comparable clinicopathologic and genetic characteristics (Koga et al., 2018).

Cognitive impairment, which includes deficits in executive, attention, memory, language, and visuospatial function, is prevalent, even in the early stages of Parkinson's disease (PD) (Amboni et al., 2018). In contrast to people who have Parkinson's disease (PD), people with PSP have rapid disease progression, supranuclear gaze palsy, significant gait and balance impairment that manifests early in the course of the illness, and lower survival periods. While neuroimaging techniques such as PET scans, MRIs, f-MRIs, ECGs, EEGs, and others are helpful for identifying cognitive impairment in the brain, they are very difficult to interpret manually (Jayasudha et al., 2025). PSP people often fall because of their "drunken sailor" stride (Amano et al., 2015). Accelerometer-based comparative studies have revealed several common gait anomalies, including decreased mean acceleration, cadence, step length, and velocity (De Vos et al., 2020). The "Rocket sign," "I-Beam sign," and "spiral sign" are examples of gait irregularities unique to PSP, a term for uncontrollably rotating and sitting down (Sharma et al., 2023). Due to their impaired motor abilities, people with PSP find it difficult to perform the demanding task of circular walking (Ohara et al., 2024). One of the main causes of hospitalization and mortality in older people

is fall-related injuries, and they are also linked to high medical expenses. Fall-related fractures occur in 28.6% of PSP patients compared to 19.8% of individuals with other forms of atypical Parkinsonism, including multiple system atrophy and corticobasal syndromes (Brown et al., 2020). It is widely accepted that falls in PSP are caused by bradykinesia, axial rigidity, vertical supranuclear gaze palsy, and decreased postural reflexes. (Bluett et al., 2017) Rhythmic auditory stimulation (RAS) is a sensorimotor method for improving gait; prior research on Parkinson's disease has demonstrated that RAS dramatically enhances stride length, cadence, and gait velocity (Thaut et al., 1996).

Although much research has examined the effects of rhythmic auditory stimulation (RAS) on Parkinson's disease, its effects on Progressive Supranuclear Palsy (PSP) are less well understood. PSP differs from Parkinson's disease in that it is characterized by increased axial rigidity, vertical gaze palsy, and early postural instability. These characteristics may make gait and balance problems more difficult to treat with conventional rehabilitation methods. It is critical to determine whether RAS can produce gait improvements in PSP comparable to those observed in Parkinson's disease. Thus, this study aims to investigate the effects of rhythmic auditory stimulation on gait impairment in individuals with progressive supranuclear palsy (PSP).

2.0 MATERIALS AND METHOD

60 participants from Saveetha Medical College and Hospital participated in this randomized controlled trial (RCT). The closed-envelope approach was used to randomly assign participants to experimental and control groups after they were selected using a realistic selection process based on inclusion and exclusion criteria. To ensure allocation concealment, the random allocation sequence was manually created in advance by a separate researcher and placed in opaque, sequentially numbered envelopes, which were sealed. Each envelope was opened only after the participant's enrollment. The 10-Meter Walk Test (10MWT) and Timed Up and Go (TUG) scores were collected by an outcome assessor who was blinded to group allocation in order to reduce measurement bias. However, because of the nature of the treatment, the participants and therapists were aware of their individual interventions. G*Power (version 3.1) was used to calculate the sample size based on an a priori power analysis. Considering a moderate-to-large effect size (Cohen's d = 0.7) from earlier studies examining how rhythmic auditory stimulation affects gait performance in neurological disorders (Thaut et al., 1996; De Dreu et al., 2012), 33 people per group were found to be the necessary sample size for a two-tailed comparison with a power (1–β) of 0.80 and an alpha level of 0.05. Taking into account feasibility and potential dropouts, 30 participants were recruited per group, which gave about 77% power to detect an effect of this magnitude.

2.1 Inclusion criteria

- People between the ages of 40 and 80 years.
- Individuals clinically diagnosed with PSP according to the MDS 2017 criteria.
- The presence of clinically apparent gait abnormalities, such as bradykinesia, freezing of gait, and postural instability.
- Able to walk ten meters or more, either with or without aids.
- A score of 24 or above on the Mini-Mental State Examination (MMSE)

2.2 Exclusion criteria

- History of stroke or other neurological conditions affecting gait.
- Individuals with hearing loss.
- Severe musculoskeletal disorders (e.g., arthritis, fractures)
- Uncontrolled cardiac or respiratory disease.

Clinical assessment was used to assess disease severity because Progressive Supranuclear Palsy (PSP) does not easily fit into conventional Hoehn and Yahr staging. With a diagnosis of PSP-Richardson syndrome, each subject was in the mild to moderate stage of the disease's progression, which is defined by their capacity to walk around with little to no assistance. The inclusion criteria ensured that subjects could safely complete gait and balance exercises, which roughly corresponded to Hoehn and Yahr Stages 2–3 in Parkinsonian disease. The severity of the disease remained consistent between the two groups using this method.

2.3 Fall Assessment

In order to determine each participant's baseline fall history, the number of falls that took place in the six months before the research was documented. The term "an unexpected event in which the participant comes to rest on the ground, floor, or lower level" was used to describe a fall. Using a falls diary that each participant or caregiver kept and the therapist checked weekly, falls were prospectively tracked over the 6-week intervention period. Activities during the fall, date, time, and any injuries sustained were all recorded in the diary.

Every entry was examined and noted for future examination.

2.4 Procedure

Sixty individuals were selected according to the inclusion and exclusion criteria. Using a closed-envelop method, participants were divided into two groups: the Rhythmic Auditory Stimulation (RAS) group (n = 30) and the control group (n = 30) (gait training with visual cues). A random sequence that had been created in advance and sealed opaque envelopes were used to assure allocation concealment. Both groups' subjects received signed consent after being informed about the study's methodology. After six weeks, the post-test values were measured, and the pre-test values were tabulated.

2.5 Rhythmic Auditory Stimulation (RAS) group

The rhythmic auditory stimulation group received rhythmic auditory stimulation with conventional exercise, such as balance training, for 40 minutes, five times a week, over six weeks. A digital metronome app was used to train RAS, and it was played through portable Bluetooth speakers at a comfortable volume (around 60-70 dB). After determining each participant's baseline walking cadence using the 10-Meter Walk Test, the first metronome speed was set to 100% of that cadence, typically between 90 and 110 beats per minute. Depending on the participant's capacity to precisely synchronize their steps with the auditory signal, the tempo was introduced incrementally every two sessions by 5–10%. Each 30-minute RAS session included tasks such as turning, forward walking, and obstacle navigation, all performed in time with the rhythmic cue. A total of ten minutes was spent on the balance training activity.

2.6 Control group (Visual Cueing Gait Training)

The control group engaged in visual cueing gait training and balancing exercises five times a week for a total of 40 minutes over six weeks. Visual cueing gait training was performed for 30 minutes. The colored adhesive floor tapes were placed on the walking path at 50 cm intervals. Cues' complexity and intensity will gradually rise based on the individual's performance. Balance training exercises are performed for 10 minutes, which include static and dynamic balance.

2.7 Conventional balance exercise

In addition to the specific interventions, participants performed a standardized 10-minute conventional balance exercise program at the end of each session. The program focused on improving static and dynamic stability and included:

- Static balance tasks: standing with feet together, semi-tandem and tandem stance, and single-leg stance with hand support (30–60 seconds each).

- Dynamic balance tasks: weight shifting in standing (10 repetitions each direction), multidirectional reaching (10 repetitions), stepping in different directions (forward, sideways, backwards, 10 repetitions), and sit-to-stand transitions (1–2 sets of 10).

All sessions were supervised by the same therapist, and session content and progression were standardized using a written checklist to ensure full reproducibility of the intervention. The 10-Meter Walk Test and the Timed Up and Go (TUG) Test were used for evaluations both before and after the intervention.

2.8 Outcome measures

The Timed Up and Go (TUG) Test and the 10-Meter Walk Test (10MWT) were selected as outcome measures because of their extensive use, validity, and reliability in assessing gait speed, mobility, and functional performance in individuals with neurological disorders. Although the TUG Test evaluates broad functional mobility, balance, and fall risk by including transitions such as standing, walking, turning, and sitting, the 10MWT focuses on measuring walking speed over a short distance, which reflects gait endurance and efficiency. Both measures have been widely validated in populations with Parkinsonism and Progressive Supranuclear Palsy, offering simplicity in administration, being sensitive to change after rehabilitation therapies, and are perfect for measuring gait and balance outcomes in this study.

2.9 Ethical considerations

The Saveetha Medical College and Hospital's Institutional Ethical Committee gave its approval to the study (Approval No: 02/12/2024/ISRB/FR/SCPT). Each participant provided written informed consent prior to data collection after being informed about the study's objectives and methodology. This study was conducted as part of an institutional academic project and was not prospectively registered as a clinical trial.

3.0 RESULTS

3.1 Baseline characteristics

The study participants' baseline clinical and demographic data are shown in **Table 1**. Age, sex, and baseline outcome measures did not significantly differ between the Visual Cueing Gait Training group and the Rhythmic Auditory Stimulation group ($p > 0.05$). Using the independent t-test, baseline characteristics of the two groups were statistically compared, and no significant differences were observed ($p > 0.05$).

3.2 Falls and safety

Over the course of the 6-week intervention, there were no falls or unfavorable incidents. Every participant successfully finished every session and the post-intervention tests. No new falls were reported during the intervention phase, and each participant's fall history was documented at baseline

3.3 Data collection

A Microsoft Excel spreadsheet was used to organize, process, and enter the data, and SPSS version 21.0 was used for analysis. The Shapiro-Wilk test and visual analysis of histograms were utilized to verify that the data distribution was normal. For statistical analysis, parametric tests (paired and independent t-tests) were employed because the data satisfied the assumption of normality. Mean ± standard deviation (SD) is used to present all results. Group comparisons were made using the independent t-test, whereas within-group (pre- and post-intervention) comparisons were made using the paired t-test. For statistical significance, a p-value of less than 0.05 was considered. The 10-Meter Walk Test (10MWT) and the Timed Up and Go (TUG) Test were two outcome measures used to assess the impact of therapy.

3.4 Statistical analysis

Statistical analysis of the quantitative data revealed that both the Visual Cueing Gait Training group and the Rhythmic Auditory Stimulation (RAS) group experienced significant improvements in gait performance and functional mobility following the intervention. As seen in **Table 2**, the RAS group had a highly significant improvement ($p < 0.001$) in both the 10-Meter Walk Test (10MWT) and the Timed Up and Go (TUG) Test. The Visual Cueing Gait Training group also showed a significant improvement on the same end measures after the intervention (**Table 3**, $p < 0.001$). The RAS group improved to a greater extent in both mobility and gait performance than the Visual Cueing group, with the post-test findings showing a significant difference ($p < 0.0001$). In addition to p-values and effect sizes, 95% confidence intervals (CI) were calculated to indicate the precision of the effect estimates. These results show that people with progressive supranuclear palsy can improve their gait characteristics by receiving rhythmic auditory stimulation.

4.0 DISCUSSION

In this study, the impact of rhythmic auditory stimulation on gait impairment in people with progressive supranuclear palsy was examined. The study included 60 participants, aged 40 to 80. The groupings were split in half by random group allocation. The experimental team performed Rhythmic auditory stimulation in addition to conventional exercise, while the control group performed visual cueing gait training in addition to conventional exercise. The trial lasted 6 weeks, and workouts were given 5 days each week.

The outcomes were evaluated both before and after the treatment using the 10-Meter Walk Test (10MWT) and the Timed Up and Go (TUG) Test. Rhythmic auditory stimulation significantly improved gait training compared to visual cueing. Comparing the responses from the two groups revealed that rhythmic auditory stimulation differed significantly from visual cueing gait training. Data from the experimental group, which received rhythmic auditory stimulation in addition to balance exercise, showed a statistically significant difference in gait parameters between the 10-Meter Walk Test (10MWT) and the Timed Up and Go (TUG) Test when analyzed using paired t-tests within the study population.

Table 1. Baseline demographic and clinical characteristics of participants

Variable	RAS Group (n=30)	Visual cueing Group (n=30)
Age (years, Mean ± SD)	63.8 ± 7.1	64.3 ± 6.8
Sex (Male/Female)	18/12	17/13
Height (cm, Mean ± SD)	161.4 ± 8.5	160.8 ± 7.9
Weight (kg, Mean ± SD)	62.5 ± 9.4	63.7 ± 10.1
Pre-test Timed Up and Go (sec)	20.29 ± 2.27	21.26 ± 3.20
Pre-test 10-Meter Walk Test (m/s)	0.67 ± 0.09	0.68 ± 0.08

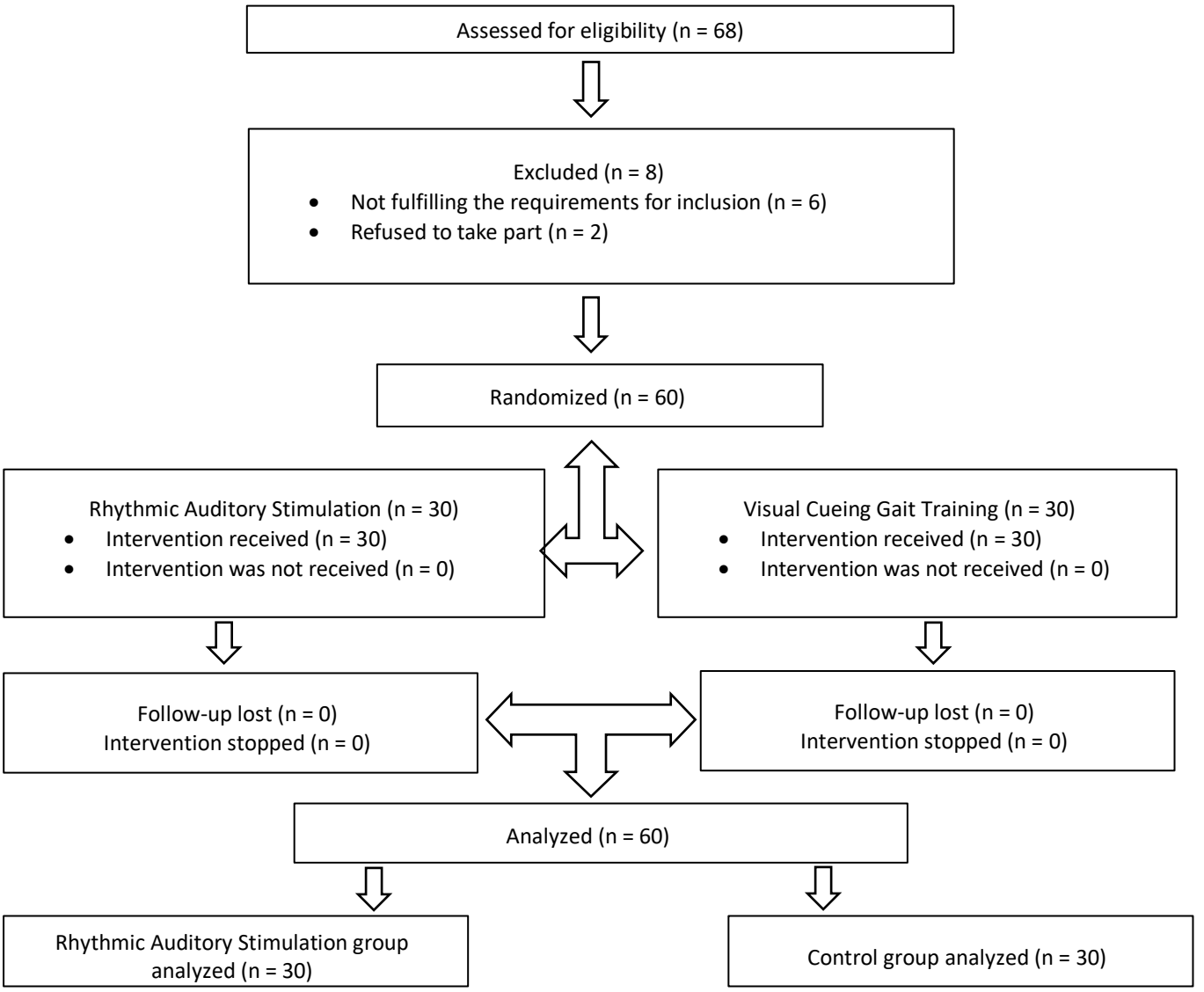

Figure 1. CONSORT Participant Flow Diagram

A study by De Dreu et al. (2012) concludes that External auditory cueing techniques are a popular and effective method for improving mobility and gait function in Parkinson's disease. By providing an external timing signal for motion, auditory cues such as music or rhythmic beats help control stride length and cadence. The obtained results demonstrate the beneficial role of rhythmic auditory stimulation in enhancing gait metrics and are consistent with the body of prior research. Use of rhythmic auditory stimulation for people with Progressive Supranuclear Palsy (PSP), a population in which cueing-based therapies have rarely been studied, is what makes this study novel. A study by Thaut et al. (1996) demonstrates that patients who underwent gait training with rhythmic auditory stimulation (RAS) exhibited significant increases in cadence, stride length, and gait velocity compared with individuals who did not receive auditory cues.

Clerici et al. (2017) evaluated the effectiveness of two multidisciplinary rehabilitation programs in PSP patients and reported that balance, motor function, and daily living activities significantly improved as a result of multimodal therapy that included physical, occupational, and speech therapy. According to the results of the current study, participants who received RAS-based training showed noticeably greater benefits in gait speed and mobility, as measured by the 10-Meter Walk Test (10MWT) and the Timed Up and Go (TUG) Test. A study by Nicolai et al. (2010) investigated the use of audio-biofeedback to improve balance in older adults with high fall risk and observed that auditory feedback can enhance postural control and stability. Therefore,

both studies support the concept that auditory-based interventions can positively influence motor performance and reduce fall risk.

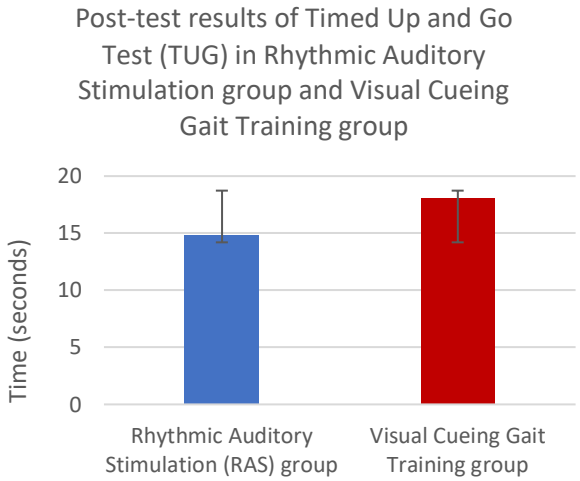

Figure 2. The comparison of Post-test results of Timed Up and Go test in Rhythmic Auditory stimulation Group and Visual Cueing Gait Training Group. Values are expressed as mean ± SD.

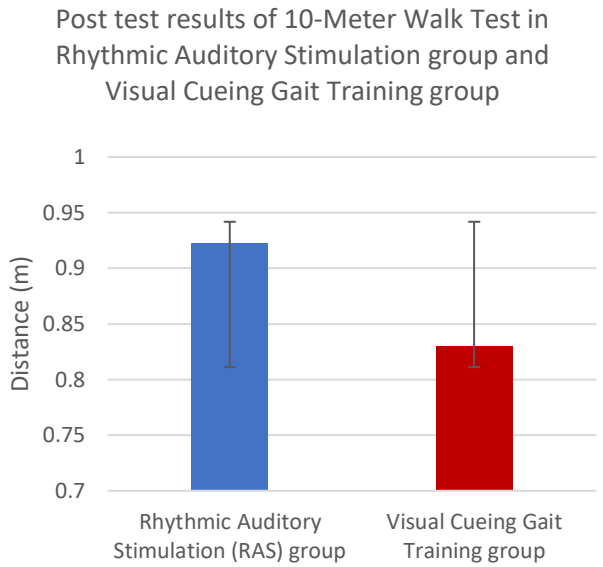

Figure 3. The post test results of 10-Meter Walk test in Rhythmic Auditory stimulation Group and Visual Cueing Gait Training Group. Values are expressed as mean ± SD.

Rhythmic auditory stimulation and other neurologic music therapy techniques improve movement by activating the brain's auditory–motor coupling systems, according to earlier systematic evaluations. By coordinating movement with the regular beat of auditory inputs, rhythmic cueing enhances coordination and gait in those with Parkinson's disease, compensating for compromised internal timing processes. This supports the potential neurophysiological basis for the use of rhythmic stimulation in PSP gait rehabilitation (Nombela et al., 2013). Amano et al. (2015) sought distinguishing characteristics of PSP patients' gait performance, concluding that these patients exhibit unique gait abnormalities, including lower cadence, shorter strides, increased double-support time, and decreased walking velocity. The present study demonstrates that rhythmic auditory stimulation can meaningfully improve gait impairments. Brown et al (2020) state that falls are the hallmark and early features of PSP, driven by impairments in balance, gait control, postural instability and executive dysfunction. The present study suggested that auditory-based rehabilitation could play a key role in reducing the fall risk and improving functional mobility.

Although the findings of the current study demonstrated statistically significant improvements in gait metrics after rhythmic auditory stimulation, it is equally crucial to consider the therapeutic implications of these findings. Since there are currently no disease-specific minimal clinically significant difference (MCID) values for Progressive Supranuclear Palsy (PSP), reference criteria from Parkinsonian and older-adult cohorts are frequently used. A change of roughly 0.10–0.20 m/s in gait velocity and 3–4 seconds in the Timed Up and Go (TUG) test has been determined clinically significant in these groups (Perera et al., 2006). Our study's results came close to these thresholds, indicating that rhythmic auditory stimulation may benefit people with PSP in ways that are both statistically and clinically significant.

The current study primarily focused on gait rehabilitation in individuals with Progressive Supranuclear Palsy; the findings may have broader implications for neurorehabilitation. The advantages of rhythmic auditory stimulation align with the growing body of research showing that sensory cueing and rhythm-based therapies can enhance motor control, timing, and coordination in a range of neurological conditions. Thus, our work advances the multidisciplinary understanding of how principles of auditory-motor entrainment might be applied to promote mobility and functional independence in patients with complex movement disorder.

4.1 Limitations and recommendations

The present study has several issues, including a small sample size (only 60 participants) and a limited duration of six weeks. The long-term effects of rhythmic auditory stimulation (RAS) on gait and balance were not assessed. Incorporating more advanced gait analysis tools, such as wearable sensors or motion capture systems, could offer a more comprehensive understanding of how RAS influences specific gait parameters in PSP. Despite these limitations, the study provides valuable preliminary evidence that people with progressive supranuclear palsy may benefit from rhythmic auditory stimulation to improve gait and balance, although its long-term effects remain unknown.

Table 2. Comparison of pre- and post-test values of the TUG test and the 10-Meter walk test on the Rhythmic Auditory Stimulation Group.

Rhythmic Auditory Stimulation Group	Pre-Test		Post-Test		*t*-Test	*df*
	Mean	SD	Mean	SD		
Timed Up and Go (TUG) test	20.2967	2.2715	14.861	2.3946	51.6451	29
10-Meter Walk test	0.6737	0.0893	0.9227	0.1042	43.9937	29

Table 3. Comparison of pre- and post-test values of the TUG test and the 10-Meter Walk test on the Visual Cueing Gait training group.

Visual Cueing Gait Training Group	Pre-Test		Post-Test		*t*-Test	*df*
	Mean	SD	Mean	SD		
Timed Up and Go test	21.2657	3.2028	18.0653	5.0450	21.5179	29
10-Meter Walk test	0.6817	0.0798	0.8303	0.0824	33.6846	29

5.0 CONCLUSIONS

The present study's findings indicate that rhythmic auditory stimulation (RAS) led to a significant improvement in gait speed and mobility, with P=0.0001. Individuals who received the visual cueing gait training also showed progress. But when the two groups were compared, the people with Progressive Supranuclear Palsy (PSP) in group A who received rhythmic auditory stimulation showed a greater increase in gait speed and mobility. RAS may be administered using metronome audio via speakers or mobile devices; it is affordable, useful in normal clinical physiotherapy, and easy for patients to follow. Long-term research is required to assess these findings and determine their potential use in therapeutic contexts.

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Conflicts of Interest: The authors report no conflicts of interest.

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