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Original Article

Physiology Section

Effectiveness of Vestibular Exercise as an Adjunct with Pharmacotherapy in the Management of Cognitive Functions and Postural Control in Patients with Parkinson's Disease: A Randomised Controlled Trial

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ABSTRACT

Introduction: Parkinson's disease is the most common presenting neurological disorder worldwide. Vestibular exercises have been used in the clinical setting in the management of multiple conditions, like Down syndrome. However, studies regarding the application of exercises stimulating the vestibular apparatus in the symptomatic management of Parkinson's disease are sparse.

Aim: To evaluate the effectiveness of vestibular exercises as an adjunctive intervention to standard pharmacological treatment (L-DOPA) for enhancing cognitive function and postural control in individuals diagnosed with Parkinson's disease.

Materials and Methods: The present randomised controlled trial was conducted at the Department of Physiology, Sri Madhusudan Sai Institute of Medical Sciences and Research, Chikkaballapur, Karnataka, India from 05-08-2024 to 18-09-2025. Total 80 participants were randomly assigned into two separate groups, that is, control (n=41) and experimental groups (n=39). A structured 25-minute vestibular exercise program was implemented in the study. Spatial memory, verbal memory and 100-pin dexterity test were assessed in the participants before and after intervention and compared. Data was collected during baseline setting and after 12 weeks of intervention in both groups and compared. The data were compared using Kruskal-Wallis, One-way Analysis of Variance (ANOVA) on ranks with Dunn's post-hoc multiple comparisons test for between-group and within-group analysis. A p-value <0.05 was considered statistically significant.

Results: The mean age among control and experimental group was 57.2±1.4 years and 56.3±1.4 years, mean body mass index in control and experimental group was 20.3±0.2 kg/m^2 and 21.1±0.2 kg/m^2. Substantial improvement was observed in verbal memory, visual reaction time for green and red light, and auditory reaction time for high and low pitch sounds, 100 pin test, TUG in the experimental group in comparison to the control group (p-value <0.001).

Conclusion: Significant improvement was observed in the cognitive functions and postural control in the experimental group participants followed by vestibular exercises. The study recommends further large-scale, multicentric investigations to validate these outcomes and to explore the potential integration of vestibular exercises into the primary management strategies for Parkinson's disease.

Keywords: Eye-hand coordination, Paralysis agitans, Sixth sense, Spatial memory, Verbal memory

INTRODUCTION

Parkinson's disease is also called as shaking palsy, which is characterised by rigidity, tremors and weakness of movements that occurs in the late and middle-aged population [1,2]. It is due to damage in the nigro striatal pathway that causes a deficiency of the neurotransmitter dopamine [3]. The ratio between acetylcholine and dopamine plays a key role in the regulation of movements, and disruption of this ratio is observed in Parkinson's patients. Hence, there are hypo and hyperkinetic symptoms. Apart from these motor symptoms, non motor symptoms were also reported in these patients that include, mood changes, depression and cognitive dysfunction and autonomic dysfunction, and also sleep and digestive disorders. Hence, management of the non motor symptoms also essential for improving the quality of life of these patients [4].

It was reported that 70 in 100,000 individuals were affected with Parkinson's disease in India. The age group most affected was 50 to 60 years in both males and females [5]. Though pharmacological treatment is available that can manage the non motor symptoms of Parkinson's disease, they are associated with considerable side-effects. Hence, long-term use is restricted [6].

Alternative therapies like practising Yoga were reported to be beneficial in improving the balance, mood, cognition, and overall quality of life of Parkinson's patients [7]. One such alternative therapy is the vestibular exercises that have no side-effects and can be practised for a long-term basis. Vestibular dysfunction is commonly observed in patients with Parkinson's disease, and hence, the stimulation with optimal stimuli can offer them a better quality of life [8]. The vestibular system is known as the sixth sense for its extensive connectivity with multiple areas of the brain that are involved in the regulation of cognitive functions. Earlier studies have reported that stimulating the vestibular system through non invasive electrical stimuli, transcutaneous placing the electrodes on the mastoid process, is beneficial in altering the dopamine and GABA levels in patients with Parkinson's disease [9,10].

Further, caloric and galvanic vestibular stimulation is also recommended as an adjunctive therapy in the management of Parkinson's disease [11,12]. Vestibular exercises have been clinically implemented in the management of conditions like Down syndrome [13]. However, studies regarding the application of exercises stimulating the vestibular apparatus in the management of

Parkinson's disease were sparse. Hence, the present study aimed to evaluate the efficacy of vestibular exercises as an adjunctive therapy in the management of cognitive impairments and postural control in individuals with Parkinson's disease to offer a cost-effective therapy to Parkinson's patients.

MATERIALS AND METHODS

This open-label randomised controlled trial was conducted at Department of Physiology, Sri Madhusudan Sai Institute of Medical Sciences and Research, Chikkaballapur, Karnataka, India from 05-08-2024 to 18-09-2025. The study protocol design was reviewed and approved by the Institutional Ethics Committee (IEC/certificate/39/2024) dated 21-06-2024.

Inclusion criteria: Both male and female participants, aged 50-70 years, who provided consent, diagnosed with mild Parkinson's disease (using Hoehn and Yahr scale) [14] within last five years and are under allopathy treatment, who exhibit non motor symptoms such as balance impairments, low blood pressure, insomnia, hallucinations, and postural instability were included in the study.

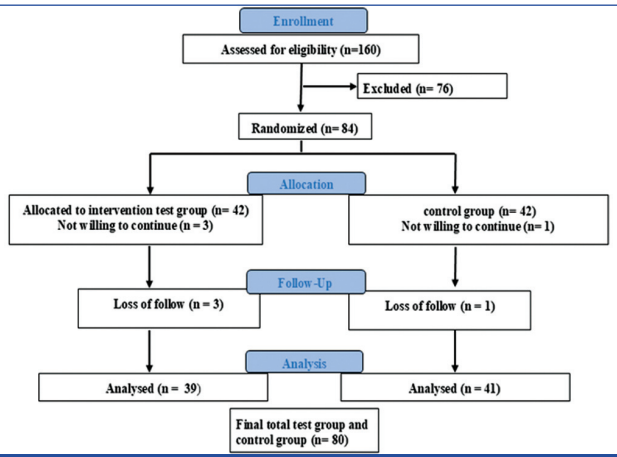
Exclusion criteria: Participants who were proven to have severe complications and were already under any alternative therapies to manage Parkinson's disease were excluded from the study.

Sample size calculation: The sample size was calculated based on previous study [15], an expected 15% difference between the means or medians of the dependent variables in the control and experimental groups, with a 20% standard deviation, 90% power, and a 5% significance level. The estimated sample size was 39 per group. It was rounded up to 40 for each group (a total of 80 participants). SigmaPlot 14.5 (Systat Software Inc., San Jose, USA) was used to calculate sample size.

Data collection: Total 80 participants were randomly assigned into two separate groups, that is, control (n=41) and experimental groups (n=39) using random numbers generated by randomiser.com software.

Control group: (n=41): Regular pharmacological ongoing treatment

Experimental group: (n=39): Regular pharmacological ongoing treatment + Vestibular exercises for 12 weeks [Table/Fig-1].



[Table/Fig-1]: Consort flow chart.

Vestibular exercises: A structured 25-minute vestibular exercise program was implemented in the study. The participants and their family members were trained for this program by the physiotherapist over one week. The participants performed the exercises daily for 25 minutes (5 minutes warm-up session prior to exercise) with the help of their trained family member and under the supervision of the physiotherapist [Table/Fig-2] [16-19]. Outcome measures were collected during baseline and after 12 weeks of intervention in both groups and compared.

S. No.	Type of exercise	Procedure	Duration
1	Gaze stabilisation exercise	The participant was asked to look straight ahead towards the index finger of the examiner. Then he was asked to turn his head 45° right and then asked to turn his head 45° left. Repeat the sequence.	5 minutes
2	Walking in a straight line	The participant was asked to walk slowly along a straight line, placing one foot exactly directly in front of the other (heel-to-toe).	5 minutes
3	Modified sit-to-stand	The participant was asked to stand up from a sitting position while keeping their gaze fixed on a specific point in front of them.	5 minutes
4	Head tilts	Participants were instructed to sit in a relaxed and comfortable position and gently tilt their head toward one shoulder, aiming to bring the ear closer to the shoulder. This movement was alternated between the left and right-sides.	5 minutes
5	Balancing on one leg	The participant was asked to stand near a stable support and lift one leg off the ground. They should maintain their balance while keeping a stable gaze. They should hold the position for a few seconds and then switch legs. This is repeated.	5 minutes

[Table/Fig-2]: Vestibular exercises [16-19].

Assessment of auditory reaction time and visual reaction time: Auditory and visual reaction times of the participants were measured using a reaction time apparatus developed by Anand Agencies, Pune. Visual reaction time was evaluated using red and green light stimuli, while auditory reaction time was assessed using both high-pitched and low-pitched sounds. Participants underwent a training session one day prior to the actual data collection to familiarise them with the procedure. Three trials were conducted for each type of stimulus, and the best performance among the three was recorded as the final reaction time [20]. The instrument digitally displays the reaction time, and the same was recorded.

100-pin dexterity test: This test was used to assess precise motor coordination. The participants were asked to place the 100 pins in the slot provided using their dominant hand. The time required to fill all slots with the pins was recorded manually [21] using a stopwatch. The participants were asked to try three times, and the best value was considered.

Assessment of spatial memory: A PowerPoint presentation comprising 20 slides was created and projected onto a screen using a Liquid Crystal Display (LCD). Each slide featured a simple line diagram designed to be easily reproducible. The illustrations included basic geometric shapes such as circles, rectangles, squares, and pyramids- figures that could be readily described verbally. Following the presentation of all 20 slides, a mathematical problem (e.g., 8-7+3-2+16+12-1+7) was displayed on the screen, and participants were instructed to solve it. Subsequently, participants were asked to recall and reproduce all the diagrams presented during the slideshow on paper within a one-minute time frame. Each accurately recreated figure was awarded a score of "1," while incorrect or unidentifiable responses received a score of "0." If the participant recalled five pictures successfully, his score was interpreted as 5. Distinct sets of diagrams were employed for the pretest and post-test assessments to avoid recall bias [21-24].

Assessment of verbal memory: A set of 20 PowerPoint slides was prepared and projected onto a screen using a LCD projector. Each slide displayed a three-letter word, such as "ZOL." After all 20 slides had been presented, a mathematical problem (e.g., 9-4+3-1+22+14-1+3) was shown, and participants were instructed to solve it. Following this task, participants were asked to recall and write down as many of the three-letter words as possible within a one-minute time frame. Each correctly recalled word was awarded a score of "1," while incorrect or missing responses received a score

of "0." If the participant recalled five words successfully, his score was interpreted as five. Distinct sets of word slides were used for the pretest and post-test sessions to prevent recall bias [21-24].

Time up and go test: This is a simple test where the participant was asked to sit comfortably, then asked to stand up and walk for three meters distance and turn around and walk back to the seat and sit down. The time taken for the task was recorded using the stopwatch manually [23].

STATISTICAL ANALYSIS

The socio-demographic variables' data were expressed either as mean and standard deviation or as a frequency table. The means were analysed using the student's unpaired t-test, and frequencies were analysed using Fisher's exact test for homogeneity and significant difference. The data were presented as medians and percentiles (25-75). Since the data were discrete variables and scores, the medians were compared using Kruskal-Wallis, ANOVA on ranks with Dunn's post-hoc multiple comparisons test for between-group and within-group analysis. A p-value < 0.05 was considered statistically significant. SigmaPlot 14.5 version (Systat Software Inc., San Jose, USA) was used for statistical analysis and graph plotting.

RESULTS

In present study, the mean age control and experimental group was 57.2±1.4 years and 56.3±1.4 years, mean height of control and experimental group was 171.1±0.6 cm and 169.7±0.9 cm, mean weight (kg) of control and experimental group was 59.6±0.8 kg and 60.9±0.9 kg, mean body mass index of control and experimental group is 20.3±0.2 kg/m^2 and 21.1±0.2 kg/m^2 [Table/Fig-3].

S.No.	Variable	Category	Con	Exp	Statistics
1	Age (years)	Mean	57.2	56.3	t = 0.456 p-value = 0.650
		SE	1.4	1.4	
2	Gender	Male	41	37	p-value = 0.494
		Female	0	2	
3	Height (cm)	Mean	171.1	169.7	t = 1.376 p-value = 0.173
		SE	0.6	0.9	
4	Weight (kg)	Mean	59.6	60.9	t = 1.031 p-value = 0.306
		SE	0.8	0.9	
5	Body mass index (kg/m^2)	Mean	20.3	21.1	t = 3.197 p-value = 0.002
		SE	0.2	0.2	

[Table/Fig-3]: Socio-demographic variables of control and experimental groups for homogeneity.
n - control = 41; experimental = 39.
The 't' and p-values are based on the student's unpaired t-test.
The p-value of gender is based on Fisher's-exact test.

The median spatial memory scores for control baseline, control week-12, experimental baseline, and experimental week-12 were 5, 6, 5, and 7, respectively. The median spatial memory scores for control baseline, control week-12, experimental baseline, and experimental week-12 were 5, 5, 5, and 7, respectively. There was a significant decrease (p-value <0.001) in the spatial and verbal memory scores in the experimental group, following the intervention [Table/Fig-4].

The median values of visual reaction time for red light right-hand and left-hand responses for control baseline, control week-12, experimental baseline, and experimental week-12 were 0.89, 0.845, 0.88, 0.71 and 0.99, 0.98, 1.1, 0.89, respectively. There was a significant increase (p-value<0.001) in the visual reaction time red-light right and left responses in the experimental group, following the intervention [Table/Fig-5].

The median values of visual reaction time, green light right and left responses for control baseline, control week-12, experimental baseline, and experimental week-12 were 1.28, 1.235, 1.3, 1.1 and 1.5, 1.47, 1.51, 1.36, respectively. There was a significant decrease (p-value <0.001) in the visual reaction time for green-light right and left responses in the experimental group, following the intervention [Table/Fig-6].

S. No.	Spatial memory	Control	Experimental	p-value (inter-group)
1	At baseline	5 (3-7)	5 (3-6.8)	1.0
2	At 12 weeks	6 (4-7.5)	7 (5-9)	<0.001
3	p-value (within the group)	0.086	<0.001	
Verbal memory				
1	At baseline	5 (3.1-7)	5 (3-7)	1.0
2	At 12 weeks	5 (4-8)	7 (5-9)	<0.001
3	p-value (within the group)	0.162	<0.001	

[Table/Fig-4]: Comparison of control and experimental groups on spatial memory and verbal memory in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

S. No.	VR Right	Control	Experimental	p-value (inter-group)
1	At baseline	0.89 (0.722-0.999)	0.88 (0.72-0.9)	1.0
2	At 12 weeks	0.845 (0.7-1.095)	0.71 (0.531-0.8)	<0.001
3	p-value (within the group)	1.0	<0.001	
VR Left				
1	At baseline	0.990 (0.900 - 1.299)	1.100 (0.900 - 1.200)	0.654
2	At 12 weeks	0.980 (0.804 - 1.590)	0.890 (0.700 - 0.900)	<0.001
3	p-value (within the group)	1.0	<0.001	-

[Table/Fig-5]: Comparison of control and experimental groups on visual reaction time for red light right-hand and left-hand responses in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

The median values for auditory reaction time, high-pitched sound right and left responses for control baseline, control week-12, experimental baseline, and experimental week-12 were 1.2, 1.1, 1.15, 0.98 and 1.36, 1.27, 1.27, 0.9, respectively. There was a significant decrease (p-value <0.001) in the auditory reaction time, high-pitched sound right and left responses in the experimental group, following the intervention [Table/Fig-7].

The median values for auditory reaction time, low-pitched sound right and left responses for control baseline, control week-12, experimental baseline, and experimental week-12 were 1.5, 1.39, 1.42, 1.21 and 1.6, 1.52, 1.55, 1.31, respectively. There was a significant decrease (p-value <0.001) in the low-pitched sound right and left responses in the experimental group, following the intervention [Table/Fig-8].

The median values of 100-pin test and TUG scores for control baseline, control week-12, experimental baseline, and experimental

S. No.	VGRt	Control	Experimental	p-value (inter-group)
1	At baseline	1.28 (1.18-1.358)	1.3 (1.18-1.34)	1.0
2	At 12 weeks	1.235 (1.11-1.39)	1.1 (1.02-1.129)	<0.001
3	p-value (within the group)	1.000	<0.001	
VGLt				
1	At baseline	1.500 (1.400 - 1.680)	1.510 (1.376 - 1.680)	1.000
2	At 12 weeks	1.470 (1.362 - 1.689)	1.360 (1.300 - 1.428)	<0.001
3	p-value (within the group)	1.000	<0.001	

[Table/Fig-6]: Comparison of control (Con) and experimental (Exp) groups on visual reaction time for green light right-hand and left-hand responses in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

S. No.	AHPRt	Control	Experimental	p-value (inter-group)
1	At baseline	1.2 (0.95-1.22)	1.15 (0.9-1.22)	1.0
2	At 12 weeks	1.1 (0.93-1.24)	0.98 (0.8-1.1)	0.001
3	p-value (within the group)	1.0	<0.001	
AHPLt				
1	At baseline	1.360 (0.961-1.440	1.270 (0.900 - 1.440)	1.000
2	At 12 weeks	1.275 (0.900 - 1.460)	0.900 (0.800 - 0.947)	< 0.001
3	p-value (within the group)	1.000	<0.001	

[Table/Fig-7]: Comparison of control and experimental groups on auditory reaction time for high pitch sound right-hand and left-hand responses in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

S. No.	ALPRt	Control	Experimental	p-value (inter-group)
1	At baseline	1.5 (1.08 - 1.52)	1.42 (1.084 - 1.52)	1.0
2	At 12 weeks	1.395 (1.071 - 1.55)	1.21 (0.9 - 1.26)	<0.001
3	p-value (within the group)	1.0	<0.001	
ALPLt				
1	At baseline	1.600 (1.220 - 1.690)	1.550 (1.220 - 1.680)	1.000
2	At 12 weeks	1.520 (1.220 - 1.690)	1.310 (1.100 - 1.400)	<0.001
3	p-value (within the group)	1.000	<0.001	

[Table/Fig-8]: Comparison of control and experimental groups on auditory reaction time for low pitch sound right-hand and left-hand responses in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

week-12 were 13,12,13,12 and 17,16,17,14, respectively. There was a significant decrease (p-value <0.001) in the 100-pin test and TUG scores in the experimental group, following the intervention [Table/Fig-9].

S. No.	100PT	Control	Experimental	p-value (inter-group)
1	At baseline	13 (9.1-14)	13 (12-14)	0.054
2	At 12 weeks	12 (9.05-13.95)	12 (9-12)	0.333
3	p-value (within the group)	0.358	<0.001	
TUG				
1	At baseline	17 (15-20)	17 (16-20)	1.000
2	At 12 weeks	16 (14-19)	14 (13-17)	0.003
3	p-value (within the group)	0.184	<0.001	

[Table/Fig-9]: Comparison of control and experimental groups on 100 pin test and time up and go test in baseline (Base) and after 12-week post-test (Week-12) in Parkinson's disease.

DISCUSSION

The current study helped determine the effectiveness of specific vestibular exercise in the controlled management of cognitive domain functions in Parkinson's disease patients. In the present study, there is no significant difference in the mean age, height, weight and BMI among the control and experimental participant. This denotes homogeneity both the group. In this study, baseline special memory score was significantly reduced in experimental group participants in comparison to control group. A 100-pindexterity test showed significant decrease, when compared to control group.

In this study, baseline verbal memory score, VRT red light, VRT green light, ART high pitch and ART low pitch showed significant increase in experimental group compared to control group. Even spatial memory scores were slightly decreased in experimental group, but not reached statistical significance.

As it was well-known that moderate physical exercises positively affect neuro plasticity, various exercises have shown to selectively render effect in various regions of the brain [25]. Training programs emphasising aerobic exercises have demonstrated significant benefits, particularly in brain regions such as the superior temporal, prefrontal, and parietal cortices, as well as in the anterior and transverse white matter tracts connecting the frontal and parietal lobes. These areas are critically involved in cognitive processes essential for daily functioning and routine activities [26].

In alignment with present study findings another study by Gobbi LTB et al., reported that team activities with motor and non motor skills can depict drastic improvement in cognitive and psychological functional aspects in patients with Parkinson's disease [27]. Yet, another systematic review of few randomised controlled trial projects by Da Silva FC et al., reported that physical strategic exercise programs can improve the cognitive domain function, sensory input processing speed, concentration and cognitive flexibility in Parkinson's disease patients, presenting with mild to moderate stage progression in patients with a 6-year long clinical diagnosis of Parkinson's disease [28].

Similarly study by Stuckenschneider T et al., reported that all categories and forms of exercise are inclined to improve cognitive function in patients with Parkinson's disease, of which aerobic training proved to enhance memory greater [29]. Vestibular enhancing exercises improve cognitive functions via its physiological and anatomical connections with the structures involved in the Papez circuit, which includes the thalamus, hypothalamus, amygdala, and hippocampus. In fact a recent study reported that the purchase decision-making can also be altered by the vestibular stimulation [30]. Studies have testified to strong connections mediating the vestibular connections and the hippocampus [31-33]. A healthy vestibular functional system is required to be present for normal functioning of the hippocampus, because the hippocampal atrophy is observed, followed by the damage of the vestibular system [34]. Caloric and galvanic vestibular stimulation has been in use in the symptoms of Parkinson's disease [35-37]. Earlier studies reported that vestibular stimulation was reported to improve the balance in post-strike hemiplegic patients and Parkinson's post-strike hemiplegic patients and Parkinson's patients [38-42]. reported as a common observation in the patients with Parkinson's disease. However, this feature was least researched [43]. Vestibular stimulation was suggested as a potential therapy for management of cognitive impairment in patients with PD [44].

The present study administered vestibular exercises as an intervention and found that these exercises were effective in improving the cognitive functions in patients with symptomatic PD.

Limitation(s)

The study was conducted at a single centre. Hence, the results cannot be generalised.

CONCLUSION(S)

The study results support vestibular exercises as an adjunctive therapy for the management of the motor and non motor symptoms of the Parkinson's disease. The study indicates need for further long-term, multicentric, studies with higher sample size to implement the vestibular exercises in the management of PD.

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