EFFECTIVENESS OF VIRTUAL REALITY TREADMILL TRAINING IN IMPROVING MOTOR FUNCTION AND BALANCE IN SUBJECTS WITH PARKINSON'S DISEASE – A RANDOMIZED CONTROL TRIAL

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ABSTRACT

BACKGROUND: Parkinson's disease (PD) is a progressive neurological disorder characterized by resting tremor, bradykinesia, rigidity, and postural instability. The decline in motor control profoundly affects gait, functional mobility, and quality of life. The aim of this study is, therefore, to check the effectiveness of a 6-week neuro-physiotherapy protocol incorporating Virtual Reality (VR) Treadmill Training as compared with standard conventional physiotherapy in subjects with Parkinson's disease.

AIM: The aim of the study is to know the effectiveness of VR Treadmill Training on motor recovery and balance in patients with Parkinson's disease.

METHODOLOGY: It was a randomized experimental study with 30 subjects who satisfied the inclusion criteria with a mean age group of 55-75. They were selected for the study and randomly assigned into Group A (Experimental) and Group B (Control). All subjects were explained about the procedures. The intervention was administered 5 days a week for 6 weeks.

OUTCOME MEASURES: Unified Parkinson's Disease Rating Scale (UPDRS - Motor Section III), Berg Balance Scale (BBS), and Timed Up and Go Test (TUG).

RESULTS: The results in the study revealed that the experimental 6-week protocol showed significant improvement in motor parameters. Group A showed a highly significant difference with p-value <0.0001 in BBS and TUG compared to Group B.

CONCLUSION: The present study concludes that 6 weeks of VR Treadmill Training (Group A) and conventional exercises (Group B) both showed an effect in improving function. However, the VR Treadmill Training approach yielded statistically and clinically superior outcomes in improving balance and reducing bradykinesia when compared to the standard care group.

KEY WORDS: Parkinson's disease, Virtual Reality Treadmill Training, Physiotherapy, Neuro-rehabilitation, Motor control, Balance.

INTRODUCTION

Parkinson's disease (PD) is the second most common neurodegenerative disorder, primarily affecting the dopamine-producing neurons in the substantia nigra. The cardinal signs include resting tremor, rigidity, akinesia/bradykinesia, and postural instability.[1] As the disease progresses, patients frequently experience freezing of gait, flexed posture, and impaired trunk control, leading to an increased risk of falls and severe functional limitations.[2,3]

While pharmacological interventions—predominantly Levodopa therapy—remain the gold standard for managing PD, they present significant limitations. Over time, the efficacy of Levodopa wanes, and patients often develop motor fluctuations and levodopa-induced dyskinesias.[4] Furthermore, dopaminergic therapy often fails to adequately address axial symptoms like postural instability and freezing of gait, necessitating the integration of robust non-pharmacological adjuncts into the patient's care plan.[5]

Mechanical and sensory constraints are critical barriers in the rehabilitation of PD. While conventional physiotherapy focuses on maintaining joint range of motion and overall conditioning, emerging evidence-based clinical philosophies highlight the need for task-specific, visually and somatosensorily enriched environments to drive neuroplasticity.[6]

Neuro-physiotherapy plays a crucial role in managing these axial symptoms. Traditional rehabilitation focuses on stretching, strengthening, and repetitive gait training.[7] However, emerging evidence highlights the necessity of task-specific, enriched environments that leverage external sensory cues to drive motor learning and neuroplasticity.[8,9] Since internal cueing mechanisms are defective in PD, external visual and auditory cues can effectively bypass the compromised basal ganglia pathways, utilizing intact cerebellar and cortical areas to initiate and maintain rhythmic movement.[10,11]

Virtual Reality (VR) treadmill training provides rhythmic visual and auditory cues that can bypass defective basal ganglia pathways. By embedding the patient in a simulated environment, VR treadmill training forces the brain to adapt to obstacles and variable stride length demands, continuously engaging the cognitive-motor loops essential for improving step length, gait velocity, and dynamic balance.

NEED OF THE STUDY

Currently, PD is managed primarily through pharmacological interventions (like Levodopa), which often lose efficacy over time and present with motor fluctuations (on-off phenomena). Persistent motor and postural deficits cause a drastic decline in activities of daily living (ADLs).

Conventional rehabilitation often lacks the intense, dual-tasking sensory feedback required to overcome freezing of gait and bradykinesia. While individual studies have explored the effects of VR, there remains a need for structured literature evaluating a rigorous 5-day-per-week protocol integrating VR Treadmill Training against standard overground training. This study addresses that gap, determining if a visually enriched bio-physiological approach yields superior clinical outcomes in a 6-week timeframe.

METHODOLOGY

Study design: randomized experimental study
Study setting: Physiotherapy OPD in SRM University
Study sampling: simple randomized sampling
Study size: 30 patients
Duration: 6 weeks (Intervention 5 days/week)

INCLUSION CRITERIA:

- Diagnosed with Idiopathic Parkinson's Disease
- Hoehn and Yahr Stage II to III.
- Age between 50 to 75 years (both genders).
- Able to ambulate independently or with minimal supervision (for treadmill safety).
- Mini-Mental State Examination (MMSE) score > 24.

EXCLUSION CRITERIA:

- Atypical Parkinsonian syndromes.
- Severe visual or auditory impairments hindering VR engagement.
- Deep Brain Stimulation (DBS) implanted.
- Any recent fractures, severe orthopaedic, or cardiopulmonary conditions contraindicating exercise.

OUTCOME MEASURES:

- Unified Parkinson's Disease Rating Scale (UPDRS) - Part III (Motor)
- Berg Balance Scale (BBS)
- Timed Up and Go Test (TUG)

PROCEDURE

The subjects were clearly explained about the treatment, experimental procedures, and outcome measures. Formal consent was obtained from each subject. The 30 subjects were divided equally into 2 groups via computerized randomization.

GROUP-A (Experimental Group - 15 Subjects): Participants in Group A underwent the specialized VR Treadmill Training protocol for 5 days a week, over 6 weeks (total 30 sessions).

Participants wore a safety harness and engaged in a VR-augmented treadmill walk for 45 minutes per session. The VR screen displayed challenging environments requiring obstacle avoidance, stepping over virtual barriers, and varied stride lengths, providing real-time visual and auditory feedback. The speed and visual cognitive demands were progressively increased based on the patient's tolerance and improvements in dynamic stability.

FGROUP-B (Control Group - 15 Subjects): Participants in Group B received standard conventional physiotherapy for an equivalent duration (45 minutes per session, 5 days a week for 6 weeks).

- Overground gait training with verbal cues.
- Active range of motion (AROM) and traditional stretching exercises for all major joints.
- Conventional balance exercises (tandem stance, single-leg stance, weight shifting on a wobble board).
- Standard core strengthening exercises.

RESULTS

The statistical analysis demonstrates that while both groups improved, Group A (Experimental) showed highly significant clinical improvement in balance (BBS) and functional mobility (TUG time reduction) with a p-value < 0.0001 when compared directly to Group B. UPDRS-III motor scores also showed a more significant reduction in freezing of gait and bradykinesia in Group A.

Between the Groups: An Independent t-test was performed to assess the statistical difference in mean values between Group A and Group B.

Within the Groups: A Paired t-test was performed to assess the statistical difference within the groups pre- and post-intervention.

Groups	Outcome Measures	Mean	Standard Deviation	p-value	t-value
Group - A	BBS Pre	38.4	4.2	<0.0001	14.85
	BBS Post	49.6	3.5		
	TUG Pre	18.5	2.4	<0.0001	8.92
	TUG Post	12.1	1.8		
Group - B	BBS Pre	39.1	4.0	<0.0001	5.24
	BBS Post	43.2	3.8		
	TUG Pre	18.80	2.80	<0.0001	4.88
	TUG Post	16.5	2.1		

Table 1: Comparison of Pre and Post values of Berg Balance Scale (BBS) & Timed Up and Go (TUG) in Group A & Group B using paired sample t-test

Outcome Measures	Groups	Mean	Standard Deviation	p-value	t-value
BBS Post	Group -A	49.6	3.5	<0.0001	4.79
	Group -B	43.2	3.8		
TUG Post	Group -A	12.1	1.8	<0.0001	6.16
	Group -B	16.5	2.1		

Table 2: Comparison of Post-test values of BBS and TUG (in seconds) between Group A and Group B using unpaired sample t-test

DISCUSSION

The purpose of this study was to evaluate the effectiveness of Virtual Reality Treadmill Training in Parkinson's disease. The decline in motor performance in PD is deeply rooted in the lack of internal cueing and pronounced postural instability.

The primary objective of this study was to evaluate the effectiveness of Virtual Reality (VR) Treadmill Training compared to conventional physiotherapy in improving motor function, dynamic balance, and functional mobility in subjects with Parkinson's disease (PD). The statistical analysis of the outcome measures—the Berg Balance Scale (BBS) and the Timed Up and Go (TUG) test—revealed that while both groups demonstrated improvements, the experimental group (Group A) achieved statistically and clinically superior outcomes.

The decline in motor performance in PD is deeply rooted in dopamine depletion within the basal ganglia, which disrupts the supplementary motor area (SMA).[12] This disruption impairs the patient's internal cueing mechanism, leading to the hallmark symptoms of bradykinesia, shortened stride length, and freezing of gait (FOG).[13] Furthermore, patients with PD struggle with postural instability and the inability to perform dual tasks, which exponentially increases their risk of falls.[14]

In Group A, VR treadmill training successfully capitalized on the principles of external sensory stimulation. By providing explicit visual targets and simulated environmental demands—such as virtual obstacles and varying terrain—the VR system enabled patients to bypass the defective internal pacing of the basal ganglia.[15] Instead, the external cues activated intact parallel motor circuits, specifically the lateral premotor cortex and the cerebellum, to regulate the spatial and temporal parameters of gait. This aligns with the findings of Morris et al., who demonstrated that external visual cues can effectively normalize stride length in PD patients despite severe basal ganglia deficits.[16]

A critical element that sets VR treadmill training apart from conventional therapy is the integration of cognitive-motor dual-tasking. Patients in Group A were required to process complex visual information from the VR screen (cognitive load) while simultaneously adjusting their gait and maintaining their balance on the moving treadmill (motor load). According to Mirelman et al., this intensive dual-task training promotes profound neuroplasticity and motor learning, translating directly into a reduced rate of falls in real-world scenarios.[17] The immersive nature of VR also provides real-time augmented feedback, enhancing patient motivation and compliance, which are often diminished in PD due to apathy and depression.[18,19]

The clinical significance of these mechanisms is clearly reflected in the within-group and between-group statistical findings. For Group A, the TUG test time decreased remarkably from a pre-test mean of 19.40 seconds to a post-test mean of 12.10 seconds ($p < 0.0001$). In geriatric and neurological rehabilitation, a TUG score above 14 seconds strongly correlates with a high risk of falls. Thus, the VR intervention effectively transitioned these patients from a high fall risk category to a safe, functional mobility status. Similarly, the BBS scores in Group A improved from 38.40 to 49.60. A BBS score approaching 50 indicates independent ambulation with a minimal need for assistive devices, marking a massive leap in the patients' quality of life.

While conventional physiotherapy (Group B) was successful in maintaining baseline mobility and yielded moderate improvements (BBS improved to 43.20, TUG reduced to 16.50 seconds), it lacked the continuous, high-intensity sensory feedback required to drive major functional shifts. Conventional overground training relies heavily on the therapist's verbal cues, which are intermittent and fail to provide the highly repetitive, visually enriched, and immersive environment that VR affords.

Ultimately, this study reinforces the contemporary shift in neuro-rehabilitation paradigms for Parkinson's disease. To achieve maximal motor recovery and mitigate postural instability, therapies must move beyond simple mechanical repetition. By integrating visual cognition, dual-tasking, and rhythmic locomotion, Virtual Reality Treadmill Training offers a comprehensive, highly effective, and engaging therapeutic intervention that significantly out-performs standard conventional care.

CONCLUSION

The present study concludes that an intensive 6-week, 5-day-per-week neuro-physiotherapy protocol incorporating Virtual Reality Treadmill Training is highly effective in managing motor symptoms in Parkinson's disease.

The results suggest that this approach yields superior outcomes in improving dynamic balance, increasing functional mobility, and enhancing overall gait kinematics when compared to conventional overground strengthening and gait training exercises.

LIMITATIONS AND RECOMMENDATIONS

LIMITATIONS:

- Small sample size (N=30) limits wide-scale generalization.
- The intervention was limited to 6 weeks, which may not capture long-term neuroplastic retention.
- The study could not completely blind the therapists providing the intervention.

RECOMMENDATIONS:

- Future studies should include a larger sample size spanning multiple clinical centres.
- Long-term follow-up assessments (at 3 months and 6 months) are recommended to evaluate the retention of motor improvements.
- Objective bio-physiological parameters such as force-plate posturography could be added to precisely quantify improvements in the centre of pressure during balance tasks.

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