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"Clinical Effectiveness of an Integrated Advanced Physiotherapy Protocol for Motor and Functional Rehabilitation in Parkinson's Disease: A Clinical Trial Study"

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Abstract:

Background: Parkinson's disease (PD) is a progressive neurodegenerative disorder associated with motor dysfunction, impaired balance, gait disturbances, and reduced functional independence. Physiotherapy supports mobility and functional performance. This study compared outcomes following clinic-based integrated multimodal physiotherapy (IPT) and home-based conventional physiotherapy (HPT) in person with Parkinson's.

Methods: This retrospective comparative study reviewed clinical records from Physiotattva physiotherapy clinics in Bengaluru, India, between January to September 2026. 81 participants completed 4 weeks of physiotherapy, and complete baseline and discharge assessments were included. Participants received either IPT incorporating LSVT-BIG training, aerobic and dual-task training, robotic-assisted therapy, virtual reality, and sensor-based feedback or HPT involving strengthening, proprioceptive neuromuscular facilitation, MAT exercises, balance, gait, and functional training. Balance and Upper-extremity function were assessed using BBS and UEFS. Non-parametric tests evaluated within-group and between-group differences.

Results: Both IPT and HPT groups demonstrated statistically significant improvements in BBS and UEFS scores following treatment ($p<0.001$). Post-intervention comparisons revealed no statistically significant between-group differences in either outcome. Changes in BBS scores did not differ significantly between groups ($p>0.05$). However, UEFS change scores demonstrated a statistically significant between-group difference ($p=0.005$), favouring HPT. Baseline age differences between groups warrant cautious interpretation of these findings.

Conclusion: Both clinic-based integrated and home-based conventional physiotherapy were associated with improved balance and upper extremity function in individuals with PD. The findings support clinical value of both approaches. Further prospective studies using baseline-adjusted analyses, standardised intervention protocols, and functional outcomes are needed to establish comparative effectiveness and guide individualised rehabilitation

planning.
Keywords: Dual-task training, LSVT-Big training, Cueing, AI-technology based tools/equipments, Virtual trainer, Advanced physiotherapy, Homecare physiotherapy

Introduction:

Parkinson's disease (PD) is a complex progressive multisystem neurodegenerative disorder (synucleinopathy) primarily associated with dysfunction of the basal ganglia (BG), not limited to dopamine loss in the basal ganglia, involving dopaminergic and non-dopaminergic networks throughout the brain, and characterized primarily by bradykinesia, resting tremor, rigidity, and gait and balance disturbances. PD is second most common but fastest-rising neurodegenerative disorder after Alzheimer's disease, with greater dependence and social isolation. Most people with parkinson's disease (pwP) are affected in age group of 60 years and beyond, whereas 5 - 10% are affected before 50 years of age 1.

The basal ganglia regulate learned and automatic movements by controlling movement planning, initiation, sequencing, timing, and amplitude. Dysfunction can cause difficulty with automatic movements, dual-tasking, switching motor tasks, and maintaining movement amplitude, contributing to bradykinesia and a shuffling gait, impacting quality of life of patients and their families.

Diagnosis of PD is mainly clinical and often occurs after motor symptoms become apparent. Potential early indicators and diagnostic biomarkers include imaging detecting dopaminergic dysfunction, hyposmia, REM sleep behavior disorder (RBD), pathological biomarker detection such as abnormal α-synuclein, medications, genetic variants and family history, increased non-motor symptoms like constipation, depression, mild cognitive impairment (MCI), and visual disturbances; these support earlier identification of PD 14.

Common features include resting tremor (with frequency of 4-6 Hz), often initially unilateral, bradykinesia involving generalised weakness, lead-pipe or cogwheel rigidity, postural instability, gait and balance disturbances with episodes of freezing, increased fall risk, mood changes, executive dysfunction, autonomic symptoms involving poor gut-brain axis function, urinary problems, drooling, excessive sweating, and excessive daytime sleepiness (EDS). Its exact cause remains unclear, although genetic and environmental factors are involved. The Movement Disorder Society (MDS) describes the course of the disease as preclinical, prodromal (non-motor/pre-motor signs), and clinical stages.

Other classical signs during motor stage are asymmetric arm swing during gait, shortened stride length, freezing in shifting/shuffling during gait, turning in sequential multiple small steps resembling log-rolling, retroplusion, difficulty in alternating movement at fast pace, monotone speech pattern, forward head posture with stooped trunk, micrographia, reduced facial expression, reduced motivation 2,3,4.

Early, appropriately prescribed exercise and physiotherapy can help maintain mobility, strength, balance, gait and functional independence, making early rehabilitation an important component of PD management. With growing evidence, moderate to intense exercise protocols initiated at motor signs of disease may promote neuroprotection and slow motor decline. Understanding rehabilitation perspective for basal ganglia which are clinically responsible for movement control, motor learning, executive functions, and behaviours, causing problems in selection or filtering of incoming signals. The default role of BG is inhibitory and, overall, reduces excitatory response, making movement more difficult 13.

A key area of physiotherapeutic interventions for which pwP are impacted under Clinical Practice Guidelines (CPG) by APTA with respect to physical capacity, transfers, hands-on and manual activities, quality of movement, postural changes, balance and fall risks are considered and predicted in association with age, duration of onset, neuro-musculoskeletal changes, reduced muscle strength, proprioception and gait speed changes, increased gait variability like freezing of gait (FOG), reduced cognitive function, judgement, distraction, personal and environmental factors, respiratory problems and pain. Use of appropriate outcome measures like Unified Parkinson's Disease Rating Scale (UPDRS), Timed Up-and-Go Test (TUG) to evaluate changes in person's status compared with present clinical symptoms with stage of progression by Modified Hoehn and Yahr Scale (M H&Y). Although individual problem/s should be evaluated as per pwP's lifestyle according to motor & non-motor symptoms 5,6,12.

There's a greater emphasis on education and self-management during earlier stages of diagnosis. Exercise focusing on mobility, flexibility, strength, and endurance using motor learning principles and approaches like mental imagery and dual-task training affects neuroprotective responses at individual level and in group setting too which is complex, powerful and intense in nature. Balance training improves reduction in fall risks by reducing postural control impairments, which enhances neuromotor function; meditative-reflective walking and Nordic walking. With progressive resistance training, task-specific

circuit training and LSVT-BIG training, aerobic exercises, healthy diet, and social engagement tend to be effective in decreasing bradykinesia and improving functional performance and quality of life (QoL). External cueing and attention provided in different ways by therapists or with self-instruction set-up, or robot-assisted or AI technology-driven tools/equipments or video exergames and virtual reality, help in cognitive-functional training and attention development. Visual, auditory, vestibular, somatosensory, and proprioceptive cueing shifts patients' habitual movements into task-specific and goal-oriented ones. Similarly, later intervention is delivered by music-based movement therapy combines physical movements and attention cueing strategies. Respiratory muscle strength training in PD rehabilitation is useful for managing respiratory function, dysphagia, ineffective coughing, speech problems and cardio-respiratory dysfunction (CRD) in later stage of PD. In PD, lifestyle and behaviour medicine aims to address evidence-based lifestyle interventions that impact QoL and support long-term function rather than focusing only on symptoms; these contribute to plan through exercise prescription, movement training, prevention, health promotion, fitness, wellness and lifestyle education [7,8].

Cognitively challenging exercises show that mind-body fitness includes learning new motor skills, adapting skill-based activities in daily living and integrating these skills with exercises helps PD patients via different resources like Yoga, tai-chi, karate, meditation, Pilates, sport as table tennis, dancing, tango, boxing, and golf. Dance combines rhythmic cueing, cognitive challenge, balance training, and social engagement, making it a useful complementary rehabilitation approach in PD. This improves physical functional capacity, helps in continuity of exercise, creates active and engaging participation by increasing repetitions, directional change, change of movement plan and executive function, dynamic muscle control, and postural control, step and segmental sequencing, target turning, changing gait and movement speed and improves reduction in time duration for completing mental rotational tasks as aid in mental imagery formation and judgment. Dancing impacts executive functioning by preventing fatigue, reducing fear of falling, and ultimately improving quality of life and emotional well-being, which helps improve self-esteem, promotes social participation and motivation. Whereas in tai-chi, movement varies, which improves mental rehearsal and visualisation of movement in pre-, during, and post-approach, including single-leg balancing, weight shifting and trunk rotation helps to train trunk rotation, overall balance and postural stability [9,10,11].

In pwP, gait disturbances like short step length, slow gait speed, reduced foot clearance and reduced arm swing, festination, freezing, difficulty in turning and walking while completing another task, which impacts increasing risk of falls, reduced confidence, reduced community mobility and participation; here physiotherapy aims to improve safe and efficient walking that will be individualised based on disease stage, medication response, fall history, freezing episodes, cognition, fatigue and functional goals. In 3D gait analysis for pwP, ankle joint range of motion (ROM) during push-off, plantarflexion at toe-off, and ankle muscle power generation during pre-swing are generally reduced. Abnormal postural response patterns in pwP involve excessive antagonist activity and difficulty in adapting to changing support conditions. With condition progression, gradual reduction in capability to perform everyday activities independently is experienced. Fluctuations in motor and non-motor symptoms further impact exercise participation and rehabilitation outcomes. And thus consequently, physiotherapy interventions need to address both measurable impairments and functional demands in activities of daily living (ADL's) [8].

Purpose & Aim of study:

Physiotherapy rehabilitation at Physiotattva Clinic complements medical/pharmacological treatment by targeting movement amplitude, strength, cardiovascular (CV) capacity, dynamic balance, walking efficiency, and functional task performance. The selection and progression of interventions are adapted to disease severity, co-morbidities, medication response, fall risk, individual goals, and patients ability to participate safely. An important clinical distinction exists between delivering a collection of exercises and implementing structured rehabilitation protocol. An integrated programme includes specific exercise selection, intensity, repetition, progression, cueing strategies, safety monitoring, and functional transfer. Nevertheless, evidence supporting individual interventions does not automatically establish superiority of every programme combining them. Conventional physiotherapy is also heterogeneous and may include strengthening, stretching, balance activities, gait and functional training. An integrated advanced multimodal physiotherapy protocol may help establish whether explicit application leads to clinical improvements in motor symptoms and functional performance. Therefore, a direct comparative investigation is required to determine whether the proposed guideline-informed protocol provides additional benefits over a conventional exercise programme. Such evidence could support standardisation of outpatient neurorehabilitation (OPD) programme while retaining flexibility for individualised care.

Materials & Methodology:

Study design, Duration of study, study setting & Data collection:

This retrospective comparative study examines physiotherapy assessments, treatment records and outcome measures from the time span of January to September 2026 in the setting of Physiotattva, Physiotherapy Clinics of 4 weeks of treatment duration. It is a Bangalore-based outpatient physiotherapy clinic that operates uniform anonymised clinical software records. Patients' records with a diagnosis of parkinson's were screened.

Inclusion & Exclusion criteria:

The inclusion criteria include adults with age of 45 years onwards, diagnosed with parkinson's, Completed their physiotherapy sessions as prescribed of 4 weeks of treatment duration, have complete baseline and discharge outcome data of Berg-balance Scale (BBS) and Upper Extremeity Functional Scale (UEFS) are mentally stable participants who are alert, conscious and oriented, participants with diagnosed at Acute or Chronic stage of motor symptoms, participants can have history of other musculoskeletal condition like Osteoarthritis (OA), Low back pain (LBP) or Frozen shoulder (FS) but not active presently, well controlled other health condition like cognitive and behavioural functions, anxiety or depression that not affecting participation for following proper commands.

The exclusion criteria are in brief history of any surgeries like installing DBS or any, post-radition or post-chemo therapy, Tumor excision from Brain or Spine; History of immedicable injury or Trauma, Infection, Tumor or Fracture conditions, participants suffering from 2 or more than 2 Neurological condition, Sppech disorders, Cognitive impairment, Non-consent person, Mentally retarded or language barrier or who unable to understand command, Unstable medical systemic illness like Cardio-vascular (CV), Hepatic or Renal emergencies, additional Neurological deficit or any Red flags conditions, Incomplete or missing clinical records.

Data sampling method & Sample size:

It was a purposive sampling method for this study. Using daily records from software data, firstly, Diagnosis, Age, location, and desired duration were processed and out of which 81 patients' records were determined as the sample size. The consent form was arranged before the data was collected and was taken from research candidates on the first day of their physiotherapy treatment.

Intervention groups are divided into two groups: Clinic-based integrated multimodal physiotherapy program (IPT), which includes advanced therapeutic approaches like LSVT-BIG training, aerobic training, dual-task training, Robotic-assisted therapy including bilateral trainers, Exoskeletal, VR trainers, Wearable/ Motion inertial sensor feedback trainer, PRE trainers, and Home-based physiotherapy program (HPT), which includes Strength training, PNF, Mat exercises, Hands-on training, balance-gait practice.

Outcome measures used for this study are BBS and UEFS. BBS is a widely used clinical assessment tool with 14 functional tasks designed to measure static and dynamic balance in adults; this evaluates risk of falls and independent mobility. UEFS is a self-reported 20-questionnaire assessing upper functionality of ADLs, which assesses strength, hand function, mobility, and ADL's. These outcome data were drawn from clinical software records from baseline to discharge for all those patients' records. Of the 137 total participants, 26 records were incomplete; 15 records were diagnosed with more than two neurological conditions along with parkinson's, and 15 of those could not complete full treatment duration. Assessments were run at baseline.

Data analysis:

Statistical analysis was done using descriptive statistics, and also to summarise demographic data of the sample size. The Shapiro-Wilk test and Kolmogorov-Smirnov test were applied for all outcome variables within each group to assess whether significantly deviated from normal distribution, defining data as Non-parametric data. Therefore, for non-parametric statistical tests, the Wilcoxon signed-rank test (W) assessed for differences within groups, and the Mann-Whitney U test (U) was used to find comparisons between outcome measures of groups and within the groups. A p-value <0.001 was considered statistically significant.

Results:

This retrospective study enrolled 81 participants, of which 51 in home-based physiotherapy group (HPT) and 31 were in clinic-based physiotherapy group (IPT). Baseline differences between age and gender distribution among demographic data is assessed using Mann-Whitney U test and Pearson chi-square test are shown in Table 1 among the total number of participants showing significantly differed in age but no statistical significant difference in gender distribution between male and female.

Table 1: Baseline demographic data representing Median values

Demographic data, Median	Clinic-based Physiotherapy group (n = 30)	Homecare-based Physiotherapy group (n = 51)	Statistical test	Test statistic	p-value
Age (Years)	68	73	Mann-Whitney U test	U = 493; Z = -2.665	0.008
Female	8	16	Pearson chi-square test	$X^2 = 0.201$	0.654
Male	22	35			

Within-group changes in BBS and UEFS scores in each intervention group were assessed using Wilcoxon signed-rank test, a non-parametric test for comparing paired measurements, which demonstrated statistically significant improvements in BBS (Z = -4.379, p < 0.001; Z = -5.972, p<0.001) and UEFS (Z = -4.460, p<0.001; Z = -5.845, p<0.001) among IPT and HPT groups respectively as shown in Table 2.

Table 2. Within-Group Changes in BBS and UEFS Scores: Wilcoxon signed-rank test

Group	Outcome	Improved	Unchanged	Declined	Wilcoxon Z	p-value
IPT	BBS	25	5	0	−4.379	< .001
	UEFS	26	4	0	−4.460	< .001
HPT	BBS	47	4	0	−5.972	< .001
	UEFS	47	4	0	−5.845	< .001

Between-group intervention comparison of Post-scores using Mann-Whitney U test showed no statistically significant difference between both groups; IPT & HPT in post-intervention among BBS and UEFS scores, with analysis values of U = 626.5, Z = –1.356, p>0.001; U = 597.0, Z = –1.522, p> 0.001, respectively. The IPT group had higher median post-intervention BBS and UEFS scores than HPT group, indicating good improvement with a clinic-based multimodal integrated physiotherapy program, as shown in Table 3.

Table 3. Between-Group Changes in BBS and UEFS Scores: Mann-Whitney U test

Post-intervention Outcome	IPT	CPT	Mann-Whitney U	Wilcoxon Z	p-value
BBS	40.5	33.5	626.5	-1.356	> .001
UEFS	38	35.6	597	-1.522	> .001

Mann-Whitney U test showed that difference in BBS change scores between groups was not statistically significant (U = 641.5, Z = -1.211, p>0.001). The median BBS change score was 6 in IPT and 8 in HPT; although HPT had a higher median change score, the difference was not statistically significant. Whereas in contrast, between-group comparison of UEFS change scores demonstrated a statistically significant difference (U = 459, Z = -2.792, p=0.005), with median UEFS change score being 5.2 in IPT and 10 in HPT, showing a statistically significant difference post-intervention, as shown in Table 4.

Table 4. Comparison of BBS and UEFS Change Scores between Intervention groups using Mann-Whitney U test

Post-intervention Outcome	IPT, median	CPT, median	Mann-Whitney U	Wilcoxon Z	p-value
BBS change score	6	8	641.5	-1.211	> .001
UEFS change score	5.2	10	459	-2.792	0.005

Altogether, the findings indicate that both groups improved significantly within groups on both outcome measures. The between-group change score analysis identified a statistically significant difference for UEFS, but not for BBS.

Discussion:

This study demonstrated that both clinic-based IPT and home-based physiotherapy (HPT) significantly improve balance and upper limb function in patients with Parkinson's. The findings demonstrated statistically significant pre-post improvements in BBS and UEFS scores within both groups. However, clinic-based multimodal integrated rehabilitation improved both outcome scores post-intervention, but UEFS change scores differed significantly from BBS change scores in the Homecare physiotherapy protocol because the sample sizes were different (HPT = 51 and IPT = 30). Importantly, findings do not establish superiority of any intervention programme across both outcomes. The observed changes may reflect not only intervention effects but also differences in initial functional status, age-related characteristics, stage of Parkinson's, prevalence and as per patient's motor and non-motor symptoms, opportunities for improvement, and other participant-level factors.

The improvements observed in IPT group are explained by potential contribution of structured, task-oriented rehabilitation, progressive exercise challenges, postural-control training and repeated functional practice. These support motor learning, movement co-ordination, postural adjustments and confidence during functional activities 15. The significant improvement in HPT exercises can provide repeated practice of fundamental movements, strengthening, flexibility, transfers and basic balance tasks. The significant baseline differences in BBS scores are particularly relevant. Participants who begin with different balance abilities may have different opportunities for measurable improvement. Those with lower initial scores may have more room to improve, whereas participants with relatively high baseline scores encounter ceiling effects. This challenges assumption that more advanced or technologically supported intervention will necessarily produce greater improvement across all functional outcomes.

Upper extremity function depends on several interacting factors, including muscle strength, joint mobility, coordination, motor control, task and environment familiarity, pain, endurance, and ability to perform meaningful daily activities. Baseline UEFS differences also require careful consideration. Participants with different initial levels of functionality may respond differently to treatment, and baseline severity, measurement variability, regression to the mean, and ceiling/floor effects can influence change scores. Conventional rehabilitation may remain effective, accessible, and particularly suitable for any selected functional goals at task-specific or environment-specific at home, aiding familiarity with functional daily activities supporting UEFS outcomes improvement. These findings should be interpreted in significance baseline differences between groups, which influence comparisons

Advanced interventions offer opportunities for structured progression, objective monitoring, task-specific practice and greater individualisation incorporated into treatment, which facilitates more systematic assessment of movement performance and more precise modification of exercise difficulty. From a clinical service perspective, an integrated approach appropriately suits the use of advanced assessment and rehabilitation tools. Cognitive attention is an important consideration in IPT, involving more than physical repetition of movements. Participants must attend to instructions, understand task, maintain concentration, respond to feedback, and adjust movement strategies according to performance. In a structured clinic environment for therapist-guided practice, immediate feedback, active participation in goal-directed tasks, and rehabilitation activities are incorporated with attention to movement quality, sequencing, decision-making and problem-solving. These elements help patients remain engage with rehabilitation process and practise movement which mimics functional goals whereas at familiar environment as in HPT they perform and do practice with ADL's which resulted into present finding. The effect of a multimodal protocol depends on its content, dose, participant characteristics, adherence, and quality of intervention.

Understanding prognostic factors of Parkinson's disease, symptom onset at older age and clinical presentation dominated by rigidity and hypokinesia (reduced movement) are associated with faster motor progression and an increased risk of earlier cognitive decline. In contrast, a tremor-dominant presentation is often associated with slower rate of disease progression and longer-lasting response to levodopa therapy, although individual outcomes vary considerably. Male sex, the presence of multiple comorbidities, postural instability, and gait disturbances may also be associated with more rapid motor deterioration and increased functional limitations. Furthermore, older age, development of dementia, and poor response to dopaminergic therapy are associated with earlier loss of functional independence and reduced survival. These prognostic factors can help guide clinical monitoring, rehabilitation planning, and patient-centred

care; however, they indicate general patterns rather than predict an individual patient's disease trajectory with certainty 16.

Importantly, pwP experiencing respiratory infection risk, poor immune function, and post-COVID era practical considerations of travel, visiting clinics, exposure to different people, duration and proximity, with individual susceptibility, have increased vulnerability to frequent illness, aiding comorbidities like advanced age, chronic neurological conditions, cardiopulmonary conditions, along with parkinson's. Home-care physiotherapy is suitable for continuity of care and rehabilitation accessibility supports flexible delivery of services, which is not only safer but also more effective with substantial balance impairment, fall risk, or complex mobility restrictions or functional impairments.

Limitations of present study defied were random allocation, adequate sample size, and baseline-adjusted statistical models. For future recommendations, an intervention protocol with details on exercise content, intensity, frequency, and progression differences can be established. Longer follow-ups would be important to check for intervention effects. Additional outcome measures such as functional assessment, falls, cognitive performance and quality of life should be defined.

Conclusion:

The present study demonstrated statistically significant pre-post improvements in BBS and UEFS scores in both Clinic-based integrated interventions and Home-based conventional intervention groups. These findings indicate that both rehabilitation approaches were associated with improvements in measures of balance and upper extremity function during study period. The between-group analysis didn't identify statistically significant difference in BBS change scores; in contrast, UEFS change scores differed significantly between groups, with greater observed improvement in home-based intervention group. This finding highlights continuity of clinical value, task-oriented therapeutic exercises across every functional domain. Clinic-based multimodal integrated approaches may complement home-based exercises through structured assessment and targeted practice, along with functional training. In post-COVID context, rehabilitation services should consider travel-related exposure, individual respiratory risk, continuity of care and appropriate infection-prevention measures. Clinic-based rehabilitation may provide supervised practice and opportunities for active cognitive-motor engagement, while home-based options may improve accessibility for selected patients. In conclusion, the findings support clinical usefulness of both intervention approaches for outcomes measured, while indicating statistically significant between-group difference in upper-extremity functional change favouring home-based intervention group. Further adequately powered studies using baseline-adjusted analyses, standardised interventions and broader functional outcomes are needed to clarify comparative effectiveness and optimal clinical application of clinic-based and home-based physiotherapy.

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