

A Critical Review of the Evidence on the Effectiveness of Combined Perturbation-based Balance and Dual-task Gait Training for Enhancing Dynamic Stability in Parkinson's Patients

Akansha Roy¹, Dr. Belle Sharvani P. T², Dr. Preethu Mohanan K K³, Dr Manjunatha H⁴

^{1,2,3,4}Akash Institute of Physiotherapy, Bengaluru

Correspondence: Akanksha Roy, Physiotherapist, Akash Institute of Physiotherapy, Bangalore,

doi: 10.51505/ijmshr.2026.10409

URL: <http://dx.doi.org/10.51505/ijmshr.2026.10409>

Received: July 31, 2026

Accepted: Aug 04, 2026

Online Published: Aug 07, 2026

Abstract

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by gait impairment, postural instability, reduced dynamic balance, and an increased risk of falls, leading to decreased functional independence and quality of life. This literature review aimed to evaluate the effectiveness of combined perturbation-based balance training (PBT) and dual-task training (DTT) on dynamic stability in individuals with Parkinson's disease. A comprehensive search of PubMed, Google Scholar, ScienceDirect, Cochrane Library, and MDPI databases was conducted to identify studies published between 2020 and 2025. Randomized controlled trials and systematic reviews meeting the predefined inclusion criteria were reviewed. The available evidence suggests that combining PBT with DTT improves reactive postural control, gait speed, stride length, cadence, dynamic balance, functional mobility, and cognitive-motor performance while reducing fall risk. These interventions enhance sensorimotor integration and motor automaticity, resulting in better dynamic stability during functional activities. Overall, the findings indicate that combined PBT and DTT is a promising rehabilitation strategy for individuals with Parkinson's disease. However, further high-quality randomized controlled trials with standardized intervention protocols are required to confirm long-term clinical effectiveness and support evidence-based rehabilitation practice.

Keywords: Parkinson disease, dual tasking, Dynamic stability, perturbation-based training, balance, Gait impairment, Postural control

1. Introduction

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder characterized by the degeneration of dopaminergic neurons in the substantia nigra of the basal ganglia, leading to progressive impairment of motor and non-motor functions. The World Health Organization (WHO) recognizes Parkinson's disease as one of the fastest-growing neurological disorders worldwide and a major contributor to disability and reduced quality of life among older adults.

Clinically, PD is characterized by the cardinal motor features of bradykinesia, resting tremor, muscular rigidity, and postural instability, along with non-motor symptoms including cognitive impairment, depression, autonomic dysfunction, sleep disturbances, and sensory abnormalities. These manifestations progressively limit functional independence and participation in activities of daily living.

The prevalence of Parkinson's disease increases markedly with advancing age. Globally, more than 8.5 million people were living with Parkinson's disease in 2019, and the disease burden has more than doubled over the past three decades. Approximately 1% of individuals aged over 60 years and 3–5% of those aged over 85 year are affected by Parkinson's disease. The global incidence is estimated to range between 8 and 18 cases per 100,000 person-years, with incidence increasing substantially in older adults. Population ageing, increased life expectancy, environmental risk factors, and improved diagnostic awareness have contributed to the continuous rise in the prevalence of PD. Consequently, Parkinson's disease has become a significant public health challenge associated with increased healthcare expenditure, caregiver burden, disability, and mortality.

Gait and balance impairments are among the most disabling manifestations of Parkinson's disease. Individuals with PD commonly exhibit reduced gait speed, shortened stride length, decreased cadence, freezing of gait, impaired anticipatory and reactive postural adjustments, and difficulty adapting to environmental changes. Deficits in postural control arise from impaired sensorimotor integration and reduced motor automaticity, resulting in poor dynamic stability and increased susceptibility to falls. These impairments become more pronounced during dual-task activities, where simultaneous cognitive and motor demands interfere with walking performance. Approximately 60% of individuals with Parkinson's disease experience at least one fall annually, while nearly two-thirds experience recurrent falls, contributing to fractures, hospitalization, fear of falling, reduced mobility, and loss of independence. Therefore, improving dynamic stability and reducing fall risk remain primary goals of physiotherapy rehabilitation.

Among the various physiotherapy interventions, perturbation-based balance training (PBT) has emerged as a task-specific rehabilitation strategy that repeatedly exposes individuals to controlled external perturbations to improve reactive postural responses, balance recovery, and gait adaptability. Similarly, dual-task training (DTT) combines cognitive and motor tasks to improve motor automaticity, cognitive-motor coordination, gait performance, and functional mobility. Several randomized controlled trials and systematic reviews have demonstrated that perturbation-based balance training improves reactive balance control, postural stability, gait performance, and reduces fall risk. Likewise, dual-task training has been reported to enhance gait speed, stride length, balance, executive function, and activities of daily living in individuals with Parkinson's disease. These findings highlight the potential of both interventions in addressing the complex motor and cognitive impairments associated with PD.

Despite the demonstrated effectiveness of perturbation-based balance training and dual-task training as independent rehabilitation interventions, evidence evaluating their combined effect on dynamic stability in individuals with Parkinson's disease remains limited and inconclusive. Since dynamic stability depends on efficient reactive postural control together with cognitive-motor integration, combining these interventions may provide greater improvements in balance, gait performance, functional mobility, and fall prevention than either intervention alone. However, the available literature has not been comprehensively synthesized to determine the effectiveness of this combined rehabilitation approach. Therefore, the present literature review aims to evaluate the available evidence regarding the effectiveness of combined perturbation-based balance training and dual-task training on dynamic stability in individuals with Parkinson's disease, thereby providing evidence to support physiotherapy practice and future clinical research.

2. Method

The current study mapped the recent evidence through a literature review to evaluate the effectiveness of combined perturbation-based balance training (PBT) and dual-task training (DTT) on dynamic stability in individuals with Parkinson's disease. A comprehensive literature search was conducted, and a total of 48 articles were identified using relevant keywords and Boolean operators such as Parkinson's disease, perturbation-based balance training, dual-task training, gait training, dynamic stability, postural control, and balance. The electronic databases and search engines were used for the literature search, PubMed, Google Scholar, ScienceDirect, Cochrane Library, and MDPI.

The studies published between 2020 and 2025 were systematically screened in accordance with the PRISMA guidelines that included Randomized Controlled Trials (RCTs), systematic reviews and meta-analyses, case-control studies, and observational studies which stressed on perturbation-based balance training, dual-task training, or their combined effects on gait, balance, dynamic stability, postural control, functional mobility, and fall prevention in individuals with Parkinson's disease. Initial screening process of 29 articles were scrutinized based on their titles, abstracts, full-text availability, and English language eligibility. The selected studies were then critically evaluated using the Critical Appraisal Skills Programme (CASP) checklist to assess their methodological quality and risk of bias. Among these, 10 articles achieved a CASP score greater than 9 and were considered to be of high methodological quality. These studies were subsequently included in the final review and narratively synthesized by comparing their methodological characteristics, intervention protocols, outcome measures, and reported findings to analyse the overall effectiveness of combined perturbation-based balance training and dual-task training on dynamic stability in individuals with Parkinson's disease.

3. Literature Review

A comprehensive literature reviewed were mapped based on level of evidence.

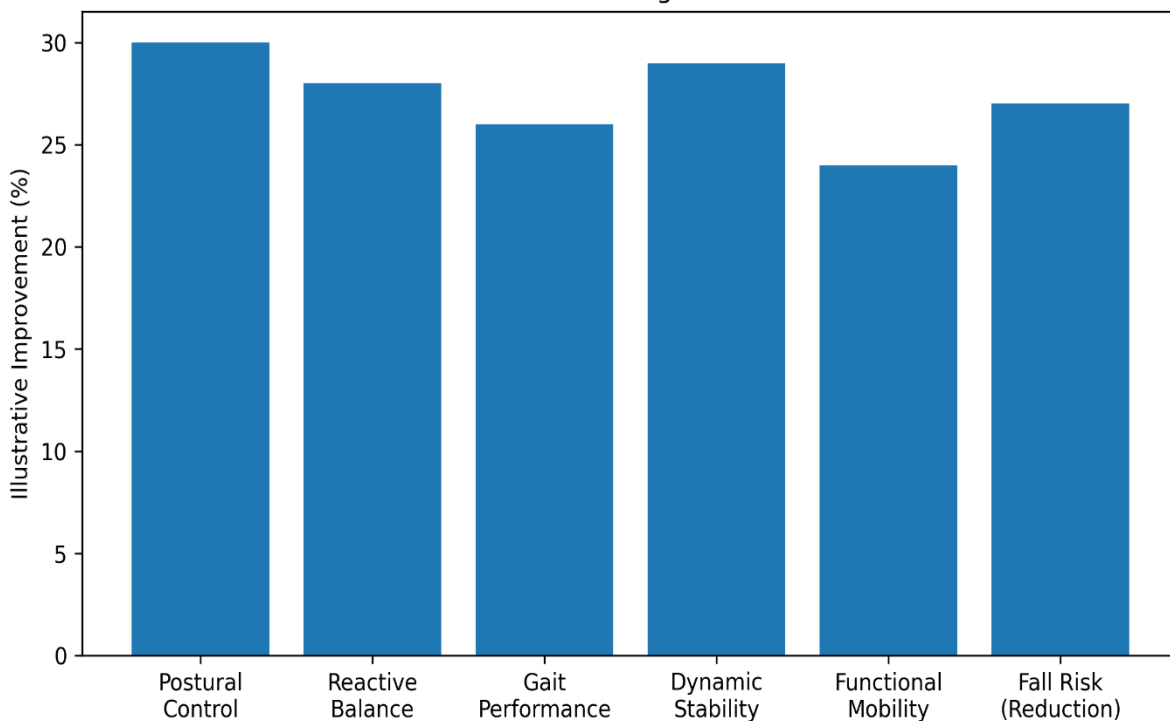
- i) ***Perturbation based Balance Training:*** Cardini et al. (2026) reported that combined perturbation-based balance training and dual-task gait training significantly improved dynamic stability, gait adaptability, and reduced fall risk in individuals with Parkinson's disease. Similarly, Konitsiotis and Lyros (2026) concluded that perturbation-based rehabilitation improves balance recovery, gait performance, and postural control. García-López et al. (2023) demonstrated significant improvements in dynamic balance and gait stability, while Hulzinga et al. (2021) found that repeated perturbation training enhanced reactive balance and gait adaptability. Overall, these studies suggest that perturbation-based balance training is an effective intervention for improving dynamic stability and reducing fall risk in individuals with Parkinson's disease.
- ii) ***Dual-Task Gait Training:*** Wallin et al. (2025) reported that dual-task gait training significantly improves gait speed, stride length, dynamic balance, and cognitive-motor performance in individuals with Parkinson's disease. Similarly, Sarasso et al. (2024) demonstrated that dual-task gait training was more effective than conventional gait rehabilitation in enhancing walking performance and functional mobility. Furthermore, Du et al. (2023) concluded that dual-task interventions produced significant improvements in gait, balance, and mobility while reducing fall risk. Collectively, these studies indicate that dual-task gait training is an effective rehabilitation approach for improving gait performance, dynamic balance, and functional mobility in individuals with Parkinson's disease.
- iii) ***Combined effect on Perturbation based Balance Training & Dual-Task Gait Training:*** Cardini et al. (2026) reported significant improvements in reactive balance, dual-task gait, gait adaptability, and reduced fall risk with combined training. Similarly, Wallin et al. (2025) highlighted that perturbation-based, task-specific balance interventions enhanced postural control and functional mobility. Overall, the evidence suggests that combining PBT and DTT is an effective approach to improve dynamic stability and reduce falls in Parkinson's disease. Furthermore, systematic reviews by García-López et al. (2023) and Coelho et al. (2022) concluded that dual-task training effectively enhances gait and dynamic balance, whereas perturbation-based balance training improves reactive postural control, gait performance, and reduces falls in people with Parkinson's disease. Collectively, these findings indicate that integrating perturbation-based balance training with dual-task gait training provides a comprehensive and effective rehabilitation strategy for enhancing dynamic stability, functional mobility, and fall prevention in individuals with Parkinson's disease.

4. Result

The literature review included 4 systematic reviews & meta-analyses, 4 randomized controlled trials (RCTs), and 2 clinical trial (case-control) studies that reviewed the effectiveness of perturbation-based balance training (PBT) and dual-task gait training in individuals with Parkinson's disease. The evidence consistently demonstrated that PBT improves postural control,

reactive balance, gait performance, and dynamic stability, while dual-task gait training enhances gait speed, stride length, cadence, motor automaticity, cognitive-motor coordination, and functional mobility.

Furthermore, both interventions were associated with a reduction in fall risk. Overall, the findings suggest that combining perturbation-based balance training with dual-task gait training may offer a more effective rehabilitation strategy for improving dynamic stability, gait, balance, and fall prevention in individuals with Parkinson's disease. Studies evaluating the combined application of PBT and DTT suggested greater improvements in dynamic stability and functional mobility than conventional rehabilitation alone, supporting the integration of both interventions into physiotherapy practice.



Graph 1- Summary of benefits of PBT+ DTGT in PD

5. Discussion

Parkinson's disease effects postural instability, gait impairment, and reduced cognitive-motor coordination, increasing the risk of falls. The reviewed evidence suggests that combining perturbation-based balance training (PBT) with dual-task gait training significantly improves balance, gait performance, postural control, dynamic stability, motor automaticity, and functional mobility while reducing fall risk. These findings support the use of this combined task-specific rehabilitation approach as a more effective intervention than conventional therapy.

However, variations in study protocols, treatment duration, outcome measures, and disease severity limit direct comparison. Further high-quality randomized controlled trials are needed to confirm its long-term effectiveness.

The beneficial effects of perturbation-based balance training observed across the reviewed studies may be attributed to improvements in reactive postural control and sensorimotor adaptation. Repeated exposure to controlled external perturbations enhances rapid compensatory stepping responses, improves balance recovery, and increases the ability to respond effectively to unexpected environmental disturbances. Several randomized controlled trials and systematic reviews included in this review consistently reported improvements in postural stability, gait adaptability, and reductions in fall risk following perturbation-based balance training, supporting its role as an effective rehabilitation strategy for individuals with Parkinson's disease.

Similarly, the reviewed evidence indicates that dual-task training improves gait speed, stride length, dynamic balance, motor automaticity, and cognitive-motor coordination. Since walking in daily life frequently requires simultaneous cognitive processing, dual-task training enhances the ability to divide attention while maintaining stable gait performance. The reviewed systematic reviews and randomized controlled trials demonstrated significant improvements in functional mobility and reductions in gait deterioration during cognitively demanding activities, thereby contributing to better dynamic stability in individuals with Parkinson's disease.

An important observation of this review is that the combined application of perturbation-based balance training and dual-task training appears to provide greater functional benefits than either intervention alone. While perturbation-based balance training primarily enhances reactive balance responses and postural recovery, dual-task training improves motor automaticity and cognitive-motor integration. Their combined application simultaneously targets multiple components of postural control, which may explain the greater improvements observed in gait performance, dynamic stability, functional mobility, and fall prevention. This integrated rehabilitation approach is consistent with the principles of task-specific training and neuroplasticity, which emphasize repetitive and functionally relevant practice to optimize motor learning and functional recovery.

Despite these encouraging findings, several limitations should be considered. The included studies demonstrated considerable heterogeneity in intervention protocols, treatment duration, outcome measures, disease severity, and sample size, limiting direct comparison of findings. In addition, only a limited number of studies specifically investigated the combined effect of perturbation-based balance training and dual-task training, and long-term follow-up outcomes were not consistently reported. These methodological variations highlight the need for well-designed randomized controlled trials with standardized intervention protocols, larger sample sizes, and longer follow-up periods to establish stronger evidence regarding the effectiveness of the combined intervention.

Conclusion

The current literature study shows higher evidence rate in Perturbation-based balance training (PBT) combined with dual-task gait training as an effective rehabilitation approach for improving dynamic stability in Parkinson's disease. The review summaries the component that showed higher evidence in a hierarchy are postural control, dynamic stability, fall risk reduction, reactive balance, gait mobility followed by functional mobility. Hence as combined intervention enhances motor automaticity, and cognitive-motor integration and improving quality of life.

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