



REHABILITATION APPROACHES FOR FREEZING OF GAIT IN PATIENT'S WITH PARKINSON'S DISEASE – SYSTEMATIC REVIEW

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ABSTRACT

Freezing of gait (FOG) is a disabling symptom in Parkinson's disease (PD), leading to falls and reduced mobility. Despite various rehabilitation strategies, a consensus on the most effective interventions remains unclear. This systematic review evaluates rehabilitation approaches for mitigating FOG severity and improving gait in PD patients. A literature search was conducted in PubMed, Embase, and Cochrane Library for studies assessing rehabilitation interventions for FOG in PD. Eligible studies included randomized controlled trials (RCTs) and controlled trials that evaluated motor and cognitive-based therapies. Various interventions, including cueing strategies, physical therapy, cognitive training, and neuromodulatory techniques, showed improvements in gait parameters and FOG reduction. However, heterogeneity in methodologies limited direct comparisons. While no single intervention proved superior, combined physical and cognitive approaches appear promising. Future research should focus on standardizing protocols and evaluating long-term outcomes.

KEYWORDS

INTRODUCTION

Freezing of gait (FOG) is a highly disabling motor symptom that is commonly experienced by individuals with Parkinson's disease (PD). However, despite its negative consequences and prevalence, there is currently no effective treatment for FOG and it does not respond well to the treatments currently used for PD, such as dopamine replacement or deep brain stimulation.¹

The cognitive contribution to freezing is hypothesized to be due to an over-demand of cognitive resources that are being used to control walking and complete a secondary task, thus leading to a freezing episode.¹

FoG is defined as a "brief, episodic absence or marked reduction of forward progression of the feet despite the intention to walk. Episodes can be brief or exceed 30 sec. Specifically, three patterns of FoG have been distinguished including: 1) trembling in place, shuffling forward, and 3) complete akinesia. These episodes are more likely to occur when initiating walking, turning, and passing through narrow passages or certain circumstances such as approaching a destination

Parkinson's disease is a progressive neurological disorder with a prevalence of 328 cases out of over 10,000 people in India. It is caused by a degeneration of dopamine-producing cells in the substantia nigra(1)

Clinical symptoms that impact gait pattern and motor performance include bradykinesia, rigidity, tremors, and postural instability (2). It is hypothesized that a malfunction in the putamen thalamus supplementary motor area causes the motor symptoms associated with Parkinson's disease (2).

Parkinson's disease is most commonly characterized by gait disturbance and freezing of gait (FOG). Approximately 38.2% of Parkinson's patients have FOG (4).

FOG is characterized as a brief, episodic absence or a significant decrease in foot forward motion even when walking is intended. About 80% of people with severe Parkinson's disease have FOG, which is the most common cause of dependency and falls (5)

Freezing of gait (FOG) affects more than one-third of individuals with Parkinson's disease (PD), and it is a common cause of falls, dependency, and poor quality of life.

FOG is a complex phenomenon and its pathophysiology remains unknown. FOG typically occurs during step initiation and turns, likely due to abnormal postural preparation for step initiation.

Individuals with FOG (freezers) show delayed step initiation

associated with repetitive anticipatory postural adjustments (APAs) as if they cannot inhibit their postural preparation and release their stepping motor program. In fact, FOG has been associated with small and prolonged APAs during step initiation and deficits in cognitive inhibition

The chance of becoming unbalanced and falling was further raised by the tiny steps and FOGG during turning. Reducing turning difficulty in individuals with Parkinson's diseases is crucial for fall prevention because turning is a crucial part of functional upright mobility (6).

To improve the cognitive mechanisms of FOG, cognitive training may be utilized as a therapy. Several studies involving individuals with PD have investigated this type of treatment, and have demonstrated improvements in general cognitive function, 14-19 as well as in the specific executive function domains, which may be responsible for FOG (ie, set-shifting ability and inhibitory control).

A collection of compensatory techniques called cognitive movement strategies is used to enhance mobility function in Parkinson's disease patients. The idea behind cognitive movement strategies is to break down a difficult motor task into manageable steps. Thus, before performing a task, those suffering from Parkinson's disease can continuously plan and practice it (6).

2. MATERIALS AND METHODS

Study Design

This systematic review follows PRISMA guidelines and includes RCTs and controlled trials that assess rehabilitation interventions for FOG in PD.

Eligibility Criteria

Inclusion Criteria:

- Studies involving PD patients experiencing FOG.
- Rehabilitation-focused interventions (e.g., cueing strategies, physical therapy, cognitive training, neuromodulation).
- Outcome measures assessing gait parameters, FOG severity, fall incidence, and quality of life.
- RCTs and controlled trials.

Exclusion Criteria:

- Studies without specific FOG outcome measures.
- Case reports, review articles, and non-English publications.

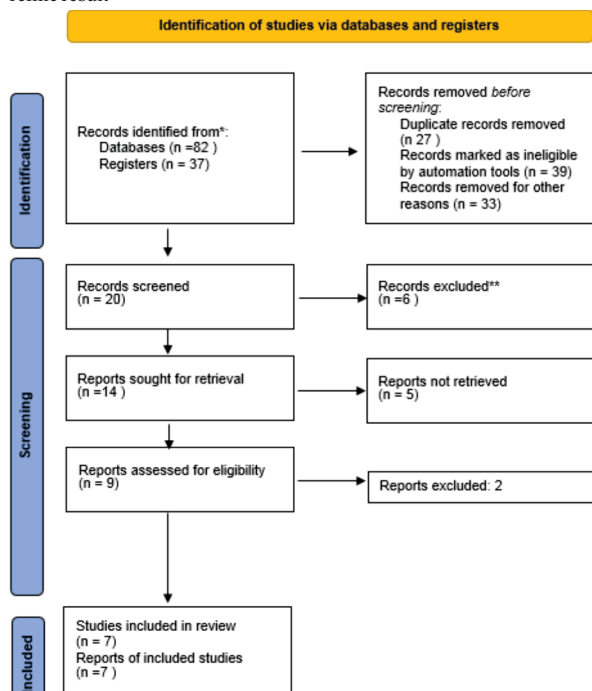
Source of Research

A systematic search was performed in PubMed, Embase, and the Cochrane Library for articles published up to [November 2023]. Additional sources included references from key studies.

Search Strategy

Keywords used included "Parkinson's disease," "freezing of gait,"

"rehabilitation," "cueing strategies," "cognitive training," and "neuromodulation." Boolean operators (AND, OR) were applied to refine result



Review Of Literature

- 1) Yu-An Che With an external focus, the non-FOG group displayed shorter ring-touching times and less variability in step length. When compared to external-focus and no-focus instructions, the FOG group demonstrated reduced step length variability, decreased cadence, increased gait velocity, and longer step lengths with internal-focus instructions. In a study titled "Attentional focus effect on dual-task walking in Parkinson's disease with and without freezing of gait," et al. (2023) found that while both internal-focus and external-focus training decreased FOG and falls following intervention, only internal-focus training decreased TUG and TUGdt in both medication-on and medication-off states. The study sought to understand (i) how attentional focus affected dual-task walking immediately in participants with and without FOG, and (ii) how attentional focus affected walking, FOG, and falls during training. According to the study's findings, an external-focus technique can improve walking automaticity in people without frontal lobe gaze disorder (FOG) and free up attention for the secondary task. Comparing internal-focus and no-instruction strategies to external-focus and no-instruction strategies, PD patients with FOG may experience reduced gait variability, a longer step length, and a faster gait speed.
- 2) The effect of transcranial direct current stimulation combined with visual cueing training on motor function, balance, and gait ability of patients with Parkinson's disease was studied by Si-A Lee et al. in 2021. The purpose of the study was to look into how patients with Parkinson's disease (PD) responded to transcranial direct current stimulation (tDCS) in terms of their ability to walk, balance, and motor function. They found that using tDCS to treat PD patients' supplementary motor areas is beneficial as an adjuvant therapy for PD patients' rehabilitation instruction.
- 3) Rebecca Chow et al.(2021) conducted a study on "Investigating Therapies for Freezing of Gait Targeting the Cognitive, Limbic, and Sensorimotor Domains". The purpose of the study was to find out if these three treatments could enhance FOG's functional outcomes. There were differences in the ways that the cognitive and proprioceptive treatments seemed to improve FOG. Therefore, FOG may benefit from either of these interventions as a viable treatment. Nevertheless, given the study's relatively small participant count, the results may still be affected even though they were statistically significant. Given equal time for each intervention and the significant results along with no significant trends in the gait and FOG measures, proprioceptive training yielded the most consistent benefits in this study.

- 4) Laurie A King ET AL,(2020) conducted a study on "Cognitively Challenging Agility Boot Camp Program for Freezing of Gait in Parkinson Disease". The goals were to ascertain (1) whether an Agility Boot Camp-Cognitive (ABC-C) program that is cognitively demanding is feasible and (2) how this intervention affects executive function, balance, FoG, dual-task cost, and functional connectivity. According to the study's findings, ABC-C is a workable exercise program that can help with executive function, balance, dual-task cost, FoG, PD, and brain connectivity. In order to fully determine the potential to improve FoG, future studies with a larger sample size and a longer duration should be designed with the effect sizes from this study in mind.
- 5) Elisa Pelosin et al.(2018) conducted a study on "Effect of Group-Based Rehabilitation Combining Action Observation with Physiotherapy on Freezing of Gait in Parkinson's Disease". The aim of study is to find out Effect of Group-Based Rehabilitation Combining Action Observation with Physiotherapy on Freezing of Gait in Parkinson's Disease. The study's findings confirm that AOT, as an explicit learning process, is effective in helping PD patients' FoG. As an adjunctive strategy for clinicians and physiotherapists, we have shown that this training is safe, feasible, and can be implemented even in a group setting.
- 6) Luis Santos et al,(2017) conducted a study on "Effects of progressive resistance exercise in akinetic-rigid Parkinson's disease patients: a randomized controlled trial". This study set out to evaluate the impact of PRE in patients with Parkinson's disease (PD) who also had rigidity and akinesia (AR-subtype). Because PRE training can enhance static posturography, gait, and quality of life, these results lend support to its use in the rehabilitation of patients with AR-subtype Parkinson's disease. Moreover, RPE scores demonstrated that people with AR-subtype Parkinson's disease believe PRE training calls for minimal effort.
- 7) Min Su Kim et al,(2015) conducted a study on "Efficacy of cumulative high-frequency rTMS on freezing of gait in Parkinson's disease". Enhancing FOG in Parkinson's disease patients may benefit from high frequency rTMS applied over the M1-LL as an adjuvant therapy. When comparing the rTMS condition to the sham condition, there were notable improvements in the steps needed to complete the SS-180 and FOG-Q, and the effects persisted for one week. In the rTMS condition, the TUG and UPDRS-III also demonstrated notable improvements over time. The MEP amplitude at 120% resting motor threshold and intracortical facilitation also increased after real rTMS condition. For enhancing FOG in Parkinson's disease, high frequency rTMS over the M1-LL may be used as an additional treatment.

RESULT

The reviewed studies present various rehabilitation strategies for freezing of gait (FOG) in Parkinson's disease (PD), targeting distinct physiological and cognitive mechanisms. Studies by Yu-An Chen et al. (2023) suggest that an internal focus strategy can lead to improved gait parameters, such as increased step length and reduced gait variability in PD patients with FOG, demonstrating a decrease in FOG episodes and fall rates. Similarly, Si-A Lee et al. (2021) found that transcranial direct current stimulation (tDCS) combined with visual cueing significantly enhances motor function, balance, and walking ability, providing an additional benefit to conventional rehabilitation methods.

Cognitive and proprioceptive training, as explored by Rebecca Chow et al. (2021), demonstrated improvements in FOG frequency and reliability, particularly with proprioceptive training, emphasizing the necessity for tailored treatment approaches. Laurie A King et al. (2020) highlighted the efficacy of a cognitively demanding agility boot camp in improving FOG ratios, balance, and neural connectivity, suggesting that cognitive-motor integration plays a vital role in PD rehabilitation. Additionally, Elisa Pelosin et al. (2018) demonstrated that action observation training (AOT) sustains improvements in motor performance and FOG control, presenting it as a viable adjunctive therapy.

Luis Santos et al. (2017) examined progressive resistance exercise (PRE), which improved postural control and quality of life, albeit with minimal impact on FOG-specific measures. In contrast, Min Su Kim et al. (2015) demonstrated that high-frequency repetitive transcranial magnetic stimulation (rTMS) over the lower limb motor cortex effectively reduced FOG severity, with effects lasting up to a week post-intervention. Collectively, these studies underline the potential of combining motor, cognitive, and neuromodulatory approaches to optimize treatment efficacy for FOG in PD patients.

Sr. No	Authors	Year	Type of Study	Intervention	Outcome Measures	Result	Analysis
1	Yu-An Chen et al	2023	RCT	2 Single Task Condition - walking interlocking ring 3 Dual Task walking – Internal focus External focus No instructions	Primary-TUG TUDdt Secondary MDS - UPDRS part III BBS	With an external focus, the non-FOG group displayed shorter ring-touching times and less variability in step length. When compared to external-focus and no-focus instructions, the FOG group demonstrated reduced step length variability, decreased cadence, increased gait velocity, and longer step lengths with internal-focus instructions. Following intervention, FOG and falls were decreased by both internal-focus and external-focus training, but TUG and TUGdt were only decreased by internal-focus training in both the on-medication and off-medication states.	The externally focused strategy of PD without FOG improves walking automaticity and frees up attention for other tasks. An internal-focus strategy, as opposed to an external-focus and no-instruction strategy, may result in PD patients with FOG walking more quickly, taking longer steps, and experiencing less variability in their gaits..
2	Si-A Lee et al	2021	RCT	EG-tDCS and Visual Cueing Simultaneously CG-Sham tDCS and Visual Cueing For 4 weeks	UPDRS FGA (functional Gait assessment) FOG-Q GAITRite system (gait velocity, cadence, Step time, Double support time, stride length)	Following the intervention, the experimental group demonstrated a significant increase in FGA and cadence and a significant decrease in UPDRS. Furthermore, a noteworthy distinction was observed between the pre-intervention and follow-up tests in terms of UPDRS and cadence.	According to a study, tDCS in addition to physical training can benefit PD patients' motor function, balance, and walking ability more than physical training alone.
3	Rebecca Chow et al	2021	RCT	Cognitive Training – computer-aided cognitive training using the web-based version of the Smart Brain tool. Limbic Training – Cognitive Behavioral Therapy one-on-one sessions with a trained psychotherapy master student supervised by a faculty member who was an experienced clinical psychotherapist. Proprioceptive Training-target-reaching	Trail-Making Test, Strop Test, Parkinson Anxiety Scale (PAS), FOG-Q Gait assessment	During the dual-task gait assessment, there were no significant effects observed in the trail-making test, Strop Test, PAS, UPDRS-III scores, NFOGQ scores, or secondary task error. Following proprioceptive training, there was a significant improvement in passive upper limb joint-angle matching in both the 30° and 60° conditions. Main-effect improvements in FOG frequency and reliability were noteworthy after cognitive treatment.	The results of this study indicate that training in both cognition and proprioception may enhance the frequency and duration of facial expressions of gross motor function. Consequently, each of these interventions may be used as a good course of treatment for FOG; however, tailored treatment plans may be required. To validate them with more participants, more work is required.
4	Laurie A King et al	2020	RCT	6 weeks of Agility Boot Camp- Cognitive program Exercises that are circuit and challenge cognitive-mobility skills (1) gait training, (2) functional skill training ²⁴ (3) agility obstacle course, (4) lunges, (5) boxing, and (6) adaptive tai chi And Educational care	FOG-Q, FOG ratio, Mini BEST, Scopa COG, Resting State Functional MRI, Trail Making Test.	A total of 108 candidates for PD and FOG were evaluated. Of these, 25 were randomly assigned to the Exercise first group and 21 to the Education first group, with the remaining 62 being excluded. Compared to education, exercise showed greater improvements with baseline FoG ratios ($r=-0.41$, $p=0.01$), but not with education. After exercise but not after education, the overall mini-BES Test revealed a moderate effect size. As seen in Figure 3D, the right SMA-PPN only displayed a significant effect size following exercise. In particular, the connectivity between right SMA and PPN was decreased in the 13 participants with imaging after exercise but not after education.	Age requirements extends across a wide age range. To ascertain whether rehabilitation can enhance FoG in Parkinson's disease, more research with longer, larger trials is required.

5	Elisa Pelosin et al	2018	RCT	During each group-based training session, two different video clips were presented twice and the complexity of the actions increased progressively over the sessions AOT = Precisely, the six actions recorded in the video clips were the following: (1) shifting the body weight from one foot to the other; (2) shifting the body weight from one foot to the other making a step forward, backward and to the side; (3) walking straight with long steps; (4) turning around a chair; (5) stepping over an obstacle after shifting the body weight from one foot to the other; (6) walking through a doorway LOT group = Precisely, during each training session LOT participants watched 2 video clips (each lasting 6 minutes and presented twice) displaying landscape scenes (e.g., pictures of mountains and seaside, countryside, and desert scenes).	FoG questionnaire, Timed Up and Go test, 10-meter walking test, and Berg balance scale	When the groups were assessed after the training, all outcome measures showed improvements in both. Only the AOT group maintained the improvements in the FoG questionnaire, Timed Up and Go test, and Berg balance scale at the FU-4w evaluation.	AOT group-based training may be added as an adjunctive option in PD rehabilitation programs because it is practical and effective on FoG and motor performance in PD patients.
6	Luis Santos et al	2017	RCT	Progressive resisted exercises	Static posturography (Centre of Pressure - CoP-parameters), gait (the Ten-Meter Walk Test [TMWT]), freezing of gait (the Freezing of Gait Questionnaire [FOG-Q]), the motor portion of the Movement Disorders Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) and patient-perceived quality of life (the 39-item Parkinson's disease Questionnaire [PDQ39]	Both the EG's PDQ39 Score and Length in Speed of Fast Rhythm Walking showed notable improvements. The motor component of the MDS-UPDRS scores, the speed of preferred rhythm walking (TMWT), the FOG-Q scores, and the Area or Speed (CoP parameters) did not show any significant differences. Throughout the entire training program, the EG reported an average RPE of 9.95, which falls between "very light" and "fairly light."	Due to its ability to enhance gait, static posturography, and quality of life, this study advocates for the use of PRE training in the rehabilitation of patients with AR-subtype Parkinson's disease. Moreover, RPE scores demonstrated that people with AR-subtype Parkinson's disease believe PRE training calls for minimal effort.
7	Min Su Kim et al	2015	RCT	EG - high frequency rTMS (90% of resting motor threshold, 10 Hz, 1,000 pulses) over the lower leg primary motor cortex of the dominant hemisphere (M1-LL) for five sessions in a week. CG- Sham Treatment	Standing Start 180° Turn Test (SS-180) with video analysis and the Freezing of Gait Questionnaire (FOG-Q). The secondary outcome measurements consisted of Timed Up and Go (TUG) tasks and the Unified Parkinson's Disease Rating Scale part III (UPDRS-III). Motor cortical excitability	When comparing the rTMS condition to the sham condition, there were notable improvements in the steps needed to complete the SS-180 and FOG-Q, and the effects persisted for a week. In the rTMS condition, the TUG and UPDRS-III also demonstrated notable improvements over time. Following the real rTMS condition, there was an increase in both the MEP amplitude at 120% resting motor threshold and intracortical facilitation.	Enhancing FOG in Parkinson's disease (PD) may benefit from high frequency rTMS over the M1-LL as an extra treatment.

DISCUSSION

The studies reviewed illustrate a diverse array of rehabilitation approaches targeting freezing of gait (FOG) in Parkinson's disease (PD), each addressing different underlying mechanisms. For instance, Yu-An Chen et al. (2023) demonstrated that strategies focusing on internal attention can lead to more consistent and efficient gait patterns in PD patients with FOG, as evidenced by improvements in TUG scores and reduced gait variability. In contrast, Si-A Lee et al. (2021) showed that combining transcranial direct current stimulation (tDCS) with visual cueing significantly enhances motor function, balance, and walking ability over a four-week intervention period, suggesting a synergistic benefit of neuromodulation with physical training.

This collection of studies highlights various strategies and interventions for addressing freezing of gait (FOG) in Parkinson's disease (PD). External-focused strategies, particularly those without specific instructions, seem beneficial for improving walking automaticity and attention allocation. Conversely, an internal-focus strategy may lead to faster walking, longer steps, and reduced gait variability in PD patients with FOG.

Rebecca Chow et al. (2021) explored cognitive, limbic, and proprioceptive training modalities and observed that while cognitive training did not significantly affect some standard neuropsychological tests, it did lead to notable improvements in FOG frequency and reliability, particularly after proprioceptive training. Similarly, Laurie A King et al. (2020) reported that a six-week Agility Boot Camp incorporating cognitive challenges yielded better outcomes in FOG ratios and gait performance compared to an educational control group, further emphasizing the importance of integrating motor and cognitive components.

Additionally, Elisa Pelosin et al. (2018) found that action observation training (AOT) maintained improvements in FOG and motor performance at follow-up, indicating its potential as a sustainable adjunctive therapy. Luis Santos et al. (2017) demonstrated that progressive resistance exercise (PRE) could improve aspects of gait and quality of life with minimal perceived exertion, particularly in patients with the AR subtype of PD, though changes in FOG-specific measures were less pronounced. Finally, Min Su Kim et al. (2015) provided evidence that high-frequency repetitive transcranial magnetic stimulation (rTMS) over the lower limb motor cortex can reduce FOG severity and improve motor performance, with effects lasting up to one week post-intervention.

Overall, these studies suggest that rehabilitation interventions—ranging from focused cognitive strategies and physical training to neuromodulatory techniques—can each contribute to mitigating FOG in PD. However, the heterogeneity in study designs, intervention protocols, and outcome measures underscores the need for standardized methodologies. Future research should aim to directly compare these approaches, identify the most effective combinations, and explore long-term benefits to optimize

CONCLUSION

Rehabilitation interventions, including cueing strategies, physical therapy, cognitive training, and neuromodulatory techniques, offer varying degrees of effectiveness in mitigating FOG in Parkinson's disease. While no single approach stands out as universally superior, multimodal strategies integrating motor and cognitive rehabilitation appear to yield the most promising results. The heterogeneity in intervention methodologies and outcome measures underscores the necessity for standardized research protocols. Future studies should prioritize longer follow-up durations, larger sample sizes, and direct comparisons between intervention types to establish optimal treatment guidelines for FOG rehabilitation in PD patients.

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