INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

ROBOT-ASSISTED GAIT TRAINING IN PATIENTS WITH PARKINSON DISEASE

Narrative Review

Muqadas Majeed[1], Muddasira Bashir[2], Rimsha Zaheer[3], Jannat Naveed[3], Wahaj Khan[4], Anbreena Rasool[5]*
[1]PT, DPT Riphah International University, MS-NMPT, The University of Faisalabad, Pakistan.
[2]DPT Government College University Faisalabad, MS-NMPT, The University of Faisalabad, Pakistan.
[3]DPT Riphah International University Faisalabad, MS-NMPT, The University of Faisalabad, Pakistan.
[4]DPT The University of Faisalabad, MS-NMPT, The University of Faisalabad, Pakistan.
[5]PT, Assistant Professor, Department of Rehabilitation Sciences, The University of Faisalabad, Pakistan.
Corresponding Author: Anbreena Rasool, PT, Assistant Professor, Department of Rehabilitation Sciences, The University of Faisalabad, Pakistan, assistant.professor.rehab.419@tuf.edu.pk
Acknowledgement: We sincerely thank the patients, healthcare providers, and all supporters who contributed to this study.

Conflict of Interest: None   Grant Support & Financial Support: None

ABSTRACT

Background: Gait impairment is one of the most disabling symptoms of Parkinson's disease (PD), significantly affecting mobility and quality of life. Parkinsonian gait abnormalities, including freezing and festinating gait, arise from basal ganglia dysfunction due to the degeneration of dopaminergic neurons, leading to reduced neuronal connections and impaired motor regulation. While pharmacological interventions targeting dopaminergic circuits are effective for some motor symptoms, gait impairments remain largely unresponsive to drug therapy, necessitating alternative management strategies.

Body: Recent advancements in neuro-rehabilitation have introduced interventions such as visual rehabilitation, tai chi, dance and music therapy, and robot-assisted gait training (RAGT). Among these, RAGT has emerged as a superior therapeutic approach due to its ability to promote neuroplasticity through task-specific, repetitive, and intensive training. By enhancing neuronal connectivity, RAGT addresses the underlying mechanisms of gait impairment in PD. The reviewed literature supports RAGT as an effective tool for improving gait mechanics, including stride length, gait speed, and overall mobility, making it a promising addition to rehabilitation protocols for PD.

Conclusion: This review underscores the potential of RAGT as a transformative intervention for managing gait impairments in Parkinson's disease. By promoting neuroplasticity and addressing the limitations of pharmacological treatments, RAGT offers a viable solution for enhancing mobility and quality of life in PD patients. Future research should focus on optimizing RAGT protocols and exploring its long-term efficacy.

Keywords: Basal ganglia, freezing gait, neuroplasticity, Parkinson disease, rehabilitation, robot-assisted gait training, walking disorders.

INTRODUCTION

Parkinson's disease (PD) is a progressive idiopathic neurodegenerative disorder marked by the gradual degeneration of dopaminergic neurons in the substantia nigra pars compacta, resulting in a dopaminergic deficit in the nigrostriatal pathway (1). This leads to motor symptoms such as bradykinesia, rigidity, resting tremor, and postural instability, alongside non-motor symptoms including autonomic dysfunction, cognitive decline, and sensory abnormalities. These multifaceted symptoms significantly impair the quality of life and functional independence of patients. Gait abnormalities are particularly debilitating, characterized by hypokinesia, shortened strides, decreased cadence, and increased double-limb support time, often persisting despite optimized medical and surgical treatments (2). Globally, PD is the second most common neurodegenerative disorder after Alzheimer's disease, with its prevalence increasing with age. It affects 1% of individuals over 60 years old, with its frequency rising to 4% in the oldest age groups. According to the Global Burden of Disease survey, 6.1 million cases of PD were reported in 2016, with a 21.7% increase in prevalence between 1990 and 2016, underscoring its growing societal and healthcare burden. Neurological disorders, including PD, are now the leading cause of disability and the second most common cause of mortality worldwide, accounting for 276 million disability-adjusted life years.

Postural instability, a hallmark of PD, exacerbates disability and increases the risk of falls, significantly impairing patients' quality of life. The complex etiology of postural instability includes impaired postural reflexes, diseased postures, excessive sway, and disordered sensory systems(3). Additionally, reduced gait automaticity, attributed to basal ganglia dysfunction, forces patients to consciously regulate walking, increasing the cognitive load and fall risk during dual-task scenarios (4). The limitations of pharmacological therapies in addressing these axial symptoms necessitate alternative interventions to enhance gait and mobility (5). Physical therapy and exercise-based interventions have shown promise in managing gait dysfunction and improving neuroplasticity in PD. Among these, robot-assisted gait training (RAGT) has emerged as a novel therapeutic modality. RAGT employs repetitive, task-specific locomotor training to promote cortical reorganization and neural plasticity (6). By enhancing balance, gait velocity, and coordination, RAGT offers a potential solution for managing axial symptoms refractory to pharmacological treatment (2). However, there is a lack of consensus on its superiority over traditional physical therapy, highlighting the need for a comprehensive review of its effectiveness.

This review aims to critically evaluate the impact of RAGT in improving gait, balance, and mobility in PD patients, comparing it with conventional therapies. By synthesizing the existing literature, this review seeks to provide clinicians and researchers with evidence-based insights to guide therapeutic decisions and advance the field of neuro-rehabilitation for PD.

BODY

Parkinson's disease is characterized by a progressive decline in dopaminergic transmission within the basal ganglia, disrupting motor control and gait automaticity. The depletion of dopamine in the sensorimotor regions impairs habitual motor regulation, forcing patients to rely on goal-directed control, which is less efficient and increases the cognitive burden (4). This loss of automaticity leads to gait hypokinesia, shorter stride length, reduced cadence, and increased double-limb support phase. These deficits are compounded by postural instability, a multifactorial impairment involving diseased postures, excessive sway, and poor compensatory strategies (3). The inability of pharmacological therapies to fully address these axial symptoms underscores the need for rehabilitative interventions that target the underlying neurophysiological deficits. Emerging evidence supports the role of neuro-rehabilitation programs in promoting neuroplasticity and improving functional outcomes in PD (7).

Physical therapy aims to preserve functional independence and mobility in PD patients. Traditional interventions, including resistance training, balance exercises, and cardiovascular activity, have been shown to improve gait velocity, step length, and postural stability (8). Goal-based aerobic exercise enhances neurochemical and mitochondrial function, promoting synaptic connectivity and neural circuit resilience. However, the variability in patient outcomes highlights the need for more targeted approaches. Robot-assisted gait training has garnered attention as a promising alternative to conventional therapy. By combining task-specific activity, high-intensity repetitive training, and multimodal stimulation, RAGT facilitates cortical reorganization and neural plasticity, addressing both motor and non-motor symptoms of PD (6).

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Studies have demonstrated the potential of RAGT to improve gait parameters, balance, and functional mobility in PD patients. Picelli et al. (2012) reported significant improvements in gait speed, cadence, and walking endurance following RAGT(2). Similarly, Capecci et al. (2019) highlighted its effectiveness in reducing freezing of gait and enhancing balance(5). Despite these findings, the superiority of RAGT over traditional therapies remains debated. A randomized controlled trial by Carda et al. (2013) found no significant difference between RAGT and conventional rehabilitation in addressing postural instability(9). Furthermore, Picelli et al. (2013) noted that equal-intensity treadmill training outperformed RAGT in improving gait parameters in patients with mild to moderate PD(10).

The therapeutic effects of RAGT are attributed to its ability to induce cortical reorganization through repetitive, task-specific training. By simulating natural gait patterns, RAGT promotes motor learning and neural connectivity (6). The use of exoskeletal and endoskeletal robots facilitates precise control of movement, allowing for tailored interventions based on individual needs. Additionally, RAGT may enhance cognitive-motor interactions, mitigating the dual-task deficits common in PD. Kang et al. (2019) proposed that RAGT improves functional connectivity within brain networks, potentially reducing the severity of freezing of gait and other axial symptoms(4).

While RAGT offers significant potential, several challenges limit its widespread adoption. The high cost of robotic devices and the need for specialized training pose barriers to implementation in resource-limited settings. Moreover, the heterogeneity in study designs and patient populations complicates the interpretation of results, necessitating standardized protocols and larger, multicenter trials. Future research should explore the long-term effects of RAGT, its impact on non-motor symptoms, and its integration with pharmacological and surgical treatments. Investigating the neurophysiological mechanisms underlying RAGT efficacy will further elucidate its role in PD management.

Comparative studies have yielded mixed results regarding the efficacy of RAGT versus traditional physical therapy. Sale et al. (2013) emphasized the importance of intensity and task specificity in driving motor improvements, suggesting that treadmill training may be equally effective for certain patient populations. However, RAGT's ability to provide consistent, high-intensity training with minimal fatigue offers a distinct advantage in managing advanced PD symptoms(8). Robot-assisted gait training represents a promising advancement in the rehabilitation of Parkinson's disease, addressing critical gaps in the management of gait and postural deficits. While evidence supports its efficacy in enhancing motor function and promoting neuroplasticity, further research is needed to define its role relative to conventional therapies and optimize its application in clinical practice. By advancing our understanding of RAGT's mechanisms and outcomes, this review aims to inform evidence-based strategies for improving the quality of life of individuals with PD.

DISCUSSION

Parkinson's disease is a progressive neurodegenerative disorder predominantly affecting the geriatric population, characterized by slowness of movement, rigidity, tremor, and postural instability. With an estimated prevalence of 1% among individuals over 60 years of age, the disease's gradual onset often begins with tremors, later progressing to more debilitating symptoms such as rigidity and gait abnormalities (11). As the disease advances, the emergence of postural instability and gait hypokinesia significantly impacts patients' quality of life, limiting mobility and participation in social activities (4), 2019). This review aimed to evaluate the effects of robot-assisted gait training (RAGT) on improving gait stability and functional independence in individuals with Parkinson's disease(12). The findings suggest that RAGT provides measurable benefits in patients with moderate to advanced Parkinson's disease, particularly in enhancing gait stability, stride length, cadence, and overall walking capacity. Robotic devices, by enabling forced and repetitive gait training, enhance exercise intensity and offer a structured approach to rehabilitation that traditional methods often fail to replicate (5). The outcomes from various studies align with the concept of task-specific, high-intensity training, which is crucial for promoting neuroplasticity and functional recovery in neurodegenerative conditions. Improvements in gait hypokinesia, freezing of gait (FOG), and walking endurance observed in RAGT studies indicate the modality's potential in addressing axial symptoms resistant to pharmacological treatments (10). These advancements are particularly relevant, as gait disturbances and postural instability remain among the most disabling features of Parkinson's disease(13).

Studies highlight that RAGT's effectiveness is primarily attributed to its ability to improve both stride length and cadence, essential components of gait speed. In some cases, secondary outcomes such as reduced fatigue and enhanced global independence in daily life activities were also noted. One pilot study demonstrated that even a 30-minute session of RAGT improved gait disorders and FOG, supporting its role in intensive gait rehabilitation (5). These findings underscore the value of RAGT in promoting mobility and reducing the risk of falls in patients with Parkinson's disease, ultimately contributing to an improved quality of life. Despite its strengths, RAGT

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

presents several limitations. A notable drawback is the high cost of robotic devices, which restricts accessibility, particularly in resource-limited settings (10). Additionally, inconsistencies in baseline measurements for key outcome variables across studies pose a potential confounding factor, complicating the interpretation of results. The absence of long-term follow-up evaluations further limits the ability to assess the sustained effects of RAGT on gait and functional mobility. Moreover, most studies did not evaluate participants in the "off" medication state, leaving a gap in understanding RAGT's efficacy independent of pharmacological interventions (2).

The variability in study protocols, including differences in session frequency, duration, and intensity of RAGT, poses challenges in establishing standardized parameters for its application. Future research should aim to define optimal training parameters and explore the comparative efficacy of RAGT with other active gait interventions to enhance walking performance in Parkinson's disease (4). Additionally, the integration of objective outcome measures, such as neuroimaging to assess brain plasticity, would provide deeper insights into the mechanisms underlying RAGT's therapeutic effects. The implications of these findings for clinical practice are significant, as they offer a pathway to address a critical gap in the management of Parkinson's disease. While pharmacological and surgical treatments effectively alleviate many symptoms, they remain insufficient for axial symptoms like gait hypokinesia and postural instability. RAGT represents a promising complementary approach that could be integrated into comprehensive rehabilitation programs. By improving mobility and reducing the cognitive load associated with gait, RAGT has the potential to enhance both physical and psychological well-being in patients with Parkinson's disease.

This review contributes to the existing body of literature by synthesizing evidence on the effectiveness of RAGT, identifying its strengths, and acknowledging its limitations. However, the heterogeneity of the included studies, coupled with the lack of long-term follow-up data, highlights the need for further research. Standardized protocols and larger, multicenter trials are essential to validate the findings and facilitate the broader adoption of RAGT in clinical practice. By addressing these gaps, future research could refine the role of RAGT in Parkinson's disease management, ensuring that its benefits reach a wider patient population.

CONCLUSION

In conclusion, this review highlights robotic gait training as a promising intervention for addressing gait abnormalities in individuals with Parkinson's disease. By providing repetitive, task-specific, and individualized therapy, robotic training demonstrates significant potential in improving gait speed, stride length, and overall mobility, contributing to enhanced functional independence and quality of life. The evidence underscores its value as a supplementary tool in neuro-rehabilitation, particularly for symptoms unresponsive to conventional therapies. However, the long-term efficacy, optimal training parameters, and cost-effectiveness of robotic therapy require further exploration. Future research should focus on establishing standardized protocols, integrating robotic training with other therapeutic modalities, and evaluating its broader impact on both motor and non-motor symptoms. Despite the need for continued investigation, the findings suggest that robotic gait training could play a transformative role in the comprehensive management of Parkinson's disease, offering new hope for improved patient outcomes.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Authors contribution

Author	Contribution
Muqadas Majeed	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Muddasira Bashir	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Rimsha Zaheer	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Jannat Naveed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Wahaj Khan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Anbreena Rasool*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Picelli A, Varalta V, Melotti C, Zatezalo V, Fonte C, Amato S, et al. Effects of treadmill training on cognitive and motor features of patients with mild to moderate Parkinson's disease: a pilot, single-blind, randomized controlled trial. Functional neurology. 2016;31(1):25.

2. Picelli A, Melotti C, Origano F, Waldner A, Fiaschi A, Santilli V, et al. Robot-assisted gait training in patients with Parkinson disease: a randomized controlled trial. Neurorehabilitation and neural repair. 2012;26(4):353-61.

3. Picelli A, Melotti C, Origano F, Neri R, Verzè E, Gandolfi M, et al. Robot-assisted gait training is not superior to balance training for improving postural instability in patients with mild to moderate Parkinson's disease: a single-blind randomized controlled trial. Clinical rehabilitation. 2015;29(4):339-47.

4. Kang M-G, Yun SJ, Shin HI, Kim E, Lee HH, Oh B-M, et al. Effects of robot-assisted gait training in patients with Parkinson's disease: Study protocol for a randomized controlled trial. Trials. 2019;20:1-8.

5. Capecci M, Pournajaf S, Galafate D, Sale P, Le Pera D, Goffredo M, et al. Clinical effects of robot-assisted gait training and treadmill training for Parkinson's disease. A randomized controlled trial. Annals of physical and rehabilitation medicine. 2019;62(5):303-12.

6. Kim H, Kim E, Yun SJ, Kang M-G, Shin HI, Oh B-M, et al. Robot-assisted gait training with auditory and visual cues in Parkinson's disease: A randomized controlled trial. Annals of physical and rehabilitation medicine. 2022;65(3):101620.

7. Kawashima N, Hasegawa K, Iijima M, Nagami K, Makimura T, Kumon A, et al. Efficacy of wearable device gait training on Parkinson's disease: A randomized controlled open-label pilot study. Internal Medicine. 2022;61(17):2573-80.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

8. Sale P, De Pandis MF, Le Pera D, Sova I, Cimolin V, Ancillao A, et al. Robot-assisted walking training for individuals with Parkinson's disease: a pilot randomized controlled trial. BMC neurology. 2013;13:1-7.

9. Carda S, Invernizzi M, BARICICH A, Cristoforo C, Croquelois A, Carlo C. Robotic gait training is not superior to conventional treadmill training in Parkinson's Disease: A single-blind randomized controlled trial. Gait & Posture. 2013;37:S17.

10. Picelli A, Melotti C, Origano F, Neri R, Waldner A, Smania N. Robot-assisted gait training versus equal intensity treadmill training in patients with mild to moderate Parkinson's disease: a randomized controlled trial. Parkinsonism & related disorders. 2013;19(6):605-10.

11. Ophey A, Eggers C, Dano R, Timmermann L, Kalbe E. Health-Related Quality of Life Subdomains in Patients with Parkinson's Disease: The Role of Gender. Parkinson's Disease. 2018;2018(1):6532320.

12. Kabra A, Sharma R, Kabra R, Baghel US. Emerging and alternative therapies for Parkinson disease: an updated review. Current pharmaceutical design. 2018;24(22):2573-82.

13. Pilleri M, Weis L, Zabeo L, Koutsikos K, Biundo R, Facchini S, et al. Overground robot assisted gait trainer for the treatment of drug-resistant freezing of gait in Parkinson disease. Journal of the Neurological Sciences. 2015;355(1-2):75-8.

