

A Pilot Table Tennis-Based Neurorehabilitation Program to Improve Parkinson's Disease Symptoms

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Abstract

Background: Exercise is the only established disease-modifying intervention in Parkinson's disease (PD), and continued exploration of innovative and engaging exercise modalities may further enhance outcomes for individuals living with PD. Table tennis (TT) is a cognitively engaging, task-specific activity integrating visuospatial processing, anticipatory motor planning, and dynamic postural control.

Objective: To examine the feasibility, including attendance, retention, and safety, and effects of a 12 week TT-based program, NeuroPong™, on motor and non-motor symptoms in individuals with PD.

Methods: In this single-arm pilot study, 30 participants were enrolled and 26 completed 12 weeks of twice-weekly, 2-h TT sessions. The primary outcome was the Movement Disorders Society-Unified Parkinson's Disease Rating Scale Part III (MDS-UPDRS III). Secondary outcomes included the Berg Balance Scale (BBS), Timed Up and Go (TUG), Six-Minute Walk Test (6MWT), Montreal Cognitive Assessment (MoCA) and several patient-reported outcomes. Pre-post comparisons were conducted using paired T-tests.

Results: Improvements were observed in the MDS-UPDRS Part III (mean change -5.73 , 95% CI -9.02 to -2.44 , $p = 0.0014$), BBS (mean change $+3.08$, 95% CI 1.987 to 4.17 , $p < 0.0001$), TUG (mean change -1.04 , 95% CI -1.69 to -0.38 , $p = 0.0032$), and 6MWT (mean change 66.77 , 95% CI 49.82 to 83.71 , $p < 0.0001$). Self-reported depression decreased (Hospital Anxiety and Depression Scale, HADS-D mean change -1.12 , 95% CI -1.97 to -0.26 , $p = 0.0129$). Attendance averaged approximately 90%, and no adverse events were reported. No significant changes were observed in other outcomes.

Conclusions: A 12-week TT-based program, NeuroPong™, was feasible and associated with improvement in motor function, balance, walking endurance and self-reported depression in PD. The multidimensional motor and cognitive demands of table tennis may contribute to these observed benefits. Larger randomized controlled trials are warranted.

Keywords

Parkinson disease, table tennis, exercise therapy, neurorehabilitation, balance training, gait endurance, motor activity

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Introduction

Parkinson's disease (PD) is a common neurodegenerative disorder (Dorsey et al., 2018) that impacts function and quality of life with both motor and non-motor symptoms (Chaudhuri et al., 2006; Schapira et al., 2017). Non-motor features can be more debilitating than motor impairments and are typically less responsive to conventional dopaminergic therapies (Chaudhuri et al., 2006; Miguelez et al., 2020).

While current pharmacological treatments for PD provide symptom relief, the only known disease-modifying therapy is exercise (Melanson et al., 2018; Moore et al., 2013; Olanow et al., 2009; Zigmond & Smeyne, 2014). While various exercise types have been evaluated in the literature, including aerobic activity (Johansson et al., 2022;

Shu et al., 2014), boxing (Combs et al., 2011; Moore et al., 2021; Sangarapillai et al., 2021), swimming (Cugusi et al., 2019), and running (Schenkman et al.,

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2018), there is no universal agreement on the optimal type, intensity, frequency, or duration of exercise required to achieve a maximal therapeutic effect (Ellis et al., 2005; Uc et al., 2014). This uncertainty underscores the need to explore novel, multimodal interventions that are both effective and sustainable. Barriers to exercise are specific to each person living with PD, and include access to equipment and programs, motivation/apathy, and imbalance.

Table tennis (TT) is an emerging exercise modality that remains underrepresented in structured neurorehabilitation programs. TT is a whole-body, moderate-intensity activity that integrates aerobic exercise with visuomotor coordination, anticipatory motor planning, dynamic balance, and rapid decision-making (Gu et al., 2019; Naderi et al., 2018). Unlike traditional exercise modalities that often target isolated domains (e.g., strength or endurance), TT simultaneously engages motor, cognitive, and adaptive processes in a dynamic and unpredictable environment. These characteristics make TT particularly well-suited to address the complex, multidimensional impairments observed in PD.

Despite these potential advantages, existing studies evaluating TT in PD are limited by small sample sizes and heterogeneous intervention designs, and few have incorporated standardized protocols or assessed both motor and non-motor outcomes (Inoue et al., 2021; Olsson et al., 2020). Therefore, there remains a need for studies evaluating structured, scalable TT-based interventions using comprehensive outcome measures.

The aim of this study was to evaluate the feasibility and effects of a 12-week, structured table tennis-based intervention (NeuroPong™) on motor and non-motor symptoms in individuals with Parkinson's disease.

Material and Methods

Study Design and Settings

This study was approved by the Colorado Institutional Review Board at the University of Colorado School of Medicine, Anschutz Medical Campus (approval COMIRB # 22-2418). The intervention was reported in accordance with the TIDieR (Template for Intervention Description and Replication) checklist; a detailed mapping of intervention components is provided in Supplementary Table S1. All participants provided written informed consent prior to enrollment. A single-center, single-arm pilot design was used to evaluate the feasibility and preliminary effects of a table tennis-based exercise intervention in individuals with Parkinson's disease.

Study Participants

Participants were recruited from the local community. Inclusion criteria were: previous diagnosis of idiopathic PD, ability to follow three-step commands, and fluency in

English. Exclusion criteria included medical or physical conditions precluding safe participation, and a screening Montreal Cognitive Assessment (MoCA) score <26. Individuals already participating in recreational table tennis were not excluded.

NeuroPong™ Table Tennis Intervention

The NeuroPong™ program is a standardized, table tennis-based rehabilitation intervention designed for individuals with neurological disorders, with specific modifications for Parkinson's disease. The 12-week intervention was delivered twice weekly in supervised small-group sessions conducted in an indoor community setting and led by 3 trained TT instructors with experience in TT coaching and guided by professionals familiar with neurorehabilitation.

Each session followed a consistent structure including: (1) preparatory exercises targeting mobility, balance, and breathing; (2) coached instruction of selected table tennis strokes and associated movement patterns; and (3) guided play to reinforce practiced skills. Instruction prioritized safety, functional movement, and participant engagement rather than technical proficiency. Details can be found in the NeuroPong Handbook (Barbera et al., 2024). The ball-throwing robot was used intermittently as a training adjunct, primarily to facilitate repetitive stroke practice under controlled conditions. It was not a required component of the intervention and was not used uniformly across all sessions or participants.

Task difficulty was individualized by adjusting stroke complexity, ball speed, distance from the table, and movement demands according to each participant's motor function, balance, and fatigue tolerance. Rest breaks were allowed as needed. Progression was based on participant performance and tolerance rather than a fixed progression schedule. Attendance and adverse events were recorded at each session.

Clinical and Patient-Reported Outcome Measures

Baseline demographic data included age, sex, race, years of education, disease duration, and current medications.

Pre- and post-intervention clinical assessments, within 1 week of the start and the end of the 12-week intervention, included the Movement Disorders Society–Unified Parkinson's Disease Rating Scale (MDS-UPDRS), Hoehn and Yahr scale (H&Y scale), MoCA, Functional Reach Test (FRT), Berg Balance Scale (BBS), Timed Up and Go (TUG), Six-Minute Walk Test (6MWT).

Patient-reported outcome measures included the Parkinson's Disease Questionnaire-39 (PDQ-39), Hospital Anxiety and Depression Scale (HADS-A, HADS-D), Activities-specific Balance Confidence (ABC) scale, and Epworth Sleepiness Scale (ESS).

The MDS-UPDRS Part III motor examination was administered by 3 trained raters: 1 movement disorder specialist, 1 movement disorder fellow and 1 physician with MDS-UPDRS certification.

All other assessments (e.g., BBS, TUG, 6MWT, MoCA, and patient-reported measures) were conducted by trained evaluators following standardized protocols. These evaluators were not acting as interventionists during the NeuroPong™ sessions. The intervention was delivered by table tennis instructors supervised by staff experienced in neurorehabilitation, whereas outcome assessments were performed independently by trained personnel. Different raters performed pre- and post-intervention assessments; however, all raters were trained in standardized administration procedures to ensure consistency and reduce measurement variability.

All outcome measures selected for this study are widely used in Parkinson's disease research and have demonstrated validity, reliability, and responsiveness in this population. The MDS-UPDRS Part III is considered the gold standard for assessing motor severity (Horváth et al., 2015) and H&Y scale is a widely used clinical staging system for Parkinson's disease that classifies disease severity based on motor symptom progression and functional impairment (Hoehn & Yahr, 1998). The MoCA is a validated cognitive screening tool in PD (Nasreddine et al., 2005). FRT (Duncan et al., 1990), BBS (Blum & Korner-Bitensky, 2008), TUG (Podsiadlo & Richardson, 1991) and 6MWT (Steffen & Seney, 2008) are validated measures of balance, mobility, and endurance, and patient-reported outcomes such as the PDQ-39 (Peto et al., 1995), and HADS (Reijnders et al., 2008) are well-established instruments for assessing quality of life and mood. ABC (Powell & Myers, 1995) is a validated measure of perceived balance confidence and fall risk, and ESS (Johns, 1991) is a commonly used and validated measure of daytime sleepiness. All clinical assessment were performed in the order they are reported in Table 1.

Statistical Analysis

Categorical variables were summarized as frequencies and percentages. Continuous variables were summarized as means $\pm$ standard deviations. Pre- and post-intervention comparisons of the mean were conducted using paired t-tests; 95% Confidence Intervals (CI) of the mean change are presented. All statistical tests were two-sided with a significance level of $\alpha = 0.05$. Standardized effect sizes were measured with the Cohen's *d* statistic, the ratio of the mean change to the standard deviations of the changes. Assumptions for parametric testing were assessed, including evaluation of the normality of difference scores using graphical and/or statistical methods, and were deemed acceptable for the use of paired t-tests. A Bonferroni correction was not applied, as this pilot study was exploratory in

nature and aimed to identify potential signals of effect; applying strict multiplicity adjustments in this context may increase the risk of Type II error. Analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Thirty participants were enrolled, of whom 26 completed the intervention and were included in the analysis (Figure 1). The mean age of completers was 70.0 ± 7.1 years; 77% were male, all participants self-identified as White, and mean years of education were 17.1. The mean disease duration was 7.1 ± 6.6 years and all but one participants were treated on carbidopa-levodopa. Feasibility outcomes demonstrated high adherence and retention, with participants attending a mean of 21.6 out of 24 sessions (~90%). No adverse events were reported.

Pre- and post-intervention clinical outcomes and patient-reported measures are summarized in Table 1. The MDS-UPDRS Part III score improved by -5.73 points; balance, as measured by the BBS, improved by $+3.08$ points; functional mobility improved, with the TUG decreasing by -1.04 s; walking endurance, assessed via the Six-Minute Walk Test, increased by $+66.77$ meters.

Depressive symptoms measured with the HADS-D decreased by -1.12 points.

No statistically significant changes were observed in cognitive function (MoCA), quality-of-life measures (PDQ-39), anxiety (HADS-A), balance confidence (ABC), sleepiness (ESS).

Discussion

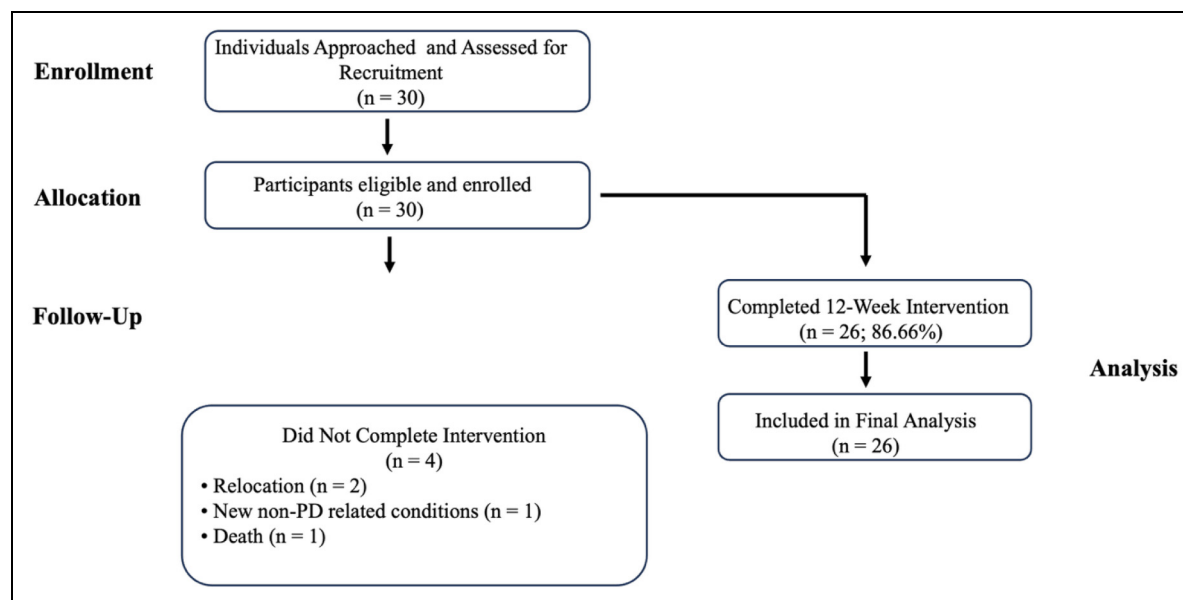
This study demonstrates that a structured TT-based intervention is feasible and associated with improvements in motor function, balance, and walking endurance in individuals with PD.

Reductions in MDS-UPDRS Part III of 3–5 points may reflect perceptible improvements in motor symptoms in individuals with PD (Horváth et al., 2015). Following the TT intervention, we observed an average improvement of -5.73 points ($d = 0.70$). The observed improvement in MDS-UPDRS Part III scores is consistent with prior research; however, important differences in study design and intervention characteristics should be considered. Previous studies examining table tennis or similar coordination-based activities have often utilized shorter intervention durations, less standardized protocols, or have focused primarily on motor outcomes (Inoue et al., 2021; Olsson et al., 2020). In contrast, the NeuroPong™ program employed a structured, multimodal approach integrating visuomotor coordination, balance, and cognitive engagement within a consistent 12-week framework. Additionally, variability in participant characteristics,

Table 1. Clinical Assessments and Patient Reported Outcomes.

Test	Pre mean $\pm$ SD	Post mean $\pm$ SD	Mean change	95% CI	Cohen's d	p value
MDS-UPDRS I	2.77 $\pm$ 2.72	2.38 $\pm$ 2.25	-0.38	-1.36 to 0.59	-0.16	0.4250
MDS-UPDRS II	10.00 $\pm$ 6.68	10.58 $\pm$ 6.83	+0.58	-0.59 to 1.74	+0.20	0.3180
MDS-UPDRS III	21.58 $\pm$ 9.17	15.85 $\pm$ 10.42	-5.73	-9.02 to -2.44	-0.70	0.0014*
MDS-UPDRS IV	2.77 $\pm$ 2.60	3.23 $\pm$ 2.87	+0.46	-0.76 to 1.69	+0.15	0.4455
H&Y Scale	3.42 $\pm$ 1.47	3.46 $\pm$ 1.27	+0.04	-0.44 to 0.52	+0.03	0.8696
MoCA	26.23 $\pm$ 3.61	26.23 $\pm$ 3.51	0.00	-1.09 to 1.09	0.00	1.000
FRT (cm)	27.96 $\pm$ 11.03	26.17 $\pm$ 7.11	-1.79	-5.084 to 1.49	-0.22	0.2716
BBS	49.12 $\pm$ 4.48	52.19 $\pm$ 4.40	+3.08	1.98 to 4.17	+1.13	<.0001*
TUG (s)	9.30 $\pm$ 2.56	8.26 $\pm$ 1.96	-1.04	-1.69 to -0.38	-0.64	0.0032*
6MWT (m)	433.81 $\pm$ 105.69	500.58 $\pm$ 119.90	+66.77	49.82 to 83.71	+1.59	<.0001*
PDQ-39 (Total)	25.81 $\pm$ 18.57	23.04 $\pm$ 16.36	-2.77	-8.11 to 2.57	-0.21	0.2958
HADS-A	4.50 $\pm$ 2.96	4.35 $\pm$ 3.39	-0.15	-1.04 to 0.73	-0.07	0.7226
HADS-D	4.54 $\pm$ 2.80	3.42 $\pm$ 2.70	-1.12	-1.97 to -0.26	-0.53	0.0129*
ABC	1327.69 $\pm$ 380.07	1250.38 $\pm$ 447.10	-77.31	-227.45 to 72.84	-0.21	0.2991
ESS	7.11 $\pm$ 3.72	7.85 $\pm$ 4.69	+0.73	-0.84 to 2.30	+0.19	0.3465

MDS-UPDRS: Movement Disorders Society-Unified Parkinson's Disease Rating Scale; H&Y: Hoehn & Yahr scale; MoCA: Montreal Cognitive Assessment; FRT: functional reach test; BBS: Berg balance scale; ; TUG: timed up-and-go; 6MWT: six minute walk test; PDQ-39: Parkinson's Disease Questionnaire 39; HADS-A and D: Anxiety and Depression Scale; ABC: Activities-specific Balance Confidence; ESS: Epworth Sleepiness Scale. CI = confidence interval. * = p value <0.05.

**Figure 1.** Participants flow diagram.

including disease severity and baseline functional status, as well as differences in intervention dose and outcome assessment timing, may contribute to the range of MDS-UPDRS changes reported across studies. These distinctions suggest that the magnitude of improvement observed in the present study may reflect not only the specific characteristics of table tennis as an intervention, but also the structured and progressive nature of the NeuroPong™ program, supporting its potential relevance as a comprehensive neurorehabilitation strategy.

Improvements were observed in objective measures of balance and functional mobility, including the BBS and TUG, indicating enhanced postural control and functional performance. The BBS improved by +3.08 points ($d = 1.13$), a magnitude consistent with meaningful functional gains associated with reduced fall risk (Blum & Korner-Bitensky, 2008). These findings parallel reports in Tai Chi and dance interventions, which similarly incorporate multidirectional movement and coordinated weight transfer (Li et al., 2012). The faster TUG (-1.04 s, $d =$

0.64) and increased walking endurance (66.77 meters, $d = 1.59$), are both metrics which represent clinically relevant improvements.

However, no corresponding change was observed in balance confidence as measured by the ABC scale. This discrepancy may reflect the distinction between objective physical performance and subjective perception of ability. While participants demonstrated measurable functional gains, perceived confidence may be influenced by longer-standing factors such as fear of falling, prior experiences, and self-efficacy, which may require a longer duration or targeted psychological interventions to change. This dissociation between physical performance and perceived confidence has been previously reported in individuals with Parkinson's disease and older adults (Ellis et al., 2013; Powel & Myers, 1995). These findings highlight the importance of assessing both performance-based and patient-reported outcomes, as improvements in physical function do not necessarily translate into immediate changes in perceived confidence.

Although the reduction in depressive symptoms was small-to-modest (-1.12 ; $d = 0.53$) and baseline scores were low, the absence of parallel changes in anxiety or cognition may indicate a selective mood-related benefit. Depression is highly prevalent in Parkinson's disease and is associated with reduced quality of life and poorer functional outcomes (Reijnders et al., 2008). Exercise and socially engaging activities have been shown to positively influence mood and psychological well-being in this population (Teixeira et al., 2012). The social, engaging, and skill-based nature of table tennis may contribute to improvements in mood through mechanisms such as increased social interaction, perceived competence, and intrinsic motivation.

No significant changes were observed in the severity of the disease based on motor symptom progression and functional impairment (H&Y), cognitive function (MoCA), quality of life (PDQ-39), anxiety (HADS-A), sleepiness (ESS), with effect sizes generally small ($d < 0.30$). These findings suggest that the benefits of the intervention may be domain-specific, with stronger effects on motor and functional outcomes over the 12-week period.

From a clinical standpoint, several explanations are plausible: ceiling effects, particularly for cognition (baseline MoCA scores were above the cut-off for mild cognitive impairment); insufficient intervention duration to impact broader psychosocial domains; measurement sensitivity, as some instruments may not detect subtle changes over short timeframes. These results are consistent with prior studies indicating that changes in cognitive and quality-of-life outcomes may require longer or more intensive interventions to become detectable (Johansson et al., 2022).

The mechanisms by which exercise influences Parkinson's disease progression are multifactorial and

include neuroplasticity, modulation of neuroinflammation, and mitochondrial adaptations (Hirsch et al., 2016; Lubomski et al., 2020; Petzinger et al., 2013). TT may be uniquely poised to target domain-specific deficits through demands on visuospatial processing, task switching, and anticipatory motor planning, engaging frontal and parietal networks implicated in executive and motor control (Zheng et al., 2024). In addition, the balance training performed in TT programs, may improve the integration of visual, vestibular, and proprioceptive input (Zheng et al., 2024), which is commonly impaired in PD (Bronstein et al., 1990). Lastly, the inherent variability and game-like nature of TT, unlike gym exercises, may enhance adherence and long-term engagement, which are critical for sustained benefit (Deci & Ryan, 2000; Teixeira et al., 2012).

From a neurorehabilitation perspective, these findings support the use of table tennis as a multimodal, task-oriented, and community-based intervention. Multimodal exercise approaches combining motor and cognitive challenges are increasingly recognized as effective strategies in Parkinson's disease rehabilitation (Petzinger et al., 2010).

The structured nature of the NeuroPong™ intervention and its alignment with TIDieR reporting standards support its reproducibility and potential for broader implementation.

Importantly, the absence of adverse events and high attendance rates further support its feasibility and safety, addressing common barriers to sustained exercise participation in this population (Ellis et al., 2013).

Several limitations should be acknowledged. This was a small, single-arm pilot study without a control group. The sample was racially and educationally homogeneous, limiting generalizability. Participants varied in baseline physical activity levels, including some with prior TT experience. In addition, different raters administered pre- and post-intervention clinical assessments, although standardized procedures were followed. Medication effects were not controlled, and repeated testing may have introduced learning effects.

Future studies should employ blinded randomized controlled designs and more diverse samples.

Conclusion

This pilot study supports the feasibility and potential effectiveness of a table tennis-based neurorehabilitation intervention in individuals with PD. Improvements were observed in motor function, balance, walking endurance, and depressive symptoms. These findings contribute to a growing body of evidence suggesting that task-specific, cognitively engaging, and socially interactive physical activities may be effective in treating Parkinson's disease. We identified improvements not only in isolated domains but across systems, fitting nicely into a holistic model of rehabilitation.

It will be worthwhile to have a larger and more prolonged blinded interventional trial to evaluate whether additional impacts require longer intervention, and whether the changes identified in this pilot are sustained over time.

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Ethical Considerations

This study was approved by the Colorado Institutional Review Board at the University of Colorado School of Medicine, Anschutz Medical Campus.

Consent to Participate

All participants provided written informed consent prior to enrollment.

Consent for Publication

Consent for publication was obtained as part of the written informed consent provided by all participants.

Author Contributions

Antonio Barbera - Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Writing-original draft, Writing-review and editing; Matthew Woodward - Formal analysis, Investigation, Methodology, Writing-review and editing; Isabelle Buard - Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing-review and editing; Stefan Sillau - Data curation, Formal analysis, Validation, Writing-review and editing; Ramon Ortega Montes - Writing-review and editing; Jeanne Feuerstein - Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing-original draft, Writing-review and editing.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

All data generated or analyzed during this study are available upon reasonable request.

Supplemental Material

Supplemental material for this article is available online.

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