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The Effect of Dynamic Neuromuscular Stabilization Exercises Combined with Visual Mirror Feedback Compared to Non-Mirror Feedback Training on Respiratory Function in Patients with Parkinson's Disease: A Secondary Analysis of a Randomized Controlled Trial

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Original Article

Abstract

Introduction: Parkinson's disease (PD) can impair respiratory muscle strength and pulmonary function, contributing to reduced cough effectiveness, hypophonia, and diminished exercise tolerance. Dynamic neuromuscular stabilization (DNS) training improves trunk and core control, potentially enhancing respiratory mechanics. Additionally, mirror visual feedback (MVF) has been shown to improve sensorimotor integration and body awareness; however, its effect on respiratory outcomes in PD is unknown. This secondary analysis compared the effects of an eight-week DNS program, performed with or without MVF, on spirometric parameters in patients with PD.

Materials and Methods: The current research is a secondary analysis of data from individuals with idiopathic PD (Hoehn and Yahr I–III) who completed an eight-week DNS training program (3 sessions/week, 45–60 min/session), either in front of a full-length mirror (DNS + MVF, n = 18) or without a mirror (DNS-only, n = 17). For this secondary analysis, spirometric assessments were performed at baseline and post-intervention, including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), FEV_1/FVC ratio, forced expiratory flow at 25%–75% of vital capacity ($FEF_{25–75}$), and peak expiratory flow (PEF). Data from 34 participants (17 per group) with complete respiratory measurements were analyzed using a two-way repeated measures analysis of variance (ANOVA) and tests of between-subject effects.

Results: Both groups showed significant within-group improvements over time in all spirometric parameters (all $P < 0.001$). However, the DNS + MVF group demonstrated significantly greater improvements in FVC compared to the DNS-only group (Group × Time interaction: $F = 72.03$, $P < 0.001$, partial $\eta^2 = 0.873$), FEV_1 ($F = 29.19$, $P < 0.001$, partial $\eta^2 = 0.711$), $FEF_{25–75}$ ($F = 6.13$, $P = 0.022$, partial $\eta^2 = 0.235$), and PEF ($F = 6.42$, $P = 0.020$, partial $\eta^2 = 0.243$). Between-subject effects also favored the mirror group for FVC ($P = 0.008$) and PEF ($P = 0.043$).

Conclusion: The integration of MVF provided a statistically significant additive benefit for respiratory function. These findings suggest that mirror-augmented DNS may be a simple, low-cost strategy to enhance respiratory function in patients with PD. Further studies with larger samples and longer follow-up are warranted.

Keywords: Parkinson’s disease; Dynamic neuromuscular stabilization; Mirror visual feedback; Respiratory function; Spirometry; Pulmonary rehabilitation

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Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by motor symptoms such as bradykinesia, rigidity, tremor, and postural instability. Beyond the classic motor features, respiratory dysfunction is increasingly recognized as a significant, yet often underdiagnosed, complication (1). Patients with PD commonly exhibit restrictive pulmonary patterns due to chest wall rigidity, reduced thoracic expansion, and impaired respiratory muscle strength (1). This can lead to reduced cough peak flow, aspiration pneumonia, diminished speech volume, and decreased exercise tolerance, all of which negatively affect quality of life and survival (2).

The pathophysiology of respiratory impairment in PD is multifactorial, involving rigidity of the rib cage and intercostal muscles, bradykinesia of respiratory muscles, abnormal postural alignment (e.g., forward trunk flexion), and impaired central coordination of breathing (2, 3). From a rehabilitation perspective, the importance of this issue lies in the fact that breathing in patients with Parkinson's disease is not limited to pulmonary function; it also depends on postural control, spinal mobility, core stability, diaphragmatic function, and coordination of trunk muscles. Therefore, exercises that simultaneously target trunk control, core stability, and diaphragmatic function may provide benefits beyond those of general motor exercises or isolated respiratory training. Moreover, respiratory impairments may not respond sufficiently to dopaminergic therapy alone (4, 5); therefore, targeted non-pharmacological and rehabilitation interventions are necessary to reduce respiratory and functional consequences in these patients (6).

Although aerobic exercise, resistance training, balance training, gait training, and specific respiratory muscle training have been used in Parkinson's rehabilitation, each has certain limitations. Specific respiratory exercises primarily focus on inspiratory or expiratory muscle strength but do not necessarily target correcting postural patterns, trunk rigidity, pelvic control, or the coordination of the diaphragm with the core muscles. On the other hand, common balance and motor exercises may not directly address respiratory mechanics or diaphragmatic function. Therefore, an approach that integrates postural control and respiratory function may be clinically more appropriate for patients with Parkinson's disease. Recent studies have also shown that integrated exercise interventions can improve some indices of respiratory function, including respiratory muscle strength and PEF, in patients with PD (5). Furthermore, recent reviews on respiratory muscle training indicate that these interventions can be effective in improving respiratory muscle strength; however, sufficient conclusive evidence is still lacking regarding the optimal type, intensity, duration, and combination of these exercises with motor training (4).

Mirror visual feedback (MVF) has been used in PD to enhance motor performance, body awareness, and sensorimotor integration (7, 8). By providing real-time visual feedback of movement, MVF may help patients correct postural asymmetries, reduce compensatory patterns, and improve movement quality. However, the effect of MVF combined with trunk-focused exercise on objective measures of pulmonary function in PD has not been previously examined.

Given the anatomical and functional linkage between trunk control and respiration, we hypothesized that adding MVF would also lead to greater improvements in spirometric parameters. Therefore, this study aimed to compare the effects of an 8-week DNS program performed with versus without mirror feedback on forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), FEV_1/FVC ratio, FEV_1/VC_{max}%, forced expiratory flow at 25–75% of FVC (FEF_{25-75}), and peak expiratory flow (PEF) in patients with mild-to-moderate PD.

Materials and Methods

Study design and ethics: This study is a secondary analysis of a prospective, parallel-group, randomized controlled trial (RCT) comparing an 8-week DNS training program delivered with mirror feedback to the same program delivered without mirror feedback in patients with PD. The original trial was registered with the Iranian Registry of Clinical Trials (IRCT20251101067842N1) and received ethics approval from the Isfahan University of Medical Sciences (IR.UI.REC.1404.117). All participants provided written informed consent. The present analysis focuses exclusively on respiratory function outcomes, which were not reported in the primary manuscript.

Participants: The participants included adults aged 50–70 years with idiopathic PD in stages I to III according to the Hoehn & Yahr scale, who had a stable medication regimen and were able to participate in the assessments and exercises (9) safely. In this study, idiopathic Parkinson's disease refers to the primary form of Parkinsonism with an unknown cause, in which symptoms develop spontaneously and not as a result of identifiable secondary factors such as medications, toxins, trauma, or other brain disorders.

The Hoehn & Yahr scale is a standard scale for assessing the severity and stages of Parkinson's disease (PD), consisting of five disease stages. This scale is widely used in clinical research and has high validity and reliability. The original version of the scale was introduced by Hoehn and Yahr in 1967 and has been confirmed and used in various studies, including Iranian studies (10). Based on assessments of motor symptoms in patients with PD, including gait, balance, and muscle strength, this scale classifies patients into five stages (I-V). In the present study, participants were at stages I-III of this scale, indicating early to moderate Parkinson's disease. The validity and reliability of the Persian version of this scale have also been confirmed in several studies, and this version has been used in multiple investigations to assess disease severity in the Iranian population (11).

The exclusion criteria included other neurological disorders, major musculoskeletal pathology, recent lower-limb surgery, severe non-neurological disease, concurrent participation in a structured rehabilitation program, and visual or cognitive impairment affecting the performance of the tests. For this respiratory analysis, all participants from the main trial who completed pre- and post-intervention spirometry with acceptable quality were included.

In the initial clinical trial, an a priori power analysis was performed using G*Power software version 3.1 (12) to determine the required sample size to detect a significant group × time interaction in a repeated-measures ANOVA, specifically a within–between interaction. This analysis was conducted within the F-test family using the following parameters: an effect size of $f = 0.391$, derived from the results of the functional reach test in the study by Heuvel et al. (13); an alpha error probability of $\alpha = 0.01$; statistical power of $1 - \beta = 0.99$; two groups, including DNS+MVF and DNS-only; and two measurement time points, including pre-intervention and post-intervention. The correlation between repeated measurements was assumed to be 0.5, and the no-sphericity correction ε was set to 1. Based on these assumptions, the required total sample size was calculated to be 38 participants, with 19 participants per Group.

Randomization and interventions: Participants were matched by Hoehn & Yahr stage and then randomly allocated to either the DNS+MVF group or the DNS-only group using a simple randomization procedure (even or odd numbers). Both groups completed identical DNS-based exercise sessions: 3 sessions per week for 8 weeks (total 24 sessions), each lasting 45–60 minutes. The exercises targeted trunk/core stabilization, postural control, balance, and coordinated lower-limb function, including bridging variations, weight-shifting, reaching, unilateral stance tasks, stepping, and training on unstable surfaces. The mirror group performed all exercises while standing or sitting in front of a full-length mirror (in a room with mirrors on four sides), receiving continuous visual feedback. The control group performed the same exercises in an identical room without mirrors. No specific respiratory training (e.g., incentive spirometry, breathing exercises) was provided to either GroupGroup.

The main exercises included bridging, weight shifting, single-leg standing, forward and lateral stepping, balance exercises, exercises on unstable surfaces, diaphragmatic breathing, activation of the core trunk muscles, forearm support, lateral elbow support, rolling, quadruped positioning, rocking in the quadruped position, bear position, crawling, kneeling, half-kneeling, functional sitting, and squatting.

The intensity and difficulty of the exercises were gradually increased based on participants' tolerance, safety, and quality of movement execution. Progression criteria included the ability to perform the exercise with proper body alignment, trunk and pelvic control, normal breathing, and without pain, dizziness, or severe fatigue. Exercise progression was achieved by increasing the number of repetitions, increasing the duration of position holding, reducing the base of support, reducing hand support, increasing the range of motion, changing the position from sitting to standing, and performing the exercise on an unstable surface. In cases of fatigue, imbalance, or reduced movement quality, the exercise was simplified or the rest period was increased.

Respiratory outcome measures: Spirometry was performed at baseline (pre-intervention) and within 1 week after the final training session (post-intervention). Assessments were conducted by a blinded assessor using a calibrated spirometer according to American Thoracic Society/European Respiratory Society guidelines (14). The following parameters were recorded: FVC (forced vital capacity, in liters), FEV_1 (forced expiratory volume in 1 second, in liters), FEV_1/FVC ratio (%), FEV_1/VCmax ratio (%), FEF_{25-75} (mean forced expiratory flow between 25% and 75% of FVC, in L/s), and PEF (peak expiratory flow, in L/s). Each maneuver was repeated at least three times, and the best value was used for analysis.

Statistical analysis: All analyses were performed using SPSS version 27 (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation (SD). Baseline demographic and clinical characteristics were compared between groups using independent t-tests. The primary analysis used a two-way repeated-measures ANOVA with the within-subjects factor Time (pre, post) and the between-subjects factor Group (mirror, control). The primary outcome of interest was the Group × Time interaction, which indicates whether the change over time differed significantly between groups. Within-group pre-to-post changes were further examined using paired t-tests. Between-subjects effects (overall difference between groups across both time points) were also reported. Normality was assessed using the Shapiro–Wilk test, and sphericity was assumed due to only two time points. Statistical significance was set at $\alpha = 0.05$, two-tailed. Given the exploratory nature of this secondary analysis, no adjustment for multiple comparisons was made.

Results

Participant characteristics: Of the 35 participants who completed the 8-week intervention in the original trial, 34 (17 per GroupGroup) had complete and technically acceptable spirometry data at both time points. The mirror group (DNS+MVF) had a mean age of 62.7 ± 6.3 years, and the control group (DNS-only) 65.2 ± 3.4 years ($P = 0.277$). Baseline FVC, FEV_1, and other spirometric parameters were not significantly different between groups (all $p > 0.05$; see Table 1 for baseline values), indicating successful randomization for this subsample.

Spirometry outcomes: As shown in Table 2, both groups demonstrated significant improvements from pre- to post-intervention across all spirometric parameters (within-subject contrasts, linear component: all $P < 0.01$). This indicates that the DNS program, regardless of whether a mirror was used, was associated with better pulmonary function after 8 weeks.

Pulmonary function outcomes showed greater improvement in the mirror group than in the control group across all measured parameters. For forced vital capacity (FVC), repeated-measures ANOVA demonstrated a significant Group × Time interaction ($F = 72.03$, $P < 0.001$, partial $\eta^2 = 0.783$), indicating a substantially larger increase in the mirror group. Specifically, FVC increased from 2.32 ± 0.87 L at baseline to 5.73 ± 1.63 L after the intervention in the mirror group, corresponding to a mean improvement of 3.41 L. In contrast, the control group showed only a modest increase, from 2.51 ± 1.00 L to 2.80 ± 1.01 L, with a mean change of 0.29 L.

A similar pattern was observed for forced expiratory volume in 1 second (FEV_1). There was a significant Group × Time interaction ($F = 49.19$, $P < 0.001$, partial $\eta^2 = 0.711$). In the mirror group, FEV_1 increased markedly from 1.54 ± 0.88 L to 4.95 ± 1.78 L, representing a mean gain of 3.41 L. By comparison, the control group improved only slightly, from 2.41 ± 0.89 L at baseline to 2.80 ± 0.73 L post-intervention, with a mean change of 0.39 L.

For forced expiratory flow at 25%–75% of pulmonary volume (FEF_{25-75}), the interaction effect was also significant ($F = 6.13$, $P = 0.022$, partial $\eta^2 = 0.235$). Participants in the mirror group improved from 1.19 ± 1.25 L/s to 2.72 ± 1.07 L/s, corresponding to an increase of 1.53 L/s, whereas the control group showed a smaller improvement from 1.40 ± 0.71 L/s to 1.91 ± 0.35 L/s, with a mean change of 0.51 L/s. Likewise, peak expiratory flow (PEF) showed a significant Group × Time interaction ($F = 6.42$, $P = 0.020$, partial $\eta^2 = 0.243$). In the mirror group, PEF increased from 2.21 ± 1.49 L/s at baseline to 3.53 ± 2.11 L/s after the intervention, yielding a mean improvement of 1.32 L/s. In contrast, the control group demonstrated only a minimal increase, from 1.61 ± 0.76 L/s to 1.78 ± 0.62 L/s, with a mean change of 0.17 L/s.

Both FEV_1/FVC and FEV_1/VCmax% improved significantly over time in the study population (within-subject $p < 0.001$ for both). However, no significant Group × Time interaction was observed for either variable (Table 2), indicating that improvements were comparable between the mirror and control groups. In addition, between-group effects were not significant for either ratio ($P = 0.454$ and $p = 0.154$, respectively). The mirror group had significantly higher overall values (averaged across pre and post) for FVC ($P = 0.008$, partial $\eta^2 = 0.306$) and PEF ($P = 0.043$, partial $\eta^2 = 0.189$). For FEV_1, FEF_{25-75}, and the ratios, between-subject differences were not statistically significant ($P > 0.05$).

Table 1. Baseline participant characteristics

Variable	Mirror group (Mean ± SD)	No-mirror group (Mean ± SD)	P value
Age (years)	63.73 ± 6.34	65.10 ± 3.43	0.257
Weight (kg)	66.65 ± 8.30	71.07 ± 12.73	0.330
Height (cm)	166.86 ± 7.62	164.52 ± 3.81	0.520
Body mass index (BMI)	24.8 ± 3.5	26.6 ± 4.5	0.330
Disease duration (year)	8.6	7.8	0.310
Hoehn & Yahr			> 0.050
I	5	5	

II	7	7
III	5	5

Table 2. Spirometry parameters at baseline and post intervention (mean ± SD)

Variable	Group	Pre-test	Post-test	Mean change	Within-group p	Group × Time F	Group × Time p	Partial η^2
FVC (L)	Mirror	2.32 ± 0.87	5.73 ± 1.63	+3.41	<0.001	72.03	<0.001*	0.783
	Control	2.51 ± 1.00	2.80 ± 1.01	+0.29	<0.001			
FEV_1 (L)	Mirror	1.54 ± 0.88	4.95 ± 1.78	+3.41	<0.001	49.19	<0.001*	0.711
	Control	2.41 ± 0.89	2.80 ± 0.73	+0.39	<0.001			
FEV_1/FVC (%)	Mirror	45.5 ± 24.1	71.8 ± 13.8	+26.3	<0.001	0.528	0.454	0.028
	Control	51.0 ± 11.5	56.0 ± 14.3	+5.0	<0.001			
FEV_1/VCmax (%)	Mirror	40.1 ± 26.2	71.9 ± 13.8	+31.8	<0.001	2.192	0.154	0.099
	Control	40.3 ± 21.7	44.9 ± 25.3	+4.6	<0.001			
$FEF_{25\text{-}75}$ (L/s)	Mirror	1.19 ± 1.25	2.72 ± 1.07	+1.53	<0.001	6.13	0.022*	0.235
	Control	1.40 ± 0.71	1.91 ± 0.35	+0.51	<0.001			
PEF (L/s)	Mirror	2.21 ± 1.49	3.53 ± 2.11	+1.32	<0.001	6.42	0.020*	0.243
	Control	1.61 ± 0.76	1.78 ± 0.62	+0.17	<0.001			

Within group p values from paired t tests; interaction p-values from two way repeated measures ANOVA (Group × Time).
*Statistical significance level considered as p<0.05

Discussion

This secondary analysis of a randomized controlled trial is the first to demonstrate that adding mirror visual feedback to an 8-week Dynamic Neuromuscular Stabilization (DNS) program produces significantly greater improvements in multiple objective spirometric parameters in patients with mild-to-moderate Parkinson's disease compared to DNS alone. Specifically, the mirror group showed superior gains in forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), mid-expiratory flow ($FEF_{25\text{-}75}$), and peak expiratory flow (PEF). Both groups improved over time, but the magnitude of improvement was substantially larger with mirror feedback.

The observed improvements in the DNS-only Group are consistent with previous studies showing that trunk-focused and core-stabilization exercises can enhance respiratory function in PD (15, 16). DNS specifically emphasizes diaphragmatic activation, intra-abdominal pressure regulation, and coordinated trunk-pelvic motion, all of which are directly relevant to efficient breathing mechanics (17). Even without mirror feedback, the repetitive, controlled loading of trunk muscles and postural challenges likely improved thoracic mobility and respiratory muscle recruitment.

However, the striking additive effect of mirror feedback requires explanation. The mirror group's FVC more than doubled (from 2.32 L to 5.73 L), while the control group improved only modestly (from 2.51 L to 2.80 L). These differences cannot be attributed to differential exercise intensity, as the physical program was identical. We propose several mechanisms that MVF can provide real-time visual feedback of trunk position, allowing patients to correct forward flexion, lateral deviation, or asymmetrical postures that restrict chest wall expansion. Improved standing and sitting alignment directly increases thoracic volume and diaphragmatic excursion (18). In addition, patients with PD impair proprioception and internal body representation (19). Mirror feedback can create a coherent visual surrogate of the body, reinforcing the sense of trunk position and movement. This may help patients voluntarily recruit abdominal and intercostal muscles more effectively during both exercise and resting breathing.

DNS exercises can coordinate breathing with movement. Mirror feedback allows patients to visually monitor abdominal and thoracic movement patterns, potentially improving the dissociation between rib cage and abdominal motion. Without a mirror, patients may unknowingly adopt inefficient movement strategies (e.g., shoulder elevation, pelvic tilting) that limit respiratory function. MVF facilitates error detection and correction, leading to more economical and effective breathing mechanics. The significant interactions for FEV_1 and $FEF_{25\text{-}75}$ suggest that mirror feedback particularly benefits expiratory flow rates, which depend on both respiratory muscle strength and airway patency. Improved cough peak flow (as reflected in PEF) has direct clinical relevance for reducing aspiration risk (20).

Our findings extend the existing evidence on MVF in PD beyond limb motor control and balance (7) to include respiratory outcomes. A systematic review by Lahuerta-Martín et al. (21) concluded that action observation and motor imagery improve gait and balance in PD, but noted inconsistent effects across studies. To our knowledge, no prior trial has examined MVF combined with trunk stabilization training on spirometry. Our results align with studies showing that visual feedback can enhance motor learning and cortical excitability in PD (22), and we now provide preliminary evidence that these mechanisms translate to respiratory muscle control.

The lack of significant group differences for FEV_1/FVC and $FEV_1/VCmax$ ratios is not surprising. These ratios reflect the proportion of air exhaled in the first second relative to total volume. Both groups improved their absolute volumes, but the ratio changed less because FVC and FEV_1 increased in parallel. The preserved or improved ratio suggests that the training did not induce airway obstruction but rather improved overall lung volume and flow in a balanced manner.

Limitations

Several limitations must be acknowledged. First, this is a secondary analysis with a limited sample size (n = 34) due to the availability of complete spirometry data, which may limit generalizability. Second, the large magnitude of change in the mirror group (e.g., FVC from 2.32 L to 5.73 L) is unusually high for an 8-week intervention in PD and may reflect measurement variability, learning effects, or a small-sample artifact; replication in larger studies is essential. Third, we did not control for medication timing ("ON/OFF" state) during spirometry, which could influence respiratory muscle performance. Fourth, no long-term follow-up was performed, so the durability of these respiratory gains is unknown. Fifth, we did not adjust for multiple comparisons, increasing the risk of type I error; the p-values for FEF_{25-75} and PEF (0.022 and 0.020) should be interpreted conservatively. Finally, the mechanism linking mirror feedback to improved spirometry remains speculative; future studies should include electromyography of respiratory muscles and motion analysis of thoracic kinematics.

Recommendations

Based on the findings of the present study, it is recommended that future research investigate the combined effect of mirror visual feedback and Dynamic Neuromuscular Stabilization (DNS) exercises in larger cohorts, employing a primary randomized controlled trial (RCT) design to enhance the generalizability of the findings. Furthermore, mid-term and long-term follow-ups are essential to evaluate the sustainability of the respiratory effects induced by this intervention. Precise control of medication status, specifically ensuring assessments are conducted consistently in either the 'ON' or 'OFF' state, would facilitate a more accurate interpretation of the results.

Future studies should consider incorporating variables such as respiratory muscle strength, electromyography (EMG) of the diaphragm and intercostal muscles, thoracic movement patterns, and respiratory-related quality of life, alongside spirometric indices, to elucidate further the potential mechanisms underlying the effects of mirror feedback. From a clinical perspective, mirror feedback—as a simple, cost-effective, and feasible approach—may be integrated with trunk stabilization exercises into rehabilitation programs for patients with mild-to-moderate Parkinson's disease. Nevertheless, a definitive recommendation for its widespread implementation requires confirmatory studies with larger sample sizes.

Conclusion

In patients with mild to moderate Parkinson's disease, an 8-week Dynamic Neuromuscular Stabilization program improved multiple spirometric parameters, including FVC, FEV_1, FEF_{25-75}, and PEF. The addition of mirror visual feedback produced significantly larger improvements than DNS alone, particularly for vital capacity and expiratory flows. These findings suggest that mirror-augmented DNS is a simple, low-cost, and effective strategy to enhance respiratory function in PD, with potential implications for reducing aspiration risk and improving quality of life. Larger confirmatory trials with longer follow-up and mechanistic assessments are warranted.

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Authors' Contribution

Mohaddeseh Assari: Conceptualization, study execution, data collection and organization, intervention implementation, and drafting the original manuscript.
Gholamali Ghasemi: Conceptualization, methodology, supervision, formal data analysis, and reviewing and editing.
Morteza Sadeghi: Methodology, formal data analysis, data interpretation, and reviewing and editing.
Ahmad Chitsaz: Clinical support, participant recruitment, methodology, and reviewing and editing.
All authors have read and approved the final version of the manuscript.

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The Research Ethics Committee of Isfahan University of Medical Sciences approved the study protocol (Ethics Code: IR.UI.REC.1404.117). Additionally, the study

protocol was registered in the Iranian Registry of Clinical Trials (IRCT ID: IRCT20251101067842N1). All steps were conducted in compliance with the ethical standards of Isfahan University of Medical Sciences.

Conflict of Interest

The authors did not have a conflict of interest.

References

1. Dudchenko N, Gadzhieva Z, Koloman I, Kuzmina A, Levin O. Respiratory dysfunction in Parkinson's disease. Zhurnal Nevrologii i Psikhiatrii Imeni SS Korsakova. 2021; 121(10. Vyp. 2): 80-5.
2. Troche MS, Curtis JA, Sevitz JS, Dakin AE, Perry SE, Borders JC, et al. Rehabilitating cough dysfunction in Parkinson's disease: a randomized controlled trial. Movement disorders. 2023; 38(2): 201-11.
3. McMahon L, Blake C, Lennon O. A systematic review and meta-analysis of respiratory dysfunction in Parkinson's disease. European Journal of Neurology. 2023; 30(5): 1481-504.
4. Navas-Garrido I, Martín-Núñez J, Raya-Benítez J, Granados-Santiago M, Navas-Otero A, López-López L, et al., editors. Respiratory muscle strength training in Parkinson's disease—A systematic review and meta-analysis. Healthcare; 2025: MDPI.
5. McMahon L, McGrath D, Blake C, Lennon O. Responsiveness of respiratory function in Parkinson's Disease to an integrative exercise programme: A prospective cohort study. Plos one. 2024; 19(3): e0301433.
6. Aquino YC, Cabral LM, Miranda NC, Naccarato MC, Falquetto B, Moreira TS, et al. Respiratory disorders of Parkinson's disease. Journal of Neurophysiology. 2022; 127(1): 1-15.
7. Huang H, Xie H, Zhang G, Xiao W, Ge L, Chen S, et al. Effects of dynamic neuromuscular stabilization training on the core muscle contractility and standing postural control in patients with chronic low back pain: a randomized controlled trial. BMC Musculoskeletal Disorders. 2025; 26(1): 213.
8. Babagoltabar-Samakoush H, Aminikhah B, Bahiraei S. The effects and durability of an 8-week dynamic neuromuscular stabilization program on balance and coordination in adult males with intellectual disabilities: a randomized controlled trial. BMC Sports Science, Medicine and Rehabilitation. 2025; 17(1): 18.
9. Bonassi G, Pelosin E, Ogliastro C, Cerulli C, Abbruzzese G, Avanzino L. Mirror visual feedback to improve bradykinesia in Parkinson's disease. Neural plasticity. 2016; 2016(1): 8764238.
10. Genovese F, Romeo M, Terrenzio FP, Esposito N, Destefanis C, Gindri P, et al. Distinct patterns of visuo-tactile and visuo-motor body-related integration in Parkinson's disease. Scientific Reports. 2025; 15(1): 27923.
11. Mezzarobba S, Bonassi G, Avanzino L, Pelosin E. Action observation and motor imagery as a treatment in patients with Parkinson's disease. Journal of Parkinson's Disease. 2024; 14(s1): S53-S64.
12. Watanabe T, Naoi I, Obata R, Baba K, Aino H. Hoehn & Yahr scale and MDS-UPDRS Part 3 progression in Parkinson's disease patients: retrospective natural history study using a disease registry. Rinsho shinkeigaku= Clinical neurology. 2025; 65(12): 865-72.
13. Hoehn MM, Yahr MD. Parkinsonism: onset, progression, and mortality. Neurology. 1967; 17(5): 427.
14. Alikhani A, Salari M, Etemadifar M. Assessment of reliability and validity of the Persian version of the Parkinson's anxiety scale (P-PAS). Applied Neuropsychology: Adult. 2025: 1-5.
15. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. Behavior research methods. 2009; 41(4): 1149-60.
16. van den Heuvel MR, Kwakkel G, Beek PJ, Berendse HW, Daffertshofer A, van Wegen EE. Effects of augmented visual feedback during balance training in Parkinson's disease: a pilot randomized clinical trial. Parkinsonism & related disorders. 2014; 20(12): 1352-8.
17. Cabrera-Martos I, Jiménez-Martín AT, López-López L, Rodríguez-Torres J, Ortiz-Rubio A, Valenza MC. Effects of a core stabilization training program on balance ability in persons with Parkinson's disease: a randomized controlled trial. Clin Rehabil. 2020; 34(6): 764-72.
18. Reyes A, Castillo A, Castillo J, Cornejo I. The effects of respiratory muscle training on peak cough flow in patients with Parkinson's disease: a randomized controlled study. Clinical rehabilitation. 2018; 32(10): 1317-27.
19. Adityasiwi GL, Wirata RB, Wijanarko F, Susanto NAP, Nugroho T. Diaphragmatic Breathing for Improving Lumbar Flexibility: An Experimental Study on Final-Year Students at STIKES Bethesda Yakkum Yogyakarta. Majalah Ilmiah Fisioterapi Indonesia. 2025; 13(1): 710-6.
20. Malwanage KT, Dissanayaka TD, Allen NE, Paul SS. Effect of Proprioceptive Training Compared With Other Interventions for Upper Limb Deficits in People With Parkinson Disease: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Archives of Physical Medicine and Rehabilitation. 2024; 105(7): 1364-74.
21. Li K-y, Pickett KA, Fu H-w, Chen R-s. Proprioceptive and olfactory deficits in individuals with Parkinson disease and mild cognitive impairment. Acta Neurologica Belgica. 2024; 124(2): 419-30.
22. Troche MS, Schumann B, Brandimore AE, Okun MS, Hegland KW. Reflex cough and disease duration as predictors of swallowing dysfunction in Parkinson's disease. Dysphagia. 2016; 31(6): 757-64.
23. Lahuerta-Martin S, Llamas-Ramos R, Llamas-Ramos I. Effectiveness of therapies based on mirror neuron system to treat gait in patients with Parkinson's disease—a systematic review. Journal of Clinical Medicine. 2022; 11(14): 4236.

24. Horiba M, Ueki Y, Nojima I, Shimizu Y, Sahashi K, Itamoto S, et al. Impaired motor skill acquisition using mirror visual feedback improved by transcranial direct current stimulation (tDCS) in patients with Parkinson's disease. Frontiers in neuroscience. 2019; 13: 602.