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Effectiveness of a dance-physiotherapy combined intervention in Parkinson's disease: a randomized controlled pilot trial

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Abstract

Background

Physical therapies have been recommended as crucial components in Parkinson's disease (PD) rehabilitation.

Objective

The study aims to examine the effectiveness of a new dance-physiotherapy combined intervention, called DArT method, in mild PD patients.

Methods

A prospective, randomized, single-blind, controlled pilot trial was conducted on 38 mild PD patients under dopaminergic therapy. The intervention consisted in an add-on protocol: the control group received 1 h of conventional physiotherapy followed by 1 h of conventional physiotherapy each day, 3 times a week, for 5 weeks. The experimental group received 1 h of conventional physiotherapy followed by 1 h of dance class each day, 3 times a week, for 5 weeks. The week before and after the training period, patients were assessed for motor, cognitive, emotional, and sensory components of PD, with MDS-UPDRS-III as primary outcome measure.

Results

DArT method was associated with a 2.72-point reduction in the post-treatment MDS-UPDRS-III total score compared to control group (95% CI − 5.28, − 0.16, p = 0.038, d = 0.71), and with a 2.16-point reduction in the post-treatment MDS-UPDRS-III upper body subscore (95% CI − 3.56, − 0.76, p = 0.003, d = 1.02). Conversely, conventional physiotherapy program was associated with a 2.95-point reduction in the post-treatment trait anxiety compared to the experimental group (95% CI 0.19, 5.71, p = 0.037, d = 0.70). Withdrawal and fall rates were equal to 0% in both groups.

Conclusion

DArT method showed to be safe, well accepted, and more effective than an intensive program of conventional physiotherapy in improving motor impairment in mild PD.

Introduction

Parkinson's disease (PD) is a multisystem disorder characterized by a core of motor symptoms (tremor, rigidity, and bradykinesia) and several non-motor symptoms (NMS), including neuropsychiatric problems and cognitive impairment [1].

Exercise and physical therapy have been recommended as crucial components in PD rehabilitation, complementing pharmacotherapy and functional surgery [2], and have symptomatic benefits on motor and NMS of PD [3]. In particular, mind-body exercises, including dance, yoga, and tai chi, have been reported to be the most common complementary strategies adopted by patients with PD to enhance their entire wellbeing [4], with several meta-analyses in the most recent years reaching favorable conclusions on dance-based intervention [5, 6].

In line with these evidences, our multidisciplinary group developed a dance-physiotherapy combined intervention called DArT method (DAnce Therapy) and addressed to mild PD patients. This pilot trial aimed to investigate the effectiveness and safety of DArT method compared with an intensive program of conventional physiotherapy.

Methods

Study design and population

A prospective, randomized, single-blind, controlled pilot trial, using an add-on design, was conducted on 38 patients diagnosed with idiopathic PD according to the Movement Disorder Society (MDS) Clinical Diagnostic Criteria for PD [1], and recruited through both the regional Reference Center of Movement Disorders (Turin, Italy) and its Reference Rehabilitation Hospital (Presidio Sanitario San Camillo, Turin, Italy) by their treating physicians. Participants were eligible for inclusion in the study if they have been classified as mild PD patients, defined as a Hoehn and Yahr (H&Y) score of 1–2 and a MDS-sponsored revision of the Unified Parkinson's Disease rating scale Part III (MDS-UPDRS-III) score of 1–32 [7], and were on stable dopaminergic therapy for at least 4 weeks. Patients were ineligible if they had cognitive impairments, had severe orthopedic comorbidities, used walking aids, and could not guarantee their presence for the whole study period. About the screening for cognitive impairment, MoCA scale was adopted as more sensitive than MMSE in detecting early cognitive changes in PD [8].

All the experimental procedures were approved by the local Ethics Committee (CS2/472) and conducted in agreement with the Declaration of Helsinki Ethical Principles. Written informed consent was obtained from all participants prior to enrollment. In particular, participants agreed to attend 5 weeks of rehabilitation activities during which the conventional physiotherapy could have been associated to other therapeutic activities.

Interventions

DArT method has been developed according to the key recommendations for Physical Therapy in PD [9]. As extensively show in the Online supplemental materials S1 and S2, our method consists in an intensive and progressive training that combines the conventional

physiotherapy with a contemporary dance style incorporating some elements of classical ballet and avoiding the aid of music, so that the effectiveness of motor rehabilitation component alone can be assessed. Each class of conventional physiotherapy and dance programs is structured as follows, respectively: a first part devoted to the therapist-patient relationship (5 min long for both programs), a warm up session with supports (5 exercises for a total of 20 min versus 4 exercises for 30 min), and a center session without supports (6 exercises for a total of 35 min versus 7 exercises for 25 min). Auditory cues are administered to all participants in form of hand clapping, breaths, and footfalls. In addition, visual, cognitive, and, in some cases, tactile cues are administered as well.

The choice to use an add-on design was due to ethical reasons (all patients were guaranteed to receive the best validated treatment, i.e., conventional physiotherapy) and because it was a novel approach in the field of physical therapy for PD [5, 6, 10]. In particular, the control group received 1 h of conventional physiotherapy followed (after 30-min break) by 1 h of conventional physiotherapy each day, 3 times a week, for 5 weeks. The experimental group received 1 h of conventional physiotherapy followed (after 30-min break) by 1 h of dance class each day, 3 times a week, for 5 weeks. The weekly training intensity was superior to the one suggested by the European Physiotherapy Guideline for PD for conventional physiotherapy (3 times a week for 45 min) and dance (3 times a week for 60 min) [11].

Each day of the training period, a physiotherapist conducted the first hour of the conventional physiotherapy program (up to 13 patients for class), whereas a different physiotherapist conducted the second hour (up to 7 patients). A dance therapist with strong background in neuroscience and work experiences with PD conducted the dance program (up to 7 patients for class).

Outcome measurements

Three cycles of rehabilitation activities were conducted. The week preceding and the week following the 5-week training period patients were assessed for motor, cognitive, emotional, and sensory components of PD. Both rehabilitation activities and patients' assessments took place at the San Camillo Hospital. In order to reduce patients' discomfort, all tests were administered over the ON medications hours. In particular, the "On time" was defined in agreement with patient's perception, who said that "he/she was in his/her best on-time."

The selected primary outcome, representative of the motor component, was the MDS-UPDRS-III total score [7, 12]. The upper, lower, and axial body subscores of the MDS-UPDRS-III were calculated as well (see S3 in Online supplemental materials).

Secondary outcomes were (1) Six-Minute Walking Test (6MWT) [11], Time Up and Go (TUG) [11, 13], Mini-Balance Evaluation Systems Test (Mini-BESTest) [11], and New Freezing of Gait Questionnaire (NFOG-Q) [14], as for the motor component; (2) Montreal Cognitive Assessment (MoCA) [8] and TUG with dual task (TUG-DT) [15], as for the cognitive component; (3) 39-item Parkinson's Disease Questionnaire Summary Index (PDQ-39-SI) [16], Beck Depression Inventory (BDI) [17], State-Trait Anxiety Inventory (STAY) Y 1 and 2 [18], and Falls Efficacy Scale-International (FES-I) [19], as for the emotional component; and (4) King's PD pain scale [20] and Parkinson Fatigue Scale-16 (PFS-16) [21], as for the sensory component. As regard the FES-I, the previously published cut-points were adopted to differentiate participants based on their degree of concern [19]. Medications were logged during the first assessment visit, and the L-dopa equivalent daily dose (LEDD) was calculated for each participant [22].

Randomization and blinding

The study coordinator, not directly involved in patients' care and recruitment, performed a simple randomization using computer-generated random numbers (1:1 ratio between control and experimental groups), and concealed the code until the first day of rehabilitation program. The performance bias due to the inability to blind participants and therapists to the interventions was addressed blinding participants to study hypothesis. All assessors were blinded for group allocation: one neurologist and one psychologist, the "first assessors," administered the array of tests and filmed patients during examinations; a "second assessor" (neurologist) evaluated the video off-line. To avoid being able to make direct comparisons, one month had to pass between viewing the pre- and post-training videos of the same patient. The potential bias of order effect due to the fact that the "second assessor" was not blind to pre- and post-condition was equally present in both control and experimental groups.

Statistical analysis

A sample size calculation for the primary outcome measure was performed and, assuming a minimal effects size of 0.7, it showed that a whole sample size of 64 participants was needed to provide a statistical power at the recommended 0.80 level. Normal distribution of baseline characteristics of patients was verified by Shapiro-Wilk test. In order to rule out possible differences, a between-group analysis was performed using the independent sample Student's t-test if the normality assumption was satisfied, or the Mann–Whitney U test if it was not. Chi-square test was used for dichotomous (sex) and ordinal (H&Y stage, FES-I cutoff points, patients affected or not by freezing) variables.

The efficacy analysis was performed by ANCOVA-POST model, using post-treatment scores as dependent variable, baseline scores as a covariate, and treatment group as independent variable. If the assumption of normality was violated, the nonparametric ANCOVA was used. Previously published values of minimal detectable change (MDC), minimal clinically important difference (MCID), or smallest detectable difference (SDD) were used as optimal

cutoff points to calculate the percentage of patients who exceeded these thresholds [23,24,25,26,27,28,29,30,31].

A within-group analysis was also conducted using the paired sample Student's t-test if the normality assumption was satisfied, or the Wilcoxon test if it was not. Due to the exploratory nature of the study, no multiplicity adjustment was applied. Since it provides additional information than any statistical test, Cohen's d effect size was calculated. In case of non-normal data R statistic was computed and then converted to Cohen's d. All the analyses were performed with SPSS, version 25.0 (IBM Corp., Armonk, NY) using two-tailed p values with a level of significance of 0.05.

Results

The recruitment period started on 26 February 2018 and ended on 28 February 2019. One-hundred and twenty PD patients were screened and 38 were eligible for the pilot trial; 19 were assigned to the experimental group and 19 to the control group. Fall and withdrawal rates were equal to 0% for both groups. All 38 patients were included in the statistical analysis and were analyzed according to the group they were originally assigned (see S4 for the CONSORT flow diagram and S5 for CONSORT checklist in Online supplemental materials). No significant differences were found in the baseline characteristics between control and experimental groups (Table 1).

Primary outcome

As shown in Fig. 1 and Table 2, post-treatment MDS-UPDRS-III total score was significantly lower in the experimental group (i.e., DArT method, adjusted mean difference − 2.72 (95% CI − 5.28, − 0.16), p = 0.038) after adjustment of post-treatment score for baseline score, with a moderate effect size (d = 0.71). Moreover, post-treatment MDS-UPDRS-III upper body subscore was significantly lower in the experimental group (− 2.16 (95% CI − 3.56, − 0.76), p = 0.003), with a large effect size (d = 1.02). Clinically significant changes in the MDS-UPDRS-III total score were found in 68% of experimental group patients and 63% of control group patients, even if these percentages did not differ between groups (p = 0.732; Table 3). Significant within-group improvements in the MDS-UPDRS-III total score were found in both the experimental (p < 0.0001, d = 1.14) and control (p = 0.001, d = 1.00) groups, as well as in both the experimental (upper p = 0.0002 and d = 1.48, lower p = 0.007 and d = 0.61, axial p = 0.021 and d = 0.81) and control (upper p = 0.004 and d = 0.76, lower p = 0.003 and d = 1.10, axial p < 0.0001 and d = 0.96) subgroups.

Secondary outcomes

Significant between-group differences were not found, except for STAI-Y2 assessments (Table 2), where post-treatment score was significantly lower in the control group (adjusted mean

difference 2.95 (95% CI 0.19, 5.71), p = 0.037) after adjustment of post-treatment score for baseline score, with a moderate effect size (d = 0.70). Significant within-group improvement for STAI-Y2 were only found in the control group (p = 0.002 and d = 0.37 vs p = 0.753 in the experimental group).

Both experimental and control groups exceeded the optimal cutoff point specific for 6MWT (21% vs 11%, respectively), Mini-BESTest (5% vs 5%, respectively), and PDQ-39 (42% vs 37%, respectively), but no significant between-group difference was observed (p = 0.374, p = 1.000, p = 0.740, respectively), as shown in Table 3.

As for the within-group analysis, significant improvements in both experimental and control groups were found for 6MWT (p = 0.002 and d = 0.73 vs p = 0.001 and d = 0.47), TUG (p = 0.010 and d = 0.58 vs p = 0.023 and d = 0.38), and PDQ-39 (p = 0.010 and d = 0.92 vs p = 0.001 and d = 1.36). Significant improvements in cognitive domain were observed in the experimental group only (MoCA p = 0.033 and d = 0.38 vs p = 0.175; TUG-DT p = 0.021 and d = 0.81 vs p = 0.799). Conversely, significant improvements in freezing (NFOG-Q p = 0.005 and d = 1.02 vs p = 0.075), BDI (p = 0.009 and d = 0.94 vs p = 0.118), King's PD pain scale (p = 0.034 and d = 0.73 vs p = 0.088), and fatigue (PFS-16 p = 0.030 and d = 0.34 vs 0.181) were only found in the control group. No significant improvements occurred for Mini-BESTest, FES-I, and STAI-Y1.

Discussion

This pilot trial investigated the effectiveness and safety of DArT method (i.e., the experimental group) as rehabilitation add-on intervention for 38 individuals affected by mild PD. First, our findings indicate that DArT method was more effective in reducing the MDS-UPDRS-III total score than the intensive program of conventional physiotherapy administered to the control group, with a moderate effect size. Second, it was more effective in reducing the MDS-UPDRS-III upper body subscore, with a large effect size. Third, the intensive conventional physiotherapy program was more effective than DArT method in reducing post-treatment trait anxiety, as assessed by means of STAI-Y2, with a moderate effect size. Fourth, the DArT method showed significant within-group improvements (i.e., post-training compared to baseline assessments) in motor impairment (MDS-UPDRS-III total score and subscores), cognitive domain (MoCA and TUG-DT), postural instability and functional mobility (TUG), endurance (6MWT), and quality of life (PDQ-39). Fifth, only the DArT method showed significant within-group improvements in cognitive domain (MoCA and TUG-DT). Sixth, it demonstrated to be safe and very well accepted by mild PD patients, confirmed by fall and withdrawal rates of 0%.

A formal comparison among the rehabilitation interventions investigated up to now is difficult to perform considering the wide variety of physical therapy interventions and the outcomes assessed [10]. Nevertheless, restricting the focus on recent meta-analyses about dance-

based interventions, the DArT method effectiveness in improving motor, cognitive, and emotional components after the training period compared to baseline is consistent with previous findings [5, 6]. Interestingly, to our knowledge the present study is the first showing that a dance-based intervention addressed to mild PD patients is able to elicit a marked improvement in motor impairment affecting the upper body, including facial expression, rigidity in neck and arms, upper body bradykinesia, postural/kinetic tremor, and rest tremor (see S3 in Online supplemental materials). This selective improvement may be explained by the daily longer warm up session delivered to the experimental group compared to the control group (20 + 30 min versus 20 + 20 min), and by the exercises characterizing this specific session of the dance program, such as the visualizations and improvisations exercises sustained by externally given visual and auditory cues. Indeed, these specific exercises have been previously shown to help PD patients in compensating the slowness of thought, in movement planning, in increasing both reaction time and bradykinesia [32], and therefore they may have also contributed to the within-group improvements observed in the cognitive domain (MoCA and TUG-DT). Moreover, the therapist-patient relationship session characterizing the first 5 min of each dance class and aimed at enhancing patients' positive expectations and both testing and pushing physical and mental limits, may have specifically contributed to improving bradykinesia in the experimental group. Indeed, this cardinal symptom of PD has been previously shown to be very sensitive to placebo effects [33, 34].

Conversely, the shorter daily center session delivered to the experimental group compared to the control group (35 + 25 versus 35 + 35 min) could explain the tendency toward a less effectiveness of DArT method on the lower body. Moreover, the reduced aerobic training experienced by the experimental group during the center session could explain the significant lower improvements obtained in trait anxiety (STAI-Y2). Indeed, recent findings show that prolonged physical activity increases serum concentrations of endocannabinoids producing both central and peripheral effects among which analgesia, anxiolysis, and a sense of wellbeing [35].

As regard the scalability and generalizability of DArT method, the obtained preliminary results could be exported also outside of the healthcare setting. The ludic phase of this new rehabilitation training, represented by the dance program, would create a bridge of interest and complicity with the patient, where caregivers could also be involved whenever possible. According to this perspective, new figures of therapists, who are both trained dancers and persons knowing the PD condition, would become of crucial importance.

Our findings should be tempered by important limitations. Eighty-two PD patients were excluded from the trial because showing the symptoms of moderate PD (H&Y of 3 and MDS-UPDRS-III of 33–58). This selection process had in fact underpowered the study, hindering the generalizability of its results, even if the minimal effects size of 0.7 for the MDS-UPDRS-III total score was confirmed by our results. The MDS-UPDRS-III upper body subscore was analyzed as a whole, without investigating the single scores. As for the Mini-BESTest, our

participants obtained high scores at baseline already, making us unable to detect significant between- and within-group improvements in this specific measure of balance. Moreover, all outcomes were determined over the ON medications hours, so the confounding effects of variable responses to dopaminergic medication could not be ruled out. As regard the role of music, the pioneering choice to exclude it from our dance program may have reduced the effectiveness of DArT method [5, 6, 36, 37]. Video assessments were not truly unbiased since all pre-intervention videos were analyzed prior to the post-intervention videos. All pre- and post-intervention videos will be randomized in future studies and their analysis will be undertaken by multiple raters, allowing inter-rater reliability to be assessed as well. Since rigorous follow-up examinations were not performed after the completion of the study, no information about long-term effects of DArT method is available. Those improvements in freezing phenomenon observed during dance classes were generally not reproduced during post-training assessments as already documented in literature [38], thus suggesting the utility of video-recording patients during both dance and physiotherapy classes.

In accordance to present findings and limitations, further studies are underway to reach the optimal sample size and investigate additional motor PD symptoms, like bradykinesia, and NMS, like heart rate variability analysis and sleep quality. Finally, the extension of DArT method to a wider PD population, ranging from mild to moderate, represents an additional possibility that we will explore from a safety and efficacy perspective in future research.

Data Availability

The data that support the findings of this study are available on request from the corresponding author (Frisaldi Elisa).

Code availability (software application or custom code)

Not applicable.

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Table 1 Comparisons of baseline characteristics between the groups

Measurement	Control group (n = 19)	Experimental group (n = 19)	p value
Age (years)	61.21 (7.18)	60.68 (6.34)	0.812
Sex			0.319
Male	13 (68%)	10 (53%)	
Female	6 (32%)	9 (47%)	
Disease duration, years	6.43 (2.50)	5.99 (2.18)	0.560
BMI	26.53 (4.33)	27.34 (4.25)	0.566
Hoehn and Yahr (on med)[a]			NA
1	0 (0%)	0 (0%)	
2	19 (100%)	19 (100%)	
MoCA	25.68 (2.89)	26.08 (3.07)	0.686
N of fallers[b]	0 (0%)	0 (0%)	NA
FES-I			1.000
16–19 low concern	9 (47%)	9 (47%)	
20–27 moderate concern	8 (42%)	8 (42%)	
28–64 high concern	2 (11%)	2 (11%)	
Patients affected by freezing			0.516
No	8 (42%)	10 (53%)	
Yes	11 (58%)	9 (47%)	
Total LEDD (mg)	638.37 (198.12)	613.11 (310.20)	0.767

BMI body mass index, *FES-I* Falls Efficacy Scale–International, *LEDD* levodopa equivalent daily dose, *MoCA* Montreal Cognitive Assessment, *NA* not applicable

[a] All participants underwent to the Hoehn and Yahr scale assessment after the dopaminergic medication intake, in agreement with patient's perception of being in their best "ON" time

[b] Number of patients who had fallen in the 6 months before the study entry

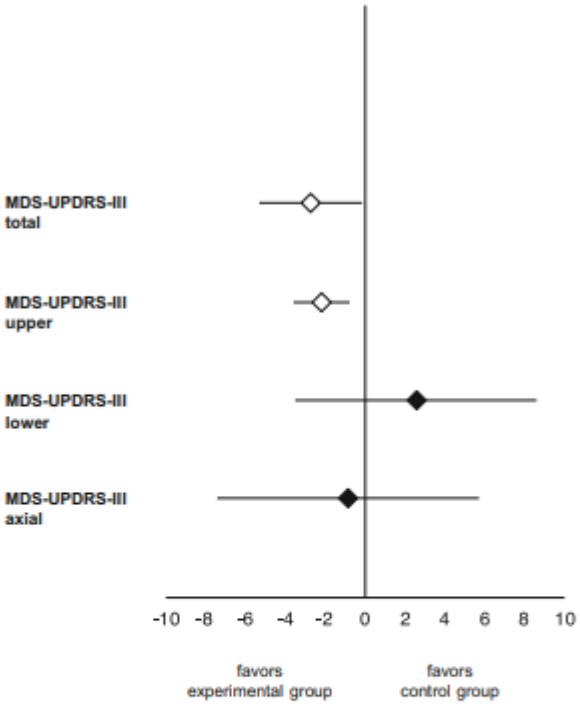

Fig. 1 Forest plot of the adjusted mean differences and their 95% confidence intervals (CIs) related to post-treatment MDS-UPDRS-III total score, and subscores, assessed in both experimental and control groups. Each adjusted mean difference was obtained by calculating the difference between post-treatment mean score adjusted for baseline mean score in the experimental group and post-treatment mean score adjusted for baseline mean score in the control group. Horizontal bars not crossing the 0 vertical line are statistically significant (marked by an open white diamond). Adjusted mean differences < 0 favor experimental (DArT method) versus control group, while adjusted mean differences > 0 favor control versus experimental group

	Experimental group[a]						Control group[a]								
	Pre-treatment			Post-treatment			Pre-treatment			Post-treatment				95% CI	
Outcome measure	Mean	SD		Mean	SD		Mean	SD		Mean	SD		Adjusted mean difference	Upper	Lower	*p* value and effect size
	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3	Median	Q1	Q3				
MDS-UPDRS-III total	16.79	7.32		10.05	4.48		18.42	5.26		13.47	4.88		− 2.72	− 5.28	− 0.16	0.038
	15	11	22	11	7	13	19	15	23	14	9	16				0.71
MDS-UPDRS-III upper	9.37	4.65		5.37	2.95		10.16	3.44		7.89	2.66		− 2.16	− 3.56	− 0.76	0.003
	8	6	12	5	3	8	10	7	13	8	6	10				1.02
MDS-UPDRS-III lower	5.16	3.53		3.42	2.12		5.32	2.40		3.21	2.15		2.57	− 3.50	8.64	0.397
	4	2	8	4	1	5	5	4	7	3	2	4				NA
MDS-UPDRS-III axial	3.79	2.23		2.47	1.43		3.89	1.63		2.47	1.39		− 0.81	− 7.37	5.75	0.804
	4	3	5	3	1	3	4	3	5	3	1	3				NA
6MWT	497	76.69		544	55.62		526	91.54		565	78.20		− 1.81	− 28.8	25.1	0.892
	500	480	551	541	490	578	541	475	594	576	498	625				NA
NFOG-Q	5.11	6.25		3.37	4.45		5.42	6.18		2.95	4.36		0.93	− 2.94	4.80	0.630
	0	0	12	0	0	9	6	0	8	0	0	5				NA
Mini-BESTest	25.58	2.06		26.16	1.61		26.21	1.62		26.58	0.77		− 0.58	− 7.02	5.85	0.855
	26	24	27	26	25	27	27	25	27	27	26	27				NA
TUG	7.22	1.15		6.62	0.97		6.56	1.22		6.16	0.89		0.08	− 0.36	0.52	0.715
	7	6	8	7	6	7	6	6	8	6	5	7				NA
MoCA	26.08	3.07		27.11	2.51		25.68	2.89		26.55	2.62		1.49	− 3.47	6.44	0.547
	27	24	28	27	26	29	26	25	28	27	26	29				NA
TUG-DT	8.05	1.70		7.31	1.18		7.19	1.39		7.12	1.21		− 0.27	− 0.87	0.32	0.356
	7	7	9	7	6	8	8	6	8	7	6	8				NA
BDI	6.53	5.06		5.21	4.86		7.84	7.46		5.00	4.10		0.95	− 0.88	2.78	0.299
	5	2	9	4	1	9	5	3	14	5	2	7				NA
FES-I	21.79	6.75		21.16	6.57		20.84	4.87		20.26	4.76		− 0.36	− 3.62	2.91	0.826
	20	17	23	19	17	22	20	16	24	20	16	22				NA
PDQ-39	15.49	12.28		11.77	10		16.32	12.92		10.79	8.32		0.44	− 3.37	4.26	0.815
	11	6	24	9	5	13	13	7	23	11	2	17				NA
STAI-Y1	31.11	5.82		30.21	6.15		33.79	7.59		31.37	5.34		0.60	− 1.90	3.10	0.627
	31	28	34	31	26	32	32	31	38	32	27	35				NA
STAI-Y2	34.11	9.22		33.79	9.19		35.16	9.37		31.79	9.53		2.95	0.19	5.71	0.037
	33	28	37	32	26	43	35	28	40	30	24	37				0.70
PD pain scale	9.84	11.45		6.95	12.41		5.68	6.17		3.37	5.02		1.15	− 4.18	6.48	0.665
	5	2	16	4	1	5	4	0	11	2	0	5				NA
PFS-16	2.64	0.73		2.46	0.91		2.48	0.89		2.19	0.87		0.13	− 0.23	0.50	0.465
	3	2	3	2	2	3	3	2	3	2	1	3				NA

Table 2 Comparison of experimental and control groups after intervention

BDI Beck Depression Inventory; CI confidence interval; FES-I Falls Efficacy Scale–International; MDS-UPDRS-III Movement Disorder Societysponsored revision of the Unified Parkinson's Disease Rating Scale, Part III; Mini-BESTest Mini-Balance Evaluation Systems Test; MoCA Montreal

Cognitive Assessment; NA not applicable; NFOG-Q the New Freezing of Gait Questionnaire; PD pain scale (King's) Parkinson's disease pain scale;

PDQ-39 39-item Parkinson's Disease Questionnaire; PFS-16 Parkinson Fatigue Scale-16; Q Quartile; 6MWT Six-Minute Walking Test; SD Standard

Deviation; STAI-Y1 and -Y2 State-Trait Anxiety Inventory Form Y1 and Y2; TUG Time Up And Go; TUG-DT TUG with a Dual Task

a

Since some data were not normally distributed, median and quartiles are presented as well

		Experimental group		Control group		
Outcome measure	Optimal cutoff point	Mean change from baseline[a]	Responders (%)	Mean change from baseline[a]	Responders (%)	*p* value
MDS-UPDRS-III	− 3.25 MCID [23]	− 6.74 (5.33)	68	− 4.95 (5.19)	63	0.732
6MWT	82 m MDC [24]	47.36 (57.05)	21	38.97 (40.45)	11	0.374
NFOG-Q	Insufficiently reliable [25]	− 1.74 (4.15)	NA	− 2.47 (3.47)	NA	NA
MiniBESTest	3.5 MDC [26]	0.58 (1.61)	5	0.37 (1.50)	5	1.000
TUG	3.5 s MDC [27]	0.60 (0.91)	0	0.40 (0.70)	0	NA
MoCA	Not found	1.03 (1.93)	NA	0.87 (2.30)	NA	NA
TUG-DT	Not found	0.73 (1.18)	NA	0.06 (1.05)	NA	NA
DBI	8.7 MDC [28]	1.32 (3.50)	0	2.84 (4.27)	5	0.311
FES-I	≥ 10 points on an individual level, SDD [29]	0.63 (2.22)	0	0.58 (1.71)	0	NA
PDQ-39	− 4.72 MCID [30]	− 3.72 (5.52)	42	− 5.53 (8.85)	37	0.740
STAI-Y1	Not found	0.89 (2.77)	NA	2.42 (5.48)	NA	NA
STAI-Y2	Not found	0.32 (4.31)	NA	3.37 (4.14)	NA	NA
King's PD pain scale	Not found	2.89 (7.18)	NA	2.32 (4.42)	NA	NA
PFS-16	3.09 MCID [31]	0.18 (0.57)	0	0.30 (0.55)	0	NA

Table 3 Clinically significant

improvements for the investigated

outcome measures

BDI Beck Depression Inventory; FES-I Falls Efficacy Scale–International; MCID minimal clinically important

difference; MDC minimal detectable change; MDS-UPDRS-III Movement Disorder Society-sponsored revision

of the Unified Parkinson's Disease Rating Scale, Part III; Mini-BESTest Mini-Balance Evaluation Systems Test;

MoCA Montreal Cognitive Assessment; NA not applicable; NFOG-Q the New Freezing of Gait Questionnaire;

PD (King's) Parkinson's disease pain scale; PDQ-39 39-item Parkinson's Disease Questionnaire; PFS-16

Parkinson Fatigue Scale-16; SDD smallest detectable difference; 6MWT Six-Minute Walking Test; STAI-Y1

and -Y2 State-Trait Anxiety Inventory Form Y1 and Y2; TUG Time Up and Go; TUG-DT TUG with a Dual Task

a

Improvement expressed according to the adopted optimal cutoff point