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A pilot study to evaluate multi-dimensional effects of dance for people with Parkinson's disease

Maria I. Ventura [a], Deborah E. Barnes [a,b,c], Jessica M. Ross [d], Kimberly E. Lanni [e], Karen A. Sigvardt [f], Elizabeth A. Disbrow [g,*]

[a] Department of Epidemiology & Biostatistics, UC, San Francisco, CA, United States
[b] Department of Psychiatry, UC San Francisco, San Francisco, CA, United States
[c] Mental Health Research Service, San Francisco VA Medical Center, San Francisco, CA, United States
[d] Department of Cognitive Science, UC Merced, Merced, CA, United States
[e] Department of Psychology, William Jessup University, Rocklin, CA, United States
[f] Department of Neurology, UC Davis, Davis, CA, United States
[g] Department of Neurology, LSU Health Sciences Center Shreveport, Shreveport, LA, United States

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ABSTRACT

Parkinson's disease (PD) is a progressive neurodegenerative disease associated with deficits in motor, cognitive, and emotion/quality of life (QOL) domains, yet most pharmacologic and behavioral interventions focus only on motor function. Our goal was to perform a pilot study of Dance for Parkinson's—a community-based program that is growing in popularity—in order to compare effect sizes across multiple outcomes and to inform selection of primary and secondary outcomes for a larger trial. Study participants were people with PD who self-enrolled in either Dance for Parkinson's classes (intervention group, N = 8) or PD support groups (control group, N = 7). Assessments of motor function (Timed-Up-and-Go, Gait Speed, Standing Balance Test), cognitive function (Test of Everyday Attention, Verbal Fluency, Alternate Uses, Digit Span Forward and Backward), and emotion/QOL (Geriatric Depression Scale, Falls Efficacy Scale-International, Parkinson's Disease Questionnaire-39 (total score and Activities of Daily Living subscale)) were performed in both groups at baseline and follow-up. Standardized effect sizes were calculated within each group and between groups for all 12 measures. Effect sizes were positive (suggesting improvement) for all 12 measures within the intervention group and 7 of 12 measures within the control group. The largest between-group differences were observed for the Test of Everyday Attention (a measure of cognitive switching), gait speed and falls efficacy. Our findings suggest that dance has potential to improve multiple outcomes in people with PD. Future trials should consider co-primary outcomes given potential benefits in motor, cognitive and emotion/QOL domains.

1. Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disease. Cardinal motor symptoms of PD—including resting tremor, bradykinesia, rigidity and gait dysfunction—can be debilitating [1]. However, approximately 25–40% of people newly diagnosed with PD experience cognitive and emotional impairments, which can be as debilitating as motor symptoms [2]. Pharmacological and surgical interventions are partially effective in reducing PD motor symptoms, however cognitive and emotional impairments are difficult to address with current treatments [3]. Thus there is a need to test alternative interventions that can simultaneously address motor, cognitive and emotional symptoms associated with PD, thereby improving daily functioning and quality of life.

A wide range of exercise interventions including aerobic exercise, resistance training, and stretching have been shown to improve some aspects of physical functioning such as balance and gait speed in people with PD [4–6]. There is growing evidence that exercise can also potentially improve non-motor symptoms, including cognitive and emotional deficits, in PD [7]. However, despite growing evidence of the multi-dimensional benefits of exercise, most people with PD are not regularly active and the factors that contribute to exercise behaviors in PD remain poorly understood [8]. Until recently, identifying barriers to exercise in people with PD has received little attention [9,10]. It is important to understand what influences physical activity engagement so that programs can be designed to increase participation and maintain interest in the PD community.

Dance is rapidly gaining mainstream popularity in people with PD because it is enjoyable in nature and may offer multi-dimensional

* Corresponding author at: Dept. of Neurology, LSU Health Sciences Center Shreveport, PO Box 33932, Shreveport, LA 71130-3932, United States.
E-mail address: edisbr@lsuhsc.edu (E.A. Disbrow).

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benefits [11,12]. Clinical trials have shown that dance improves motor symptoms, particularly problems with balance and mobility [13], as well as overall physical fitness [14]. Dance also may improve cognitive functioning—including executive functioning, working memory, action planning and attention—because it requires the ability to connect one movement to the next and execute complex motor plans [15]. Some studies have shown that dance participants report improved mood after having shared the dance experience with others [16,17] and that they feel more accepted and understood [11], which could improve emotional well-being and quality of life. Yet few studies have simultaneously examined the effects of dance on motor symptoms, cognitive function and emotional well-being in a single study.

Our long-term goal is to perform a full-scale randomized, controlled trial of dance in people with PD. Given the potential multi-domain benefits of dance, the primary goal of the current study was to perform a pilot trial to inform selection of primary and secondary outcomes for this larger trial [18]. We included a non-randomized, no-contact control group to provide additional information about expected changes in these measures without intervention.

2. Materials and methods

2.1. Recruitment

Participants for the intervention group were recruited by distributing recruitment flyers to a pre-existing Dance for Parkinson's program. Those who expressed interest in our study contacted our study team and were then provided more detailed information about our study. Participants for the no-contact control group were recruited by contacting community-led PD support groups that provide talks from health professionals on topics such as nutrition, physical therapy services, and legal matters for individuals with PD. Recruitment flyers were distributed and those who expressed interest in our study contacted our study team and were provided more information about our study.

2.2. Inclusion and exclusion criteria

Inclusion criteria were: self-reported diagnosis of PD, age 55–80 years and no previous dance experience. Exclusion criteria were: history of stroke, significant head trauma, prior neurosurgery, significant vision impairment, atypical PD (i.e. age of onset < 55), and global cognitive impairment (Mini-Mental State Exam score < 25). The study was performed with the approval of the University of California, Davis, Committee for Human Research (#217359–2), and all participants provided written informed consent.

2.3. Testing procedures

All participants were evaluated at two time points: time point 1 (T1) and time point 2 (T2). For the dance intervention group, assessments were completed at T1 prior to beginning dance classes and after completing 10 dance classes at T2. Six participants completed 10 consecutive dance classes, while two participants completed 10 dance classes in non-consecutive weeks due to other obligations (e.g., travel, caring for sick family members). Median time between T1 and T2 for the dance intervention group was 4.5 months. For the no-contact control group, assessments were completed at T1 and T2 but they did not receive the dance intervention. Time between T1 and T2 was matched to the dance intervention group. Median time between T1 and T2 for the no-contact control group was 4 months.

2.4. The dance intervention

Dance classes were led by 2 instructors trained in Dance for PD® methodology and consisted of 10–20 participants (not all of whom were study participants). The duration of each class was 1.25 h once per week following the 3-part format of the Dance for PD® program [11]. Part I: classes began with a 20 minute seated warm-up session. Participants were instructed to focus on connecting their breath to their movements. Instructors first demonstrated the movements, then participants practiced small movements on their own, isolating different parts of the body (i.e. moved feet first, then moved arms, practiced head movements). Part II: participants transitioned to a standing position behind the chairs, held chairs for support during a 20 minute standing warm-up, and practiced weight shifting and balance poses. Although the entire dance class could be completed in the seated position if so desired, participants in our study were able to complete all standing exercise positions. Again, instructors first demonstrated the movements and participants then repeated the movements once on the left-side of the body and once on the right-side of the body. Part III: participants moved to the center of the dance floor and completed a series of choreographed dance movements (dance forms included ballet, jazz, Broadway style dance), improvisational movement such as mirroring, or movement across the floor for 20 min. Movements were performed at least twice, with and without music. A list of sample music pieces is provided in Supplementary material. Every class concluded in a circle dance in which participants stood facing one another, held hands and passed a "pulse" (e.g., hand squeeze) to the next person in the circle. This allowed the participants to acknowledge one another and to acknowledge the shared experience in the class.

2.5. No-contact control group

Participants in the no-contact control group were instructed to engage in usual activities during the study period. They were offered to enroll in Dance for Parkinson's classes after study completion. During the duration of the study, participants in the dance intervention group did not interact with participants in the control group.

2.6. Outcome measures

We selected outcome measures in three domains: motor function, cognitive function and emotion/quality of life. Tests were administered in a university research laboratory setting by a trained assessor who was blind to group assignment at T1 and T2. Participants were assigned a subject identification code and group assignment information was stored in a separate locked file cabinet from the testing material so that the assessor remained blind to group assignment. In addition, participants were instructed not to discuss the dance intervention during evaluation sessions to ensure that the assessor remained blind to group assignment. Evaluation sessions averaged 2 h in duration, and in order to avoid fatigue, frequent breaks were provided to keep participants alert and motivated during testing. Each participant completed the testing while "ON" medication at T1 to establish the degree of impairment in aspects of motor and cognitive performance known to be affected by PD. To reduce practice effects at T2, alternate forms of tests were used when possible. For example, we used two versions of the Alternate Uses test: one version included common objects such as a shoe, button, key, wooden pencil, automobile tire, eyeglasses; a second version included objects such as a chair, watch, safety pin, bed sheet, milk carton, nail. If a participant was given one version at T1, they were given the alternate version at T2. Two versions of the Test of Everyday Attention and Letter Fluency were also available. Therefore, one version of each test was administered at T1 while the second version was administered at T2. Testing at T2 was completed in the same university research laboratory setting at the same time of day as T1 testing while participants were "ON" medication.

2.6.1. Motor domain

Three measures of motor function were used. The Timed-Up-and-Go (TUG) test was used to measure mobility. Participants started from a

seated position, stood up, walked for 3 m as quickly and as safely as possible, then returned to the chair. Time to complete the sequence of tasks was recorded in seconds. Test-retest reliability for the TUG is high (r = 0.80) [19]. On the timed gait speed test, participants walked 5 m on hard surface at their normal comfortable pace and time to complete was recorded in seconds. Gait speed was calculated as m/s. Test-retest reliability for gait speed is high (r = 0.84) [19]. The Standing Balance Test was used to measure balance abilities on each leg [20]. Parkinson's disease has unilateral onset, so one side of the body is usually more severely impaired than the other. Participants self-reported which side of the body was more affected (i.e. weaker). We measured balance abilities for their more affected leg and less affected leg. Participants stood on each leg for as long as possible, arms beside their body, and timing stopped when the elevated foot touched the ground or the participant lost their balance position. The total length of time in the balance position (maximum time of 30 s allowed) was recorded for three attempts on each leg then averaged to generate one balance score per participant. Test-retest reliability for the Standing Balance test ranges from r = 0.41–91 [21].

2.6.2. Cognitive domain

Five measures of cognitive functioning were used. The Test of Everyday Attention (TEA): Visual Elevator test was used as a measure of attention and cognitive switching abilities [22]. Participants counted up or down as they followed a series of static visually presented doors of an elevator. Time to complete 10 trials was recorded. The score is the mean time per switch in seconds on correct trials, with lower (faster) scores indicating better performance. Test-retest reliability for the TEA is high (r = 0.75) [23]. Action Fluency was used as a measure of verbal fluency abilities [24]. Participants were asked to list as many "things that people do" (i.e. verbs) as they could in 60 s. Verbal fluency score was the total number of words generated minus errors (i.e. repetitions or words that were not verbs), with higher scores indicating better performance. Test-retest reliability for Action Fluency is high (r = 0.73) [25]. The Alternate Uses (AU) test was used to measure originality, fluency, creativity and elaboration [26]. Participants were presented with 6 common objects and common uses for those objects (i.e. a *newspaper* is commonly used for *reading*). Participants were asked to list as many uses for each object they could think of (i.e. a newspaper can also be used to start a fire, swat flies, wrap garbage). Alternate Uses score was total number of correct responses in 60 s, with higher scores indicating better performance. Test-retest reliability for Alternate Uses is high (r = 0.80) [27]. Digit Span (Wechsler Adult Intelligence Scale-III) forward and backward was used to measure participants' auditory attention and working memory, respectively. Participants were presented with progressively longer numerical sequences and asked to repeat them in either the same order (Digit Span Forward) or reverse order (Digit Span Backward) [28]. Higher scores indicate better performance. Test-retest reliability for Digit Span is high (r = 0.83) [23].

2.6.3. Emotion and quality of life domain

Four measures of emotional function and quality of life were used. The Geriatric Depression Scale (GDS) long form is a 30-item self-report inventory composed of yes/no questions relating to characteristics of depression later in life including somatic concern, negative affect, perceived cognitive difficulties, feelings of discrimination, lowered motivation, lack of future orientation, and poor self-esteem [29]. A GDS score of 0–9 is considered normal, 10–19 indicates mild depression, and 20–30 indicates severe depression. Test-retest reliability for the GDS is high (r = 0.85) [29]. The Falls Efficacy Scale-International (FES-I) is a 16-item questionnaire used to measure participants' concern about falling while doing everyday tasks including house cleaning, getting dressed, preparing meals, and bathing [30]. Each item was rated on a 4-point scale (i.e., 1 = "not at all concerned" to 4 = "very concerned") and summed to produce a total score that ranged from 16 to 64, with higher scores reflecting greater fear of falling. Test-retest reliability for the FES-I is high (r = 0.96) [30]. The Parkinson's Disease Questionnaire-39 (PDQ-39) is a 39-item self-report measure that covers eight areas of quality of life (QOL) specific to PD including mobility, activities of daily living, emotional well-being, stigma, social support, cognition, communication, and bodily discomfort [31]. Higher scores indicate poorer quality of life. Test-retest reliability for the PDQ-39 is high (Cronbach's α = 0.89) [32]. We also examined the PDQ-39 Activities of Daily Living (ADL) subscale (one of the dimensions covered in the PDQ-39) to assess health status with regard to activities of daily living.

2.6.4. Other measures

A modified Hoehn & Yahr scale (H & Y) scale was used to characterize stage of PD symptom severity [33]. Level of disability was rated from 0 to 5: 0 = symptoms associated with beginning stages of disease and 5 = symptoms associated with the latter stages. Inter-rater reliability for the H&Y ranges from r = 0.44–0.71 [34]. The Mini-Mental State Exam (MMSE) is a brief estimate of general cognitive function and was used as a screening for dementia and included five areas: orientation, attention, memory, language, and construction [35]. Scores range from 0 to 30 with higher scores indicating better performance. Test-retest reliability for the MMSE is high (r = 0.71) [36]. The North American Adult Reading Test-Revised (NAART-R) was used as an estimate of premorbid full scale intelligence quotient (FSIQ) [37]. It required participants to read aloud 61 irregularly spelled words. Scores range from 0 to 61 with higher scores indicating better performance. Test-retest reliability for the NAART-R is high (Cronbach's α = 0.93) [38]. Adverse events (e.g., falls) during dance classes were monitored by dance instructors and adverse events (e.g., fatigue) during assessments was monitored by the assessor. Participants self-reported the dosage/day of PD-related medications. Medication status (mg/day, Table 1) was determined by calculating levodopa equivalents (total dose/day of standard levodopa) [39,40].

2.7. Statistical analysis

Data analyses were primarily descriptive and were performed using Stata 14.0 (StataCorp LP, Release 14; College Station, TX, USA). Baseline characteristics of intervention and control participants were summarized using numbers and percents for categorical variables and means, medians, standard deviations (SDs), and ranges for continuous variables. Means and SDs were calculated for all outcome measures at T1 and T2 separately for intervention and control groups. Within-group effect sizes were calculated as the mean change from T1 to T2 divided by the baseline SD within each group. Between-group effect sizes were calculated by subtracting control and intervention within-group effect sizes. Signs for within-group effect sizes were reversed for measures in which lower scores indicate better performance so that positive values reflect better outcomes at T2 for all measures. Positive values for between-group effect sizes reflect greater improvement in the intervention versus control group.

Table 1
Participant characteristics at baseline.

Group	Intervention (N = 8)	Control (N = 7)
Gender, female	8	5
Age in years (SD)	71.8 (3.6)	70.4 (5.5)
Years of education (SD)	16.9 (3.5)	17.8 (1.1)
H&Y score [range]	1.7 [1–2]	1.6 [1–2]
Time since diagnosis in years (SD)	6.1 (3.1)	4.3 (2.6)
Medication status (mg/day) [range]	660 [200–1050]	860 [450–1500]
MMSE total [range]	29 [28–30]	29 [29–30]
FSIQ score (SD)	116.7 (6.1)	112.8 (7.5)
Daily exercise in minutes per week (SD)	58.6 (80.0)	47.4 (58.8)

Values reflect means (SD) and/or median [range] for continuous variables, and N for categorical variables.

3. Results

3.1. Participant characteristics

The intervention group consisted of eight female volunteers with PD (mean age 71.8 years, SD = 3.6). The control group consisted of seven volunteers with PD (5 females, 2 males; mean age 70.4 years, SD = 5.5). All study participants had mild to moderate disease severity (modified Hoehn and Yahr, 1 to 2). Prior to study enrollment, participants in the intervention group self-reported an average of 58.6 min/week of daily exercises including stretching, weight lifting and light cardiovascular activity such as walking. Participants in the control group self-reported an average of 47.4 min/week of daily exercises. No adverse events in either group were reported during the study period.

Outcome measures at baseline (T1) and follow-up (T2) as well as mean change within each group are summarized in Table 2. Twelve of twelve outcomes were positive (better at T2) in the intervention group compared to 7 of 12 in the control group.

Standardized within- and between-group effect sizes for each measure are shown in Table 3. In the intervention group, large (≥0.8) within-group effect sizes were observed for measures of cognitive switching (TEA), gait speed, falls efficacy (FES-I), depressive symptoms (GDS) and attention (Digit Span Forward). In the control group, a large positive effect size was observed for balance, and a large negative effect size was observed for gait speed. When comparing changes between the two groups, large effect sizes favoring the intervention group were observed for cognitive switching, gait speed and falls efficacy.

4. Discussion

This pilot study suggests that group dance therapy has potential to improve multiple outcomes in people with PD and that larger randomized, controlled trials are warranted. The outcomes with the largest effect sizes included measures of gait speed (motor function), cognitive switching as measured with TEA (cognitive function) and falls efficacy (emotion/QOL) suggesting that future trials may want to consider co-primary outcomes.

Our findings are consistent with previous work showing improved overall health-related quality of life in people with PD after participation in dance programs, which has been attributed to increased social network size and the fostering of personal relationships through dance [41,42]. It is possible that the sense of belonging to a community can help motivate participants to attend weekly classes [14]. Prior studies also have observed a reduction in negative mood state after participation in group dance classes [43–45].

Our preliminary results suggest that dance may also help reduce fear of falling in people with PD because strategies for changing positions safely can be taught in class. For example, in our Dance for Parkinson's curriculum, transitioning from the seated position in chairs to the standing position using the chairs for support was incorporated into choreography. Participants were reminded to stabilize their feet and keep them at a shoulder-width distance, they practiced leaning forward in their chairs and were made aware of their weight shift before standing from their chairs. Once standing using the chairs for support, participants were encouraged to shift their weight from leg to leg and practice a gentle rocking movement. These movements were practiced until participants felt safe standing from the chair without support. Practicing these strategies may generalize to help reduce restriction of other activities, thus leading to increased independence outside of the dance class setting. Additionally, while embarrassment about symptoms associated with PD, or fear of negative evaluation from others due to having PD, can cause a great deal of anxiety [46], dance classes specifically designed for people with PD may allow participants to feel less self-conscious about their PD symptoms and temporarily forget that they have a chronic disease [11].

Unlike previous studies, we examined the impact of dance intervention on several aspects of cognitive functioning in people with PD, including cognitive flexibility, verbal fluency, working memory and creativity. The largest effect size was observed with the cognitive switching task (TEA). Dance may improve cognitive switching in PD because it requires the ability to connect one movement to the next and switch motor plans. We cannot rule out the contribution of rhythmic, musical sounds that may have helped potentiate movement [47]. McIntosh and colleagues in 1997 suggested that rhythmic auditory stimulation (RAS) may influence motor response, even in cases of brain disease such as PD [48]. Music is highly incorporated with dance and therefore may have influenced changes in motor and cognitive behavior. Neuroimaging studies of dance in healthy individuals have revealed shifts in cortical activation and dance-induced neuroplasticity [49,50]. For example, Calvo-Merino and colleagues in 2005 found that primary motor regions and motor-planning regions, including pre-motor and supplementary motor areas, were activated while participants learned complex dance motor sequences, and suggested that dance impacts motor and pre-motor networks in the brain [49]. It is possible that

Table 2
Summary of all motor, cognitive, and emotion/quality of life outcomes.

Domain	Measure	Intervention group: time 1	Intervention group: time 2	Intervention group: change	Control group: time 1	Control group: time 2	Control group: change
Motor	TUG[a,*]	11.8 (2.0)	11.3 (1.9)	+0.5 (0.8)	17.9 (8.0)	16.3 (6.5)	+1.7 (5.9)
	Gait speed[a,*]	6.0 (1.0)	5.0 (1.4)	+1.0 (0.8)	5.5 (1.4)	6.9 (3.3)	−1.4 (2.8)
	Balance[b,*]	15.1 (9.1)	21.8 (10.4)	+6.7 (11.1)	6.6 (3.2)	10.5 (10.8)	+3.9 (9.6)
Cognitive	TEA[a]	4.7 (0.5)	3.6 (0.8)	+1.0 (1.0)	4.9 (1.7)	4.9 (1.1)	−0.0 (0.9)
	Fluency[c]	19.8 (6.3)	21.8 (4.2)	+2.0 (6.9)	17.7 (3.2)	17.9 (3.8)	+0.1 (5.0)
	Alternate Uses[c]	15.3 (8.1)	20.6 (7.9)	+5.4 (4.8)	15.1 (7.5)	15.9 (7.6)	+0.7 (4.5)
	Digit Span 1[c]	10.6 (2.1)	12.4 (1.7)	+1.8 (2.5)	10.3 (2.7)	10.9 (2.9)	+0.6 (0.8)
	Digit Span 2[c]	7.3 (2.3)	7.8 (2.0)	+0.5 (1.3)	7.6 (3.4)	7.7 (2.9)	+0.1 (1.6)
Emotion/ QOL	GDS[d,*]	4.4 (2.4)	2.3 (1.4)	+2.1 (2.9)	6.3 (2.6)	5.8 (2.4)	+0.5 (1.9)
	FES-I[d]	26.3 (6.7)	20.4 (4.5)	+5.9 (4.6)	35.3 (12.9)	36.4 (10.5)	−1.1 (5.7)
	PDQ-39[d]	24.6 (15.1)	16.5 (12.7)	+8.1 (7.4)	47.7 (20.5)	51.7 (24.9)	−4.0 (10.4)
	PDQ-39 ADL[d]	3.3 (2.7)	2.4 (2.3)	+0.9 (0.6)	7.1 (4.9)	8.3 (5.3)	−1.1 (1.9)

Values reflect mean (standard deviation, SD). Signs changed so that positive values for change scores reflect better performance at time 2 for all measures.
TUG, Timed-Up-and-Go; TEA, Test of Everyday Attention; GDS, Geriatric Depression Scale; FES-I, Falls Efficacy Scale-International; PDQ-39, Parkinson's Disease Questionnaire—39; ADL, Activities of Daily Living.
[a] Faster completion times indicate better performance.
[b] Slower completion times indicate better performance.
[c] Higher scores indicate better performance.
[d] Lower scores indicate better performance.
[*] Data missing as follows: balance (n = 1 intervention, n = 2 control); TUG (n = 1 control); GDS (n = 1 control).

Table 3
Standardized effect sizes for all motor, cognitive, and emotion/quality of life measures.

Domain	Measure	Intervention Group: Effect Size	Control Group: Effect Size	Between Group: Effect Size Difference
Motor	TUG	+0.25 (−0.09, 0.59)	+0.21 (−0.57, 0.99)	+0.04 (−0.63, 0.71)
	Gait speed	+0.94 (0.32, 1.55)	−1.00 (−3.13, 1,13)	+1.93 (0.26, 3.61)
	Balance	+0.73 (−0.40, 1.86)	+1.21 (−2.49, 4.91)	−0.47 (−2.27, 3.22)
Cognitive	TEA	+2.05 (0.45, 3.65)	−0.02 (−0.47, 0.44)	+2.06 (0.45, 3.68)
	Fluency	+0.32 (−0.60, 1.23)	+0.04 (−1.41, 1.50)	+0.27 (−1.23, 1.77)
	Alternate Uses	+0.66 (0.17, 1.16)	+0.10 (−0.46, 0.65)	+0.57 (−0.10, 1.23)
	Digit Span forward	+0.85 (−0.16, 1.86)	+0.21 (−0.06, 0.48)	+0.63 (−0.38, 1.65)
	Digit Span Backward	+0.22 (−0.26, 0.71)	+0.04 (−0.39, 0.48)	+0.18 (−0.42, 0.77)
Emotion/ QOL	GDS	+0.87 (−0.11, 1.84)	+0.19 (−0.57, 0.95)	+0.68 (−0.51, 1.89)
	FES-I	+0.88 (0.30, 1.46)	−0.09 (−0.50, 0.32)	+0.97 (0.31, 1.63)
	PDQ-39	+0.54 (0.13, 0.95)	−0.20 (−0.66, 0.27)	+0.74 (0.18, 1.29)
	PDQ-39 ADL*	+0.32 (0.13, 0.52)	−0.23 (−0.58, 0.12)	+0.55 (0.21, 0.90)

Effect sizes for all measures were calculated as mean change divided by baseline SD within each group. Signs have been changed for within group effect sizes estimates so that positive values reflect improvement from Time 1 to Time 2. Positive values for between-group effect sizes reflect greater improvement in the intervention versus control group.
TUG, Timed Up-and-Go; TEA, Test of Everyday Attention; GDS, Geriatric Depression Scale; FES-I, Falls Efficacy Scale-International; PDQ-39, Parkinson's Disease Questionnaire—39; ADL, Activities of Daily Living.
* Data missing as follows: balance (n = 1 intervention, n = 2 control); TUG (n = 1 control); GDS (n = 1 control).

motor and cognitive networks are strengthened through dance, as well as communication between motor and cognitive networks.

There has been tremendous progress over the past decade in the field of exercise neuroscience highlighting the neuroprotective role of physical activity [51–53]. Dance may be effective in targeting motor symptoms of PD because it incorporates the stretching and strengthening of muscles and increases flexibility throughout the body, which may help maintain balance in people with PD [11]. Earhart and colleagues in 2015 have hypothesized that dance may change underlying neural mechanisms in PD by improving functional connectivity in the motor network resulting in improved motor performance, including gait and balance [54]. Thus, community-based dance may prove to be a valuable intervention with wide-spread availability.

4.1. Strengths and limitations

Several important limitations must be considered. First, our sample size for this pilot study was very small, leading to wide confidence intervals and imprecision in our estimates. Second, study participants were not randomized, making between-group comparisons difficult to interpret. Third, we cannot rule out selection bias: people with PD who proactively seek adjunct forms of therapy to help alleviate parkinsonian symptoms may experience different effects than those who are less active. Fourth, we did not collect detailed data on changes in daily exercise or other co-interventions that may have occurred. Fifth, we did not have the means to measure motor symptom severity using the clinical gold-standard Unified Parkinson's Disease Rating Scale motor subtest (UPDRS-III) or ON/OFF medication manipulation which could have better characterized motor changes [34]. None-the-less, this pilot study provides important information about the outcomes that are most likely to improve with dance interventions and suggests that a larger randomized, controlled trial is warranted.

5. Conclusion

This pilot study provides preliminary evidence that dance may benefit multiple outcomes in people with PD. Future trials of dance in people with PD may want to consider co-primary outcomes given potential benefits in motor, cognitive and emotion/quality of life domains.

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Appendix A. Supplementary data

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