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ORIGINAL ARTICLE

Instruction prioritization in task-based balance training for individuals with idiopathic Parkinson's disease

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ABSTRACT
The objective of the study was to evaluate the effect of prioritization of instruction in balance training for individuals with Parkinson's disease (PD). Thirty-six participants were evaluated before and after the training using the Berg Balance Scale, Dynamic Gait Index, and Geriatric Depression Scale. Results show that dual task training with variable priority instruction is as effective as single task training in improving the balance performance of individuals with idiopathic PD.

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KEYWORDS
Dual task training; fixed and variable priority instruction; Parkinsonism

Introduction

Individuals with Parkinson's disease (PD) have gait disturbances and instability which may lead to a fall (Schaafsmaa et al. 2003; Grimbergen et al. 2004). Further, the fear of falling may lead to restriction of the performance of daily activities and loss of independence and increased mortality (Gray and Hildebrand 2000). This poor motor performance is usually associated with depression in individuals with PD (Bejjani et al. 1999) which along with anxiety are the most common associated psychiatric problems in PD (Vågerö 2000).

Gait was once considered an automatic and pure physical activity, but alternative theories have proven that cognition plays an important role in gait, especially the executive function and attention. Fall risk and balance impairments amongst PD patients increase when patients are engaged in a secondary task, such as talking while walking (Canning 2005). Hence, while planning for the management of gait and balance issues, it is necessary for the therapist to look into task-based activities with cognitive involvement.

Physiotherapists and rehabilitation specialists have been working on this fall prevention and gait training using task-based exercises and activities (Hirsch et al. 2003; Ebersbach et al. 2008). A few studies carried out on older adults reported that dual task training improved balance in some ways as this training included cognitive aspects along with physical training (Silsupadol et al. 2006, 2009; Buragadda et al. 2012). Such a balance training program that focused on dual tasks with gradual increase in difficulty and shifting priorities between two tasks was effective in improving balance and functional recovery in PD (Sethi and Raja 2012).

During the dual task training, when the individual carries out simultaneous activities, conflict might occur and there is a need to find which of the tasks received priority, especially in conditions like PD where reduction in cognition function exists (Pashler 1994; Tombu and Jolicœur 2003). The concept of "posture first" strategy suggests that ecologically, normal people prioritize gait stability over cognitive tasks (Shumway-Cook et al. 1997). A few other studies on the prioritization of tasks in normal adults also reported that healthy individuals spontaneously prioritized gait stability over cognitive tasks (Bloem et al. 2001a, 2001b, 2006). But in the dual task training, "posture second" strategy is used in which the cognitive task is prioritized over posture and this could be dangerous. In the absence of explicit instruction, individuals with PD have more risk of falling while performing dual task activities (Bloem et al. 2001a). On the other hand, gait was found to be improved when individuals with PD were exposed to explicit instruction in which they were directed to focus their attention on gait (Baker et al. 2008; Fok et al. 2010).

Kramer et al. (1995) investigated the importance of the instructional set in dual task training. They analyzed if placing equal amounts of attention on both tasks would be better than shifting attention between tasks. Their study concluded that young and older adults who were trained with variable priority instructions learned and performed better than those who were trained with fixed variable priority instructions (Kramer et al. 1995). Similar studies on individuals with PD who experience cognitive decline during the process of the condition are not known.

In this study, we hypothesized that dual task training would be better than single task training in improving gait and balance in individuals with PD. Our second hypothesis was that the variable priority instruction set will be better than the fixed priority instruction set for improving balance in individuals with PD.

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Thus, the main aim of this study was set as to evaluate the effect of prioritization of instruction in improving balance in individuals with idiopathic PD. To achieve this, comparison was made between single task training, dual task training with fixed priority instruction, and dual task training with variable priority instruction on balance in individuals with idiopathic PD. Further, we wanted to find the influence of this training on the cognitive status of participants, hence, the secondary aim was to find if these intervention strategies have any effect on the depression status of participants.

Participants

Individuals with idiopathic PD, who were diagnosed as per the UK Brain Bank Criteria (Gelb et al. 1999), were recruited from a local community. Inclusion criteria required that participants were in stage 3–4 of the modified Hoehn & Yahr (H&Y) scale (Hoehn and Yahr 1967) and had a score of less than 52 (out of 56) on the Berg Balance Scale (BBS). Scoring less than 52 on the BBS is associated with a decline in the ability to maintain balance (Shumway-Cook et al. 1997). Participants also required scoring more than 24 on the Mini-Mental State Examination (MMSE) (Folstein et al. 1975). Participants were included if their age was between 50 and 80 years and if they had a fall at least once in the last 6 months and if they had no other prior neurological or musculoskeletal disorders, visual or vestibular defect.

Procedure

All participants signed a written consent form after the detailed procedures were explained to them in their own language. Their socio-demographic data including age, gender, height and weight, and medical history including details about the condition, duration of condition, and history of falls in the last 6 months were collected using a form. MMSE was done to assess the cognitive status of the participant.

Participants were allotted into the three groups, that is, single task training group, dual task training with fixed priority instruction group, or dual task training with variable priority instruction group by using a simple random sampling method (Figure 1). Three measures were used to assess the performance of the participant before and after the intervention, for instance, Dynamic Gait Index (DGI), Berg Balance Scale (BBS), and Geriatric Depression Scale (GDS).

Primary outcome measures

Dynamic Gait Index (DGI)

The DGI was developed by Shumway-Cook, and evaluates and documents a patient's ability to modify gait in response

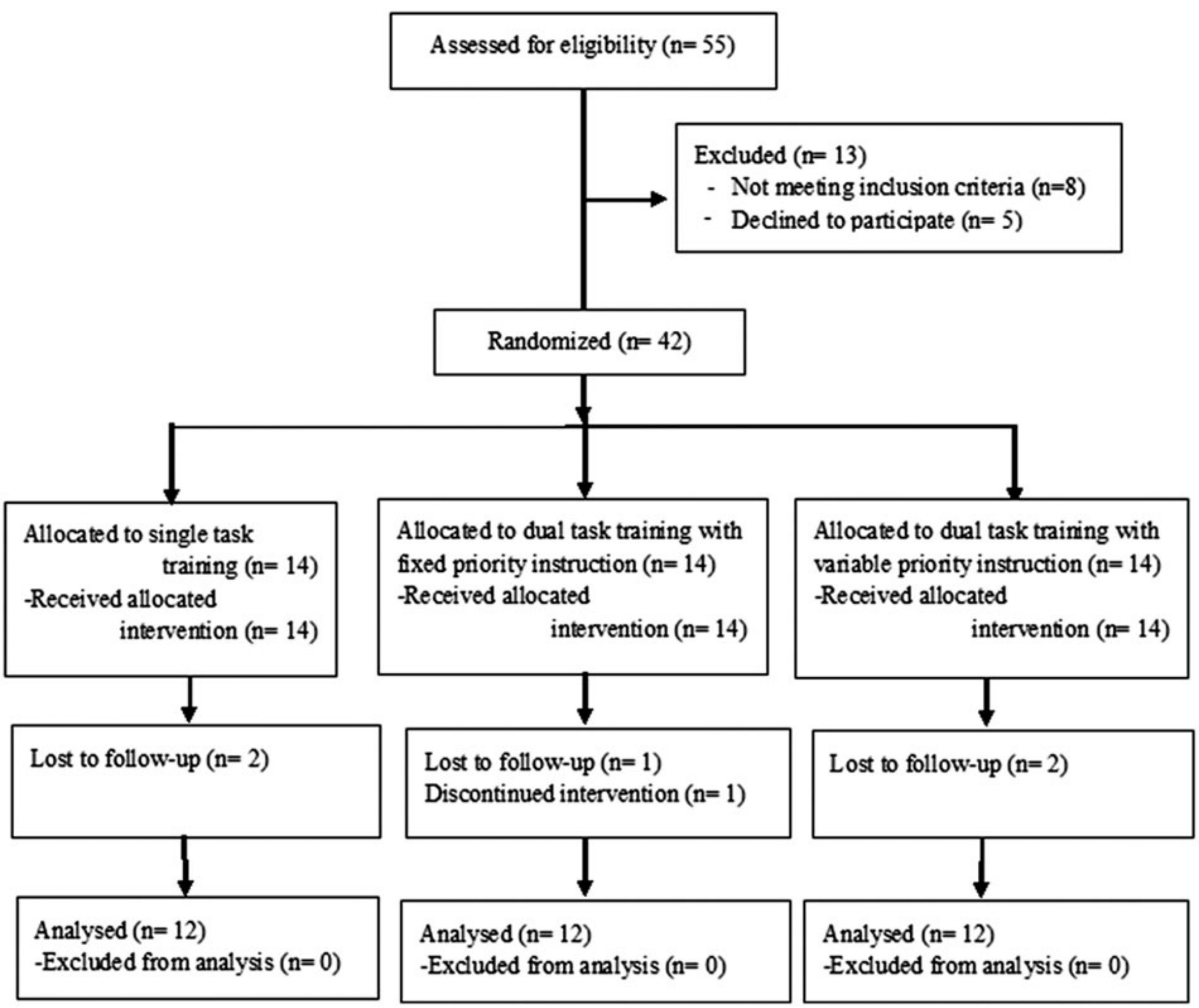

Figure 1. Flow diagram of the study process.

to changing task demands. This index was developed as part of a profile of tests and measurements effective in predicting the likelihood of falls in older adults. Performance is rated on a 0–3 scale; individuals are rated on eight different tasks (Wrisley et al. 2003).

Berg Balance Scale (BBS)

The BBS is an objective measure of balance abilities and used as a screening and ongoing assessment tool for patients with PD (Qutubuddin et al. 2005). It has been used to identify and evaluate balance impairment. The scale consists of 14 tasks common in everyday life. The items test the subject's ability to maintain position or movements of increasing difficulty by diminishing the base of support from sitting and standing to single leg stance. The subject's ability to change positions is assessed as well.

Secondary outcome

Geriatric Depression Scale (GDS)

The GDS is a 30-item self-report assessment to identify depression in older people and in PD patients (McDonald et al. 2006). Scores range from 0 to 30 with higher scores equated to greater symptoms.

Intervention

Participants received training sessions 3 times a week for 4 consecutive weeks. Each session lasted for 45 min. The intervention programs were based on an existing training program for older adults with balance impairment (Silsupadol et al. 2006). Activities used in training programs were progressively designed to increase the complexity from a simple to a difficult level, depending on the learning ability of each individual to master it. Tasks increasing in complexity were progressively integrated into the training program.

Group 1 ($n = 12$) received single task training activities under single task conditions. They received only balance task activities which were classified into three categories as stance activities, transitional activities, and gait activities.

Stance activities included standing with a narrow base of support with eyes open or closed, semi-tandem with eyes open or closed, stepping on a small stool in different directions, standing on foam with eyes open or close, standing with hip abduction or adduction, step sideways, draw letters with right/left foot, hip movements in all directions, stand with narrow base of support and reach in different directions, body stability plus hand manipulation activities such as standing on foam with rapid alternating hand movement or throwing and catching a ball, and tandem standing while holding a basket.

Transitional activities included sit to stand on different chair heights, sit to stand and pick up objects from the ground, sit on a ball and move in all directions, and sit to stand, walk and stop with different speed holding a basket. Gait activities included, walking with narrow base of support, walking sideways, walking backwards, walking around obstacles, walking while holding a book, walking while kicking a ball, walking under different light conditions, walking up and down stairs, and walking while reaching for objects placed at different heights.

Group 2 ($n = 12$) received dual task training under a fixed priority instruction. They practiced the same balance activities as group 1 while simultaneously performing secondary tasks. Secondary tasks included auditory, visual discrimination, and cognitive activities. Participants were instructed to maintain attention on both postural and cognitive tasks through the training session.

These secondary tasks included identifying different known voices, identifying noises, and naming things. Tasks such as listening, speaking, conversing, generation of simple and complex lists, language, calculation, and matching pictures were also included. Activities that are reflected in daily functions such as recalling directions, carrying bags, counting money, making a shopping list, and getting keys out of a pocket were also included. Cognitive activities including counting backwards, random digit generation, spelling words backward, and calculations were also integrated gradually along with the balance training activity.

Some of the activities given for the group 2 participants were tandem/semi-tandem walking while counting backward from 100 to 1, crossing obstacle while counting backward from 100 to 1, semi-tandem/tandem walking while counting with auditory tone discrimination, and obstacle crossing while counting with auditory tone discrimination (low volume vs. high), semi-tandem standing with eyes open/closed and arm alteration with spelling words forward as cognitive task; and drawing letter with left and right foot and naming any word starting with the letter given by the trainee.

Group 3 ($n = 12$) participants were given the same training as group 2, but under a variable priority instruction set. Participants were trained to focus attention on the postural task performance during half of the training session and in the rest of the session they focused their full attention on the cognitive task performance. They focused their attention on improving specific subcomponents of the dual task at different times.

Data analysis

Data were analyzed using SPSS version 20 (IBM Corp 2011). The Pearson chi-square test and one-way analysis of variance (ANOVA) tests were used for analyzing the demographic data. A two-way mixed ANOVA with time as the within-subject factor and group as the between-subject factor was used to determine the treatment effectiveness.

Results

A total of 55 individuals with PD were assessed for eligibility and only 42 individuals met the criteria and were considered for the study. Out of these, follow-up assessment was not possible with 5 individuals and 1 discontinued due to personal reasons. Finally, the data of 12 participants from each

Table 1. Demographic data of all three groups.

Variables	Group 1 $n = 12$	Group 2 $n = 12$	Group 3 $n = 12$	F values	p values
Gender (male/female)	8/4	7/5	6/6	0.69 (χ^2)	0.71[a]
Age (years)	68.75 ± 4.92	68.17 ± 4.86	67.75 ± 5.40	0.12	0.89[a]
Height (cm)	166.08 ± 8.50	165.17 ± 10.81	166.12 ± 8.49	0.04	0.96[a]
Weight (kg)	61.33 ± 5.24	62.87 ± 4.77	61.33 ± 4.45	0.41	0.67[a]
Disease duration (years)	5.1 ± 1.98	4.6 ± 2.43	4.2 ± 1.76	0.53	0.60[a]
MMSE	26.50 ± 1.57	26.25 ± 1.14	26.58 ± 1.62	0.17	0.84[a]

n: number of subjects; group 1: single task condition balance training; group 2: dual task condition with fixed priority balance training; group 3: dual task condition with variable priority balance training; F value: one-way ANOVA; χ^2: Pearson chi-square value; MMSE: Mini-Mental State Examination.
[a]Statistically non-significant ($p > 0.05$).

Table 2. Values of outcome measures by treatment group and time of measurement.

Outcome measure	Single task group Mean ± SD (95% CI)	Dual task group with fixed priorities Mean ± SD (95% CI)	Dual task group with variable priorities Mean ± SD (95% CI)
DGI			
Pre	19.75 ± 0.75 (19.27–20.23)	19.58 ± 0.52 (19.26–19.91)	19.42 ± 0.67 (18.99–19.84)
Post	22.00 ± 1.13 (21.28–22.72)	22.42 ± 1.24 (21.63–23.20)	23.33 ± 1.16 (22.60–24.07)
BBS			
Pre	45.83 ± 4.86 (42.75–48.92)	46.58 ± 4.62 (43.65–49.52)	46.58 ± 4.50 (43.72–49.44)
Post	51.33 ± 3.17 (49.32–53.35)	52.17 ± 3.41 (50.00–54.33)	54.58 ± 1.24 (53.80–55.37)
GDS			
Pre	18.29 ± 2.16 (16.92–19.66)	18.71 ± 2.05 (17.41–20.01)	17.58 ± 2.11 (16.24–18.92)
Post	17.92 ± 1.78 (16.78–19.05)	18.33 ± 1.97 (17.08–19.58)	17.25 ± 1.91 (16.03–18.47)

DGI: Dynamic Gait Index; BBS: Berg Balance Scale; GDS: Geriatric Depression Scale.

Table 3. Test of within-subject effects for all outcome measures.

	F value		
Source	DGI	BBS	GDS
Time	261.84[a]	129.25[a]	2.68
Time[a] × Group	6.94[a]	2.15	0.04

DGI: Dynamic Gait Index; BBS: Berg Balance Scale; GDS: Geriatric Depression Scale.
[a]Statistically significant ($p < 0.05$).

group were analyzed. The demographic data of all the three groups are shown in Table 1.

A Pearson chi-square test of 2 × 3 cross-tab analysis proved that there were no differences in gender distribution among these groups ($\chi^2(2) = 0.69$, $p = 0.71$). Further analysis showed no statistical difference of age ($F(2) = 0.12$, $p = 0.89$), height ($F(2) = 0.04$, $p = 0.96$), weight ($F(2) = 0.41$, $p = 0.67$), disease duration ($F(2) = 0.53$, $p = 0.60$), and MMSE ($F(2) = 0.17$, $p = 0.84$) among all three groups.

The values of all outcome measures according to the groups are given in Table 2.

Analysis of the pre-test scores of all the three dependent variables showed no difference between groups (DGI: $F(2,27) = 0.78$, $p = 0.47$; BBS: $F(2,27) = 0.10$, $p = 0.90$; GDS: $F(2,27) = 1.88$, $p = 0.43$). This proves that all the three groups recruited in this research were homogeneous in nature before intervention.

Results of the mixed ANOVA done to find out the interaction between all the three dependent variables (DGI, BBS, and GDS) across the three groups (single task, dual task with fixed priority, and dual task with variable priority) are shown in Tables 3 and 4.

There was a significant main effect of time, $F(1,33) = 261.84$, $p < 0.05$, for DGI and for BBS $F(1,33) = 129.25$, $p < 0.05$. There was no significant main effect of time on GDS $F(1,33) = 2.68$, $p > 0.05$. There was a significant time × group main effect of DGI scores $F(1,33) = 6.94$, $p < 0.05$ while no significant interaction effect was found for time × group scores of BBS $F(1,33) = 2.15$, $p > 0.05$ and GDS $F(1,33) = 0.04$, $p > 0.05$.

Between-subject analysis shows that there was no significant main effect of groups for all the three outcome measures DGI $F(1,33) = 1.37$, $p = 0.27$; BBS $F(1,33) = 1.02$, $p = 0.37$; GDS $F(1,33) = 1.05$, $p = 0.36$.

Discussion

Balance training improves the posture and gait in individuals with PD (Smania et al. 2010). The results of this study also demonstrate that task-based balance training is effective in improving the balance and gait of individuals with PD. After 4 weeks of training, all the participants in the single task group and dual task groups had improved gait and balance as measured by DGI and BBS, respectively. In the within-group analysis significant change was observed for DGI, but for balance the changes were not statistically significant which could be due to the shorter intervention time and small sample size.

The significant interaction effect in DGI score means that the effect of time was different across training groups. No specific research studies have been examined that support the improvement in the DGI in task condition balance training in PD (Verma and Sehgal 2013). DGI was found to be effective in finding the minimal detectable change (Huang et al. 2011) and sensitive to changes which might have been missed by other measures of mobility (Herman et al. 2009). This helps the clinicians and researchers to determine if the change in PD is a true change (Huang et al. 2011). This

Table 4. Test of between-subject effects for all measures.

	Groups	Mean differences (95% CI)	Pairwise comparison *p*	Between-subject effects *p*
DGI	ST vs. DTF	−0.12 (−0.92 to 0.67)	1.00	0.27
	ST vs. DTV	−0.50 (−1.29 to 0.29)	0.36	
	DTF vs. DTV	−0.38 (−1.17 to 0.42)	0.73	
BBS	ST vs. DTF	−0.79 (−4.35 to 2.76)	1.00	0.37
	ST vs. DTV	−2.00 (−5.56 to 1.56)	0.50	
	DTF vs. DTV	−1.21 (−4.76 to 2.35)	1.00	
GDS	ST vs. DTF	−0.42 (−2.36 to 1.53)	1.00	0.36
	ST vs. DTV	0.69 (−1.26 to 2.63)	1.00	
	DTF vs. DTV	1.10 (−0.84 to 3.05)	0.48	

DGI: Dynamic Gait Index; BBS: Berg Balance Scale; GDS: Geriatric Depression Scale; ST: single task training group; DTF: dual task training with fixed priorities group; DTV: dual task training with variable priorities group.

sensitivity of the DGI could have been the reason for identifying the changes post task-based training in our study. Protas et al. (2005) found that task-specific gait and step training resulted in a reduction in falls and improvement in gait speed and dynamic balance. Further, Cakit et al. (2007) reported significant changes in DGI scores in PD after 8 weeks of incremental speed-dependent treadmill training. The cortical reorganization, which occurred in the supplementary motor area, might be a possible mechanism underlying the improvement in gait followed by specific task-based gait training on a treadmill (Miyai et al. 2000).

The improvement seen in the single task training group and in both the dual task training groups suggests that task-based balance training is good for the individual with PD. An earlier study done by Silsupadol et al. (2009) also had similar results in elderly people with balance impairment. Their study further reported that single task and dual task training programs were equally effective in improving balance and walking performance (Silsupadol et al. 2009). A similar result has also been obtained in the present study on individuals with PD.

Improvement in the single task training group can be explained by the task automatization hypothesis which suggests that practicing only one task at a time allows the trainee to automatize the performance of individual tasks. Further, this single task training demands less processing requirement which leads to faster skill acquisition. In PD the processing ability is already impaired, hence single task training could have improved the gait and balance in the participants.

Results from some studies did not support this theory and proposed the task integration hypothesis which suggests that practicing two tasks together enables the participants to develop task-coordination skills (Oberauer and Kliegl 2004; Voelcker-Rehage and Alberts 2007). It might be difficult for the person with PD to do multiple tasks such as talking while walking, because the ability to coordinate multiple tasks does not improve after single task training (Voelcker-Rehage and Alberts 2007). Therefore, efficient coordination and integration between two tasks which happens in dual task training is essential for improving dual task performances (Kramer et al. 1995).

Silsupadol et al. (2009) also highlighted that single task training resulted in maintained performance after a 12-week follow-up and also a similar result was found in a group which had undergone dual task training with variable priority (Silsupadol et al. 2009). In another study Kramer et al. (1995) suggested that individuals who received dual task training with variable priority instructions had an advantage over those who received training with fixed priority instructions.

In dual task training with variable priority instructions, participants' attention was shifted between two tasks, hence the processing demand needed to perform the task was less (Kramer et al. 1995). This gives an advantage to the participants undergoing dual task training with variable priority instruction to learn the task faster and to maintain it for longer duration.

Our study also evaluated the difference between the effects of single task training, dual task training with fixed priority instruction, and dual task training with variable priority instruction. The between-group analysis suggests that all the three groups had equal changes in all three measurements. This demonstrates that all the participants displayed similar responses to all the three training sessions.

This result can be compared with an earlier study done on patients with PD, in which balance and activities of daily living (ADL) functions were significantly improved following dual task training (Sethi and Raja 2012). Studies on dual task training for older adults also have shown improvement in single and dual task training (Buragadda et al. 2012; Verma and Sehgal 2013).

The significant changes in the variable priority instruction could be due to the fact that the participants in this group had undergone training to learn and coordinate two different tasks which improved their attention, hence the processing demand required was less while performing real-time activities after intervention.

This improvement of gait and balance in the variable priority instruction group might be because they practiced the whole task, but focused their attention on specific subcomponents of the task at different times of the training. Most of the daily activities require simultaneous performance and coordination of many different component tasks, and variable priority training accelerates learning and results in superior performance (Gopher et al. 2007). The variable priority group performed the dual task while shifting their focus; as a result, they learned the task faster and achieved a higher level of mastery compared with other participants who emphasized both task components equally.

Previous studies also have demonstrated that when the individuals with PD focused their attention on a cognitive task other than walking, gait performance was found to be reduced (Canning 2005; Verghese et al. 2007; Yogev-Seligmann et al. 2010). But in our study, it was noted that in response to explicit instructions, the change in patients' performance on the gait and balance was similar to the participants in the single task training group.

The prioritization process relies, to a great extent, on cognitive processes, and with intact cognition, individuals with PD can change priorities to the same degree as others (Yogev-Seligmann et al. 2012). However, the age-associated declines in the mental flexibility, reduced ability to prioritize, and flexibly allocate attention among different tasks should be studied further. To fully understand this process, a more detailed assessment of both balance and cognition is needed. The significant increase in the risk of falling during dual task training also has to be taken into account.

In our study, it can be seen that no significant change in the depression status was seen in all the three groups. As most of the Parkinson's patients suffer with depression, we wanted to find if the gain in the performance has any role in improving their depression status. Kramer et al.'s (1995) study also noted that the self-reported confidence was increased while performing daily activities. In our study, though there were mild changes in the post intervention scores, there was no significant improvement observed. This may be due to the fact that cognitive constructs such as self-confidence and self-efficacy do not change at the same frequency as physical function. Further, over a period of time, with rigorous training, the participant's self-confidence could have been affected which led to less improvement in depression.

Overall, significant changes in performance in all the three task-oriented groups were found in regard to all primary outcome measures, however, in the secondary outcome measure, no significant changes were observed in all three groups. This signifies that explicit instruction with dual task training can be implemented in individuals with PD to improve their gait and balance along with single task training.

Limitations and further research

The number of participants studied was relatively small and the intervention duration was short, and these factors may have affected some of the findings. Further difference in the gender- and age-associated changes were not studied. In this study, only single task balance performance was evaluated. Further studies with more reliable cognitive and balance testing in a larger heterogeneous sample could be investigated in the future.

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All the authors contributed equally to the work.

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