Title: Effects of dual-task training on balance and executive functions in Parkinson's disease: A pilot study

Short-Title: Dual-task training in Parkinson´s

Ângela Fernandes (MSc)
Escola Superior da Tecnologia de Saúde do Instituto Politécnico do Porto,
Área Científica de Terapia Ocupacional,
Centro de Estudos de Movimento e Actividade Humana,
Rua Valente Perfeito, 322 - 4400-330 Vila Nova de Gaia, PORTUGAL
Faculdade de Engenharia, Universidade do Porto,
Rua Dr. Roberto Frias, s/n, 4200-465 Porto, PORTUGAL
E-mail: amf@estsp.ipp.pt; angelamfernandes@gmail.com

Nuno Rocha (PhD)
Escola Superior da Tecnologia de Saúde do Instituto Politécnico do Porto,
Área Científica de Terapia Ocupacional,
Centro de Estudos de Movimento e Actividade Humana,
Rua Valente Perfeito, 322 - 4400-330 Vila Nova de Gaia, PORTUGAL
E-mail: nrocha@eu.ipp.pt

Rubim Santos (PhD)
Escola Superior da Tecnologia de Saúde do Instituto Politécnico do Porto,
Área Científica de Física,
Centro de Estudos de Movimento e Actividade Humana,

Rua Valente Perfeito, 322 - 4400-330 Vila Nova de Gaia, PORTUGAL
E-mail: rss@estsp.ipp.pt

João Manuel R. S. Tavares (PhD)
Instituto de Engenharia Mecânica e Gestão Industrial,
Departamento de Engenharia Mecânica,
Faculdade de Engenharia, Universidade do Porto
Rua Dr. Roberto Frias, s/n, 4200-465 Porto, PORTUGAL
E-mail: tavares@fe.up.pt
(**corresponding author**)

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Abstract

The aim of this study was to analyze the efficacy of cognitive-motor dual-task training compared with single-task training on balance and executive functions in individuals with Parkinson's disease.

15 subjects, aged between 39 and 75 years old were randomly assigned to the dual-task training group (n=8) and single-task training (n=7) groups. The training was run twice a week for six weeks. The single-task group received balance training, and the dual-task group performed cognitive tasks simultaneously with the balance training. There were no significant differences between the two groups at baseline. After the intervention, the results for mediolateral sway with eyes closed were significantly better for the dual-task group and anteroposterior sway with eyes closed was significantly better for the single-task group. The results suggest superior outcomes for the dual-task training compared to the single-task training for static postural control, except in anteroposterior sway with eyes closed.

Keywords

Parkinson's disease, dual-task training, executive functions, balance

Introduction

Parkinson's disease (PD) is considered to be the second most common neurodegenerative disorder affecting currently about 1% of the world population (Andlin-Sobocki, Jonsson, Wittchen, & Olesen, 2005; Campenhausen et al., 2005; Rodrigues de Paula, Teixeira-Salmela, Faria, Brito, & Cardoso, 2006). Some projections point to a large increase in this prevalence over the next decades (Campenhausen et al., 2005).

PD is clinically defined by motor symptoms such as tremor at rest, rigidity, bradykinesia, as well as postural and gait modifications (Giroux, 2007; Wielinski, Erickson-Davis, Wichmann, Walde-Douglas, & Parashos, 2005); and also by non-motor symptoms such as sleep disorders, cognitive impairment, depression and fatigue, some of which are adverse effects of the dopaminergic medication (Hubert & Fernandez, 2012). Another characteristic feature of PD is the difficulty to perform two tasks simultaneously. This difficulty is because the individuals have to focus on achieving normal movement patterns by activating the premotor cortex region without using the deficient basal ganglia circuit which is deficient in dopamine. Therefore, in dual-task situations that use the cortical resources to perform motor tasks, the performance of both the motor and cognitive components can be compromised (Brauer & Morris, 2010; Wu & Hallett, 2009). From this point of view, dual-task training should be considered as part of the rehabilitation process of these patients (Wu & Hallett, 2009), although until now no guidelines have been defined for this type of intervention. New paradigms have been studied concerning cognitive training, such as interventions of cognitive-motor dual-task. This type of intervention should be able to improve dual-task performance and/or improve motor and cognitive components individually (K. Baker, Rochester, & Nieuwboer, 2007; Montero-Odasso, Verghese, Beauchet, & Hausdorff, 2012; Silsupadol, Siu, Shumway-Cook, & Woollacott, 2006; Yogev-Seligmann, Rotem-Galili, Dickstein, Giladi, & Hausdorff, 2012).

Regarding specific dual-task training, recent studies have demonstrated its efficacy in various populations such as the elderly and individuals with neurological diseases, with the most notable improvements in gait and balance (Brauer & Morris, 2010; Sethi & Raja, 2012; Silsupadol, Lugade, et al., 2009; Silsupadol, Shumway-Cook, et al., 2009). This type of intervention for PD individuals has been focused mainly on gait (Brauer & Morris, 2010; Yogev-Seligmann, Giladi, Brozgol, & Hausdorff, 2011), and shows improvements in gait speed and gait variability during dual-task training. However, there is no evidence in the literature of the effects of this training on balance and executive functions evaluated independently for PD individuals. On the other hand, such separate evaluation of cognitive-motor dual-task training could be positive and enhance the meaningfulness of this type of training. Thus, considering the positive results of specific cognitive-motor dual-task training obtained in other populations and in other situations that could possibly be reproduced here, we conducted a randomized trial to study the efficacy of a cognitive-motor dual-task training program compared to a single-task program, and evaluated the cognitive and motor components independently, on PD individuals. Accordingly, we hypothesized that cognitive-motor dual-task training is more effective at improving balance and executive functions than single-task training in PD individuals.

Materials and Methods

Participants

Subjects with Parkinson's disease were recruited from the Portuguese Association of Parkinson's Patients. The inclusion criteria used were: capacity to walk ten meters without gait assistance, diagnosis of PD up to Stage 3 according to the modified Hoehn & Yahr scale. The exclusion criteria used were: cognitive deficit confirmed by the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975) using the following cut-off values according to the education level (≤22 for 0-2 years of literacy; ≤24 for 3-6 years; and ≤27 for ≥7 years (Morgado, Rocha, Maruta, Guerreiro, & Martins, 2009)), subthalamic neurosurgery, other neuromusculoskeletal and psychiatric disorders and illiteracy.

The subjects that voluntary accepted to participate were randomized to either the dual-task or single-task training group. The random assignment procedure was performed with numbers generated by a computer program (Microsoft Office Excel 2010), operated by an independent investigator. From a total of 23 eligible subjects, 20 were included in the two groups. Before the intervention program started, there were 3 dropouts in the single-task training group (1 for surgery, 1 due to illness and 1 who had various absences) and 2 dropouts in the dual-task training group (1 for personal reasons and 1 due to illness). Hence, 7 subjects were analyzed in the single-task training group and 8 subjects in the dual-task training group. These 15 subjects made up the intervention program as shown in Figure 1.

< Insert Figure 1 about here>

The researcher that evaluated the results was not involved in the training program and had no knowledge to which group the subjects had been assigned, in order to prevent any possible critical judgment and manipulation of the results during the evaluations. In addition, the participants were unaware of the two groups, making this a double-blind study.

The study was explained to each participant according to the intervention group in which they were randomly included. All participants gave their written informed consent in accordance to the Declaration of Helsinki, ensuring data confidentiality and freedom to withdraw from the program at any time. The study was approved by the ethics committee of “Instituto Politécnico do Porto – Escola Superior de Tecnologia da Saúde” and by the directive board of “Associação Portuguesa de Doentes de Parkinson”, in Portugal.

Intervention

All participants received balance training that was administered individually twice a week (60 min/session) for six weeks. All participants performed the same motor tasks; however, the participants of the dual-task group underwent the cognitive-motor dual-task training program and performed the cognitive tasks simultaneously with the motor tasks, while the participants of the dual-task group only underwent the single-task motor training program, and thus only performed the motor tasks. The intervention program was based on an existing training program (Silsupadol et al., 2006). The individual training sessions took place at the “Associação Portuguesa de Doentes de Parkinson” or at the “Instituto Politécnico do Porto – Escola Superior de Tecnologia da Saúde” according to each participant’s preference. Each session was organized into 4 stations of intervention, according to Gentile's taxonomy (Gentile, 2000): stability without manipulation activities (e.g. to stand on top of a foam mattress with the eyes closed); gait without manipulation (e.g.: walk on a narrow path); stability with handling activities (e.g. rotate the waist holding a ball) and gait manipulation activities (e.g. walking backwards around objects while holding a basket). The duration of the training sessions was the same for both groups. In the dual-task training, the cognitive activities included digit span (memorize a set of letters or numbers and repeat them in forward or reverse order), N-back (naming a preceding word, letter or number to the one given by the researcher), spelling words (researcher says words to be spelled in the correct order), stroop test (consists of two tasks, reading and naming colours. In both, the stimuli are colour names printed in an incongruent colour), image description (a picture is placed in front of the participant who should describe it with maximum detail), nomination (the participant must say names in a given category: flowers, animals, countries or beginning with a letter of the alphabet), counting (counting in forward and reverse order), description of daily activities and routines (describe the activities that they normally do during a weekday or weekend and describe how to do these activities, e.g. what are the stages of taking a shower).

All participants in the dual-task group performed the same cognitive activities, but not necessarily in the same order. The complexity of the exercises was increased as the sessions progressed. This increase was based on the addition of obstacles, reduction of the pause time, increasing the complexity of the cognitive task. Each participant received individual training by a professional for 12-15 minutes at each station, which led to a total of 60 minutes per session. Between stations, the participants performed a transition exercise, which was getting up from and sitting down on a chair 15 times. Before beginning the exercises, all procedures were explained to the participant. No reference was made to the tasks the participant should give more importance to.

Outcome Measurements

All outcome measurements were evaluated at baseline and after the intervention for all participants by a clinician who was blinded to the participant's group.

The outcome measurements of motor performance were obtained by Time Up and Go test (TUG), Unified Parkinson's Disease Rating Scale-part III (UPDRS-III) and pressure platform.

The Timed Up and Go test was used to assess the time the participant took to get up from a chair, walk 3 meters and return to the same chair (the total distance walked was 6 meters) and sit down again. The time value chose for each participant was the best, i.e. the lowest value, of three trials performed (Podsiadlo & Richardson, 1991). The test-retest reliability and inter-rater reliability were ICC = 0.80 and $r = 0.99$, respectively (Lim et al., 2005). UPDRS (Goetz et al., 2003) assesses the signs, symptoms and perception of individuals concerning their performance of activities of daily living (ADLs), based on a self-report and clinical observations; it should be noted that only the motor exploration (UPDRS-III) was applied. This assessment had a high internal consistency (Cronbach's alpha = 0.96) and a satisfactory inter reliability (all items had $k > 0.40$) (Martínez-Martín et al., 1994). The pressure platform used was an Emed, from Novel (Germany), model AT 25A, with a sensorial area of 380x240 mm^2 and sensor resolution equal to 2 sensors/cm^2. As a stabilometric measurement, the centre of pressure (COP) was evaluated in terms of the mediolateral direction (COPx), the anteroposterior direction (COPy), and the total velocity (Vt) (Błaszczyk & Orawiec, 2011; Ganesan, Pal, Gupta, & Sathyaprabha, 2010; Holmes, Jenkins, Johnson, Adams, & Spaulding, 2010). The participants were instructed to stand on the platform and remain in a self-selected comfortable upright position. The pressure data was taken twice: first, the subjects were instructed to remain standing on the platform and look towards a fixed point at a distance of 2 meters for 60 seconds with their eyes open (EO); second, the subjects were instructed to remain on the same platform for the same time but now with their eyes closed (EC) (Ebersbach & Gunkel, 2011). The EO/EC order was randomized in order to avoid any possible learning effect. The acquisition frequency of 25 Hz and normalized relative to each subject's body base of support.

The outcome measurements of cognitive performance were obtained by Rule Shift Cards Test (RSCardsT) and Trail Making Test (TMT) A and B. The RSCardsT is used to evaluate perseverance trends and the ability to switch from one pattern to another, by taking into account the errors and the time taken to complete the task (Golden, Espe-Pfeifer, & Wachsler-Felder, 2000). The TMT (Reitan, 1992) is a test divided into two parts: Part A evaluates attention and processing speed; and part B that assesses the cognitive flexibility and sequential alternation. In each part, the final score is the total time needed to complete the task (Reitan, 1992).

As in other similar studies with this type of population, all tests were carried out when the participants were taking the prescribed medication, denoted as "ON" medication (Conradsson, Löfgren, Ståhle, Hagströmer, & Franzén, 2012; Kelly, Eusterbrock, & Shumway-Cook, 2012).

Statistical Analysis

According to the nature of the variables under study, descriptive statistical analysis was performed using proportions for the variable gender, and measures of central tendency and dispersion for the variables age, education, hour of physical activity, height, weight, years of disease and intervention outcomes.

For the inferential analysis, the Kolmogorov-Smirnov test was used to assess data normality. Since the normality of the data distribution could not be assumed, we chose to use non-parametric tests. The Mann-Whitney test for independent samples was used to verify the differences between the two groups at baseline and after intervention. In order to analyze which of the interventions was more effective, the changed scores (after the interventions relative to baseline) were used. Two-tailed tests were used in all analyses and were considered statistically significant when $p<0.05$. The training effect was calculated using the Cohen's d rule of thumb (Cohen, 1988): low, $0.20 \le d < 0.50$; medium, $0.50 \le d < 0.80$; and high, $d \ge .80$. The data collected was conducted using IBM SPSS Statistics 22.0 (SPSS, Inc., Chicago, IL, USA).

Results

The values in Table 1 reveal that there were no significant differences between the two groups in terms of age, gender, education level, weight, height, years of illness and number of falls. Concerning the cognitive performance, there were no significant differences between groups at baseline on the RSCardsT, TMT A and B. As to the motor performance, there were no differences between groups on UPDRS-part III, TUG and COPx, COPy and Vt with eyes open and with eyes closed.

< Insert Table 1 about here>

In order to analyze which of the interventions was more effective, the differences between the two groups were statistically analyzed after the interventions relative to baseline, Table 2. In terms of the motor performance, the only differences were found in COPx and COPy with eyes closed. As to the COPx, the difference between baseline and after intervention was significantly higher for the dual-task group than for the single-task group, U=7.5, p=0.026, with high effect size, d=1.094. The difference between baseline and after intervention in terms of the COPy was significantly lower for the dual-task group than for the single-task group, U=7.5, p=0.029, with high effect size, d=1.43. Nevertheless, the total velocity (Vt) with eyes open and with eyes closed revealed a high effect size (d=0.922 and d=0.902, respectively), and the remaining variables had a medium effect size.

No significant differences were found between the two groups in terms of the executive functions performed. However, the TMT B had a high effect size (d=0.839), the RSCardsT presented a medium effect size (d =0.590) and the TMT A had a small size effect (d=0.324).

< Insert Table 2 about here>

DISCUSSION

Studies have reported the positive influence of targeted interventions for motor training, whether for different cognitive components, including level of attention, processing speed, flexibility and alternating sequential, or for neuromotor issues, mainly in terms of muscle resistance, coordination, balance and agility (L. Baker et al., 2010; Davis et al., 2013; Mirelman et al., 2011; Moher, Liberati, Tetzlaff, & Altman, 2009; Tabak, Aquije, & Fisher, 2013; Tanaka et al., 2009). Our research has demonstrated that in a cognitive-motor dual-task training program with 12 sessions, the dual-task training was only statistically more effective than the single-task training for the COPx with eyes closed. A lower oscillation, i.e. smaller COP displacements, corresponds to a higher postural stability (Mochizuki, Duarte, Amadio, Zatsiorsky, & Latash, 2006) and thus, in agreement, our results suggested a better balance after the intervention program in the dual-task training group. As to COPy with closed eyes, significant differences were also found, but the dual-task training group presented values worse than the single-task training group. This fact can be explained by the number of years of the disease that was higher in the dual-task training group. The centre of pressure of these participants was shifted to a more posterior position in order to compensate the usual postural deformities caused by high muscular rigidity (Jankovic, 2008; Matinolli, 2009). This body position, together with the loss of postural reflexes, age-related sensory changes, as well as other features, leads to greater instability in the anteroposterior component (Jankovic, 2008).

COPx and COPy values with eyes open did not show significant differences between the two groups, but these variables had lower values after intervention in both. Some authors as, for example, (Oie, Kiemel, & Jeka, 2002; Tjernström, Fransson, Hafström, & Magnusson, 2002) defend that vision provides important feedback to the subjects about the physical environment, their spatial interactions and body sway, which complements the information provided by other sensorial receivers. Thus, the eyes open provides important information about postural orientation and helps to optimize the balance control, which may explain the better results found for COP displacement under this condition.

With regard to the Vt, it was found that the results were not statistically significant, but the effect size was high, as in previous studies with elderly individuals (Li et al., 2010; Plummer-D'Amato et al., 2012). Mochizuki et al. (2006) suggested that the lower values of velocity correspond to higher postural stability; however, in our study, the Vt with eyes closed increased in the dual-task training group, which may be a mechanism to compensate for the lower oscillation.

Based on the Timed Up and Go Test as well as the UPDRS-III test, the difference in terms of mobility was higher in the dual-task training group, with medium effect size, which indicates an improvement of the functional mobility of the individuals. These findings are consistent with other studies in which the average values were better in dual-task training programs, but with no significant results (Her et al., 2011; Jiejiao et al., 2012; Plummer-D'Amato et al., 2012; Vaillant et al., 2006).

Regarding the cognitive components, the TMT A, TMT B and RSCardsT results showed a tendency for improvement in both groups after intervention, likewise in a previous study by Hiyamizu et al. (2011) with healthy elderly individuals. These findings are also in agreement with other studies where visible improvements after dual-task interventions were found, although without statistical significance (Makizako et al., 2012; Pedroso et al., 2012; Pellecchia, 2005; Silsupadol, Lugade, et al., 2009).

The present study, as far as the authors' know, is innovative as it is the first study to assess the outcomes of a dual-task intervention on balance and executive functions in subjects with Parkinson's disease. Nonetheless, there are some limitations that should be discussed. The small size of the studied sample can limit the results, particularly regarding the significance of the statistical tests performed and the generalization of the findings. Hence, this work should be considered as a pilot study that has added knowledge concerning the effects of dual-task training on balance and executive functions in patients with PD. All participants involved were "ON" cholinergic medication, but the effect of the medication on the participants' performance was not taken into account. Therefore, although the intervention adopted was selected based on other closely related studies (Silsupadol, Lugade, et al., 2009; Silsupadol, Shumway-Cook, et al., 2009), it is suggested that future studies should also include a cognitive training before or after the balance training in the group that undergo the single-task training.

In conclusion, as was hypothesized for this study, our findings revealed a more positive response with the dual-task intervention compared to the single-task intervention. The motor training with a cognitive task performed simultaneously improved the performance of some parameters related to balance and executive functions of individuals with Parkinson's disease. These observations highlight the strength of rehabilitative interventions based on dual-task training.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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TABLE CAPTIONS

Table 1. Comparison at baseline between the single- and dual-task groups.

Table 2. Comparison between the single- and dual-task groups after the intervention relatively to baseline.

TABLES

Table 1

	Single-task Group (n=8)	Dual-task Group (n=7)	p-value
Age (years)	62.3 (12.9)	63.4 (9.5)	0.862
Gender, male (%)	6 (85.7%)	5 (62.5%)	0.310[a]
Education (years)	10.4 (5.1)	8.6 (6.4)	0.288
Physical activity (hours per week)	1.9 (1.3)	1.3 (0.3)	0.208
Body weight (kg)	67.3 (13.5)	66.8 (13.2)	0.817
Height (cm)	168.3 (8.0)	163.9 (7.4)	0.121
Years of disease	7.7 (7.5)	8.8 (4.3)	0.115
Time Up and Go	11.8 (4.4)	11.3 (3.8)	0.798
UPDRS-part III	14.8 (3.9)	14.3 (4.2)	0.795
Eyes opened			
Mediolateral sway (COPx - cm)	0.938 (0.457)	0.813 (0.249)	0.848
Anteroposterior sway (COPy - cm)	1.084 (0.351)	1.120 (0.527)	0.655
Total velocity (Vt-cm/s)	0.513 (0.426)	0.337 (0.082)	0.898
Eyes closed			
Mediolateral sway (COPx - cm)	0.671 (0.248)	0.813 (0.171)	0.949
Anteroposterior sway (COPy - cm)	1.187 (0.473)	1.133 (0.434)	0.137
Total velocity (Vt - cm/s)	0.578 (0.315)	0.538 (0.447)	0.491
RSCardsT	1.71 (1.38)	2.25 (1.49)	0.475
TMT A	86.33 (69.92)	68.75 (28.40)	0.948
TMT B	186.50 (98.78)	168.75 (55.81)	0.439

Results are: mean and (standard deviation) or (%)

[a] Chi-square test

Table 2

	Single-task Group (n=8)	Dual-task Group (n=7)	p-value	Size Effect
Time Up and Go	-1.800 (1.127)	-2.900 (3.318)	0.620	0.480
UPDRS-part III	-4.833 (3.764)	-7.000 (2.204)	0.345	0.792
Eyes opened				
Mediolateral sway (COPx - cm)	-0.273 (0.325)	-0.145 (0.093)	0.535	0.581
Anteroposterior sway (COPy - cm)	-0.096 (0.366)	-0.273 (0.257)	0.848	0.605
Total velocity (Vt-cm/s)	-0.148 (0.208)	-0.012 (0.091)	0.128	0.922
Eyes closed				
Mediolateral sway (COPx - cm)	0.112 (0.370)	-0.165 (0.114)	0.026*	1.094
Anteroposterior sway (COPy - cm)	-0.341 (0.465)	0.286 (0.479)	0.029*	1.430
Total velocity (Vt - cm/s)	-0.130 (0.365)	0.096 (0.176)	0.181	0.902
RSCardsT	0.286 (0.489)	1.125 (2.031)	0.336	0.590
TMT A	-11.833 (43.190)	-2,750 (15.416)	0.950	0.324
TMT B	-31.333 (48.980)	-0.250 (32.115)	0.345	0.839

Results are: mean and (standard deviation)

* p-value<0.05

FIGURE CAPTION

Figure 1. CONSORT (Schulz, Altman, & Moher, 2010) diagram of the recruitment process adopted.

FIGURES

Figure 1