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Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: A randomised clinical trial☆

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Abstract

Objectives To investigate the effect of Nintendo Wii™-based motor cognitive training versus balance exercise therapy on activities of daily living in patients with Parkinson's disease.
Design Parallel, prospective, single-blind, randomised clinical trial.
Setting Brazilian Parkinson Association.
Participants Thirty-two patients with Parkinson's disease (Hoehn and Yahr stages 1 and 2).
Interventions Fourteen training sessions consisting of 30 minutes of stretching, strengthening and axial mobility exercises, plus 30 minutes of balance training. The control group performed balance exercises without feedback or cognitive stimulation, and the experimental group performed 10 Wii Fit™ games.
Main outcome measure Section II of the Unified Parkinson's Disease Rating Scale (UPDRS-II).
Randomisation Participants were randomised into a control group ($n = 16$) and an experimental group ($n = 16$) through blinded drawing of names.
Statistical analysis Repeated-measures analysis of variance (RM-ANOVA).
Results Both groups showed improvement in the UPDRS-II with assessment effect (RM-ANOVA $P < 0.001$, observed power = 0.999). There was no difference between the control group and the experimental group before training {8.9 [standard deviation (SD) 2.9] vs 10.1 (SD 3.8)}, after training [7.6 (SD 2.9) vs 8.1 (SD 3.5)] or 60 days after training [8.1 (SD 3.2) vs 8.3 (SD 3.6)]. The mean difference of the whole group between before training and after training was −0.9 (SD 2.3, 95% confidence interval −1.7 to −0.6).
Conclusion Patients with Parkinson's disease showed improved performance in activities of daily living after 14 sessions of balance training, with no additional advantages associated with the Wii-based motor and cognitive training.
Registered on http://www.clinicaltrials.gov (identifier: NCT01580787).

Keywords: Parkinson's disease; Virtual reality; Balance; Executive function; Motor learning; Wii Fit; UPDRS-II

Introduction

Parkinson's disease has a progressive effect on postural control, resulting in loss of postural stability [1], especially during gait [2], which limits the performance of activities of daily living and reduces the level of independence [3]. Of the motor symptoms, postural instability responds less to medication and surgical treatment [4], but several studies have shown that physical therapy can improve the balance of patients with Parkinson's disease through exercise therapy, composed by balance and strengthening exercises [5], external cues [6] and virtual reality [7]. However, there is little evidence about the effects of these interventions on independent performance of activities of daily living [8].

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Recently, the Nintendo Wii Fit™ has been proposed as a new tool for balance training for elderly [9] and neurological patients [10], but its therapeutic effects on patients with Parkinson's disease have not been established. There is evidence that these patients could benefit from conditions of balance training offered by Wii Fit games such as weight shifting, symmetric foot stepping and controlled movements near the limits of stability, as well as the high number of repetitions and variability in a complex and motivating environment that provides visual and auditory feedback and reinforcement [11,12].

Moreover, due to the complexity of tasks that involve cognitive stimulation as well as motor skills, Wii Fit could promote improved integration of motor and cognitive abilities that could contribute to increased independence in daily life compared with balance exercise training based on motor stimulation alone [13].

This study had two objectives: (1) to verify if patients with Parkinson's disease could improve their performance on Wii Fit games; and (2) to compare the effects of Wii-based motor and cognitive training with balance exercise therapy on independent performance of activities of daily living among patients with Parkinson's disease.

The hypotheses of this study were: (1) patients with Parkinson's disease would be able to improve their performance on Wii Fit games; and (2) the Wii-based motor and cognitive training would have a greater effect on independent performance of activities of daily living compared with balance exercise therapy.

Methods

Trial design

Parallel, prospective, single-blind, randomised clinical trial.

Participants

Eligible participants were patients with a diagnosis of idiopathic Parkinson's disease treated with levodopa or its synergists; age 60 to 85 years; Hoehn and Yahr stages 1 and 2 [14]; good visual and auditory acuity; 5 to 15 years of education; and no other neurological or orthopaedic diseases, dementia [assessed by the Mini Mental State Examination (MMSE), cut-off 23] [15] or depression [according to the Geriatric Depression Scale (GDS-15), cut-off 6] [16]. The participants had no prior experience of using Wii Fit and had not attended any other rehabilitation programmes. Each participant gave their consent before the intervention commenced. The study was performed in accordance with the CONSORT guidelines, and was approved by the Ethics and Research Committee of São Camilo University Centre.

Study settings

This study took place at the Brazilian Parkinson Association, Brazil, from August 2009 to April 2011.

Interventions

Patients performed 14 individual 1-hour training sessions, twice a week for 7 weeks, scheduled to coincide with the 'on period' for dopaminergic replacement therapy. Training sessions were divided into 30 minutes of global exercises and 30 minutes of balance exercises. The control group received balance exercise therapy, and the experimental group received Wii-based motor and cognitive training.

Global exercises

Global exercises were divided into four different series, each lasting for 30 minutes: 10 minutes of warming, stretching and active exercises; 10 minutes of resistance exercises for limbs; and 10 minutes of exercises in diagonal patterns for trunk, neck and limbs. Both groups performed one series of global exercises per session.

Wii-based motor and cognitive training

Balance training for the experimental group was composed of 14 sessions, each lasting 30 minutes, playing 10 Wii Fit games (five games per session, two trials of each game). Furthermore, an additional session was performed 60 days after the end of training (follow-up). Scores were recorded in the second trial of each game, which was performed without interference from the physiotherapist. The first trial of each game was carried out under the supervision of a physiotherapist, who actively participated in training through guidance about the necessary movements for good game performance by somatosensorial stimulation, postural corrections and verbal instructions. In order to assess patients' performance for motor requirements, games were divided into three groups: (1) static balance (Single Leg Extension and Torso Twist); (2) dynamic balance (Table Tilt, Tilt City, Soccer Heading and Penguin Slide); and stationary gait (Rhythm Parade, Obstacle Course, Basic Step and Basic Run). The cognitive demands of the games were attention to solve the tasks, working memory and performance management. Three games required inhibition of responses, decision-making and strategy changes. Two games required short-term memory, and two games stimulated division of attention between the movements of the upper and lower limbs. The reader is referred to Mendes *et al.* [41] for detailed descriptions of the games.

Games selection criteria

In a preliminary phase of this study, the performance of 20 patients at Hoehn and Yahr stages 1 and 2 was tested on 16 Wii Fit games, previously selected by three physiotherapists for their potential effect on balance training. After analysis of

Table 1
Patient performance on the Wii Fit games.

Game type	Initial session Mean (SD) score	Last session Mean (SD) score	Follow-up Mean (SD) score	Mean difference (SD) between scores in initial session and last session [95% CI of difference]	Mean difference (SD) between scores in initial session and follow-up [95% CI of difference]
Static balance[a]	64 (25)	75 (20)[e]	73 (23)[e]	11 (16) [5 to 17]	9 (19) [2 to 15]
Dynamic balance[b]	28 (18)	45 (30)[d,e]	42 (30)[d]	17 (26) [10 to 23]	14 (25) [8 to 20]
Stationary gait[c]	101 (94)	154 (121)[d]	138 (118)[d]	51 (68) [34 to 68]	36 (56) [22 to 50]

SD, standard deviation; CI, confidence interval.
[a] Repeated-measures analysis of variance [$F(2,62)=8.7661$, $P<0.001$].
[b] Repeated-measures analysis of variance [$F(2,126)=21.376$, $P<0.001$].
[c] Repeated-measures analysis of variance [$F(2,124)=30.850$, $P<0.001$].
[d] Post-hoc Tukey tests: initial session × last session and initial session × follow-up: $P<0.0001$.
[e] Post-hoc Tukey tests: initial session × last session and initial session × follow-up: $P<0.001$.

the performance of patients in four single-session trials, 10 games were selected in which the patients demonstrated better performance. Games in which there was no improvement in scores due to high complexity, that were incompatible with the level of patient control, or which were not challenging due to a low level of complexity were excluded (Table 1).

Balance exercise therapy

The three physiotherapists who selected games in the preliminary phase of this study performed a detailed analysis of the motor requirements of each game as well as the duration of each trial in order to develop the exercises for the control group. Thus, the control group performed balance exercises with the same movements and time required by each game in each trial; this consisted of 10 exercises (five per session, two trials of each) that were equivalent to the motor demands of the experimental group training, but without the provision of external cues, feedback and cognitive stimulation. Overall, the exercises stimulated the displacement of the centre of gravity in the sagittal and frontal planes, static balance, trunk rotation exercises in standing position and alternating steps.

Outcomes

Primary outcome

The two groups were assessed before and after training, and 60 days after the end of training (follow-up). Assessments were performed at the same time, under the same conditions by the same blinded examiner. The primary outcome was independent performance of activities of daily living, assessed by Section II of the Unified Parkinson Disease Rating Scale (UPDRS-II) which includes functions such as walking, hygiene, clothing, changing position in bed and incidence of falls. The UPDRS has been considered by the Movement Disorders Society to be the gold standard assessment for patients with Parkinson's disease, and it is the most widely used instrument for its clinical trials [17].

Secondary outcomes

Secondary outcomes were static and dynamic balance. Dynamic balance was assessed using the Berg Balance Scale, which has been used previously to assess the balance of patients with Parkinson's disease [18]. A score below 46 indicates the risk of falls.

Static balance was assessed using the Unipedal Stance Test [19], which was performed with eyes open and closed in order to investigate the influence of visual control. The Unipedal Stance Test was also performed as a dual task (concurrent with verbal fluency) in order to evaluate automatic control.

The Unipedal Stance Test is a balance test with normative values accepted by the scientific literature [19]. The subject is asked to stand on one leg for 60 seconds, keeping his/her arms crossed in front of the trunk. The time starts when the individual lifts the foot, and stops when a sudden movement occurs in the upper limbs or the foot touches the floor.

Cognitive performance was analysed by the Montreal Cognitive Assessment [20], which was designed to detect mild degrees of cognitive impairment through the assessment of different domains such as visuospatial and executive functions, naming, memory, attention, language, abstraction and orientation. The maximum score is 30, and scores of 26 or more indicate normal performance.

Sample size calculation

Sample size calculation was based on a pilot study that tested 10 patients at Hoehn and Yahr stages 1 and 2, which indicated 4 points as the difference between pre- and post-training on the UPDRS-II. Based on this difference, the sample size calculation showed that 24 patients (12 in each group) would be sufficient for a power greater than 90% ($\alpha=0.05$).

Randomisation

Participants were randomised into two groups through blinded drawing of names and random assignment into groups, performed by an independent physiotherapist.

Blinding

As the patients and physiotherapists who performed the training in both groups were aware of the allocated groups, the outcome assessor was blinded to the allocation.

Statistical analysis

Demographic and clinical characteristics of the patients in the control group and the experimental group were compared using the unpaired *t*-test. Comparisons between groups (on primary and secondary outcomes) at each assessment (before training, after training and follow-up) were made using the unpaired *t*-test.

Kolmogorov–Smirnov and Levene tests were used to assess the normality and homogeneity of variance, respectively, for all measures.

Patients' performance on Wii Fit games was assessed by comparing the scores obtained in the initial, last and follow-up sessions by three repeated-measures analyses of variance (RM-ANOVA) (one for each group of games), with training session as a factor.

In order to analyse the results for the primary and secondary outcomes, six RM-ANOVAs were conducted, after normality and homogeneity tests, one for each independent variable. The factors were: group (control, experimental) and assessment (before training, after training, follow up), with the latter as repeated measures.

For effects that reached statistical significance, a post-hoc Tukey–Kramer test was performed in order to determine where the differences lay. The statistical analysis was performed using Statistica Version 10 (Statsoft, Tulsa, Oklahoma, United States).

Results

Patient characteristics at baseline

Demographic and clinical characteristics of patients in the two groups at baseline are presented in Table A (see supplementary online material). There were no significant differences between the two groups. All participants completed the training without any adverse effects (Fig. A see supplementary online material). Thirty-two patients (17 men and 15 women) with Parkinson's disease at Hoehn and Yahr stages 1 and 2 [mean 1.7, standard deviation (SD) 0.5] with a mean age of 67.4 (SD 8.1) years participated in this study. There was no difference between the groups at any of the assessments (before training, after training and follow-up) for primary or secondary outcomes (unpaired *t*-test; $P > 0.05$).

Wii Fit games performance

RM-ANOVA showed a significant effect of session in the three groups of games (static balance, dynamic balance and stationary gait). The post-hoc Tukey test confirmed that patients had performance improvement after training that was maintained 60 days after the last session (Table 2).

Primary outcomes

Fig. 1 shows the results obtained on the UPDRS-II before training, after training and at follow-up; and the mean differences between before training vs after training and before training vs follow-up and 95% confidence intervals.

RM-ANOVA (Table 2) showed a significant effect of assessment, without a group effect or interaction between factors, on the UPDRS-II. Both groups showed a significant improvement on the UPDRS-II after training that was maintained at follow-up (post-hoc Tukey test; $P < 0.05$).

Secondary outcomes

RM-ANOVA showed a significant effect of assessment, without group effect or interaction between factors, for balance assessment on the Berg Balance Scale (Fig. 2) and Unipedal Stance Test (with open and closed eyes), and cognitive performance assessment on the Montreal Cognitive Assessment (Table 2). Both groups showed a significant improvement on the Berg Balance Scale, Unipedal Stance Test (with open and closed eyes) and Montreal Cognitive Assessment after training that was maintained at follow-up (post-hoc Tukey tests; $P < 0.05$).

RM-ANOVA showed no significant effect of assessment, group or interaction between factors for the Unipedal Stance Test when performed as a dual task (Table 2).

Discussion

To the authors' knowledge, this is the first study to investigate the possible benefits of Wii-based motor and cognitive training on the independent performance of activities of daily living of patients with Parkinson disease. First, the authors analysed whether these patients would be able to improve their performance on Wii Fit games. Next, the effects of Wii-based motor and cognitive training were compared with the effects of balance exercise therapy, which had the same motor demands but dissociated from the more complex conditions offered by the Wii games.

This study had four key findings: (1) patients with Parkinson's disease were able to improve their performance in three groups of games; (2) Wii-based motor and cognitive training improved the participants' independent performance of activities of daily living, balance and cognition, and this was maintained for 60 days after the end of training; (3) the improvement was similar to that obtained by the participants who performed balance exercise therapy; and (4) no training led to significant improvement in balance in the dual task.

The first important finding was that patients with Parkinson's disease were able to improve their performance on Wii Fit games, probably due to improvements in motor and

Table 2
Patient performance in assessments before and after training and 60 days after the end of training for experimental and control groups.

	Before training Mean (SD)	After training Mean (SD)	Follow-up Mean (SD)	Mean difference (SD) between before training and after training [95% CI of difference]	Mean difference (SD) between before training and follow-up [95% CI of difference]
Section II of Unified Parkinson's Disease Rating Scale (RM-ANOVA; $P < 0.001$; observed power = 0.999)					
Experimental group	10.1 (3.8)	8.1 (3.5)	8.3 (3.6)	−0.7 (2.8) [−2.2 to 0.7]	−0.2 (2.9) [−1.7 to 1.4]
Control group	8.9 (2.9)	7.6 (2.9)	8.1 (3.2)	−1.0 (1.7) [−1.9 to −0.1]	−0.6 (1.6) [−1.4 to 0.3]
All	9.5 (3.4)	7.9 (3.2)[a]	8.2 (3.3)[a]	−0.9 (2.3) [−1.7 to −0.6]	−0.4 (2.3) [−1.2 to 0.5]
Berg Balance Scale (RM-ANOVA; $P < 0.005$; observed power = 0.940)					
Experimental group	52.9 (4.1)	54.4 (2.2)	54.1 (2.0)	1.4 (2.6) [0.0 to 2.8]	1.1 (2.7) [−0.3 to 2.5]
Control group	51.9 (4.6)	53.1 (3.4)	53.1 (3.1)	1.1 (2.1) [0.0 to 2.2]	1.1 (2.2) [0.0 to 2.3]
All	52.4 (4.9)	53.8 (2.9)[b]	53.6 (2.8)[b]	1.3 (2.3) [0.4 to 2.1]	1.1 (2.4) [0.2 to 2.0]
Unipedal Stance Test with eyes open (RM-ANOVA; $P < 0.01$; observed power = 0.840)					
Experimental group	23.4 (22.0)	32.9 (22.6)	31.2 (23.1)	9.5 (10.5) [3.9 to 15.0]	7.8 (12.6) [1.0 to 14.5]
Control group	21.1 (20.8)	25.2 (21.4)	23.4 (19.9)	4.1 (15.5) [−4.1 to 12.3]	2.2 (14.5) [−5.5 to 10.0]
All	22.3 (21.1)	29.1 (22.0)[b]	27.3 (21.6)[c]	6.8 (13.3) [2.0 to 11.6]	5.0 (13.7) [0.1 to 10.0]
Unipedal Stance Test with eyes open, dual task condition					
Experimental group	23.8 (18.9)	26.0 (20.3)	25.0 (21.4)	2.2 (9.4) [−2.8 to 7.2]	2.2 (9.4) [−2.8 to 7.2]
Control group	18.6 (16.5)	20.3 (19.8)	20.8 (18.1)	1.7 (11.3) [−4.3 to 7.7]	1.6 (11.2) [−4.3 to 7.7]
All	21.2 (17.7)	23.2 (20.0)	22.9 (19.7)	1.9 (10.2) [−1.7 to 5.6]	1.9 (10.2) [−1.7 to 5.6]
Unipedal Stance Test with eyes closed (RM-ANOVA; $P < 0.005$; observed power = 0.894)					
Experimental group	4.0 (2.9)	5.3 (5.0)	5.3 (5.0)	1.3 (3.0) [−0.3 to 2.9]	0.8 (3.5) [−1.1 to 2.6]
Control group	3.1 (3.0)	4.2 (4.5)	4.5 (4.4)	1.2 (2.1) [0.0 to 2.3]	1.5 (2.0) [0.4 to 2.5]
All	3.5 (3.0)	4.8 (4.7)[c]	4.9 (4.6)[a]	1.2 (2.5) [0.3 to 2.1]	1.1 (2.8) [0.1 to 2.1]
Montreal Cognitive Assessment (RM-ANOVA; $P < 0.001$; observed power = 0.962)					
Experimental group	20.6 (4.5)	22.2 (4.5)	21.8 (4.5)	1.6 (2.7) [0.1 to 3.1]	1.2 (2.4) [0.0 to 2.5]
Control group	21.7 (4.6)	23.1 (4.6)	23.3 (3.4	1.4 (1.9) [0.4 to 2.4]	1.6 (2.5) [0.2 to 2.9]
All	21.1 (4.5)	22.6 (4.5)[b]	22.5 (4.0)[b]	1.5 (2.3) [0.7 to 2.3]	1.4 (2.4) [0.5 to 2.3]

RM-ANOVA, repeated-measures analysis of variance; SD, standard deviation; CI, confidence interval.

[a] Post-hoc Tukey tests: before training × after training and before training × follow-up comparison: $P < 0.001$.

[b] Post-hoc Tukey tests: before training × after training and before training × follow-up comparison: $P < 0.005$.

[c] Post-hoc Tukey tests: before training × after training and before training × follow-up comparison: $P < 0.05$.

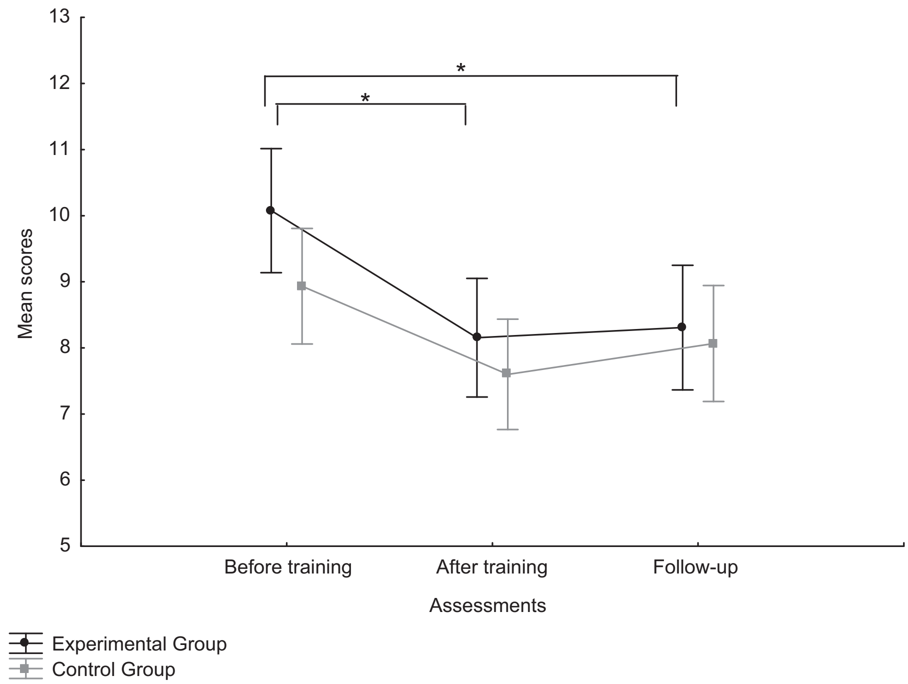

Fig. 1. Mean scores and standard error bars of performance of activities of daily living according to Section II of the Unified Parkinson's Disease Rating Scale before training, after training and at follow-up in the experimental and control groups. *Post-hoc Tukey test; $P<0.001$.

cognitive skills required by games such as weight shifting, symmetric foot stepping and controlled movements near the limits of stability [5], as well as attention, memory and decision-making [21]. Important features of this type of training probably contributed to these findings, as the wide range of visual and auditory stimulus may have worked as external cues that minimised the deficiency in movements guided by internal cues due to dopamine depletion [22]. In addition, the games provided feedback of the results, trial by trial, which may have facilitated the process of performance

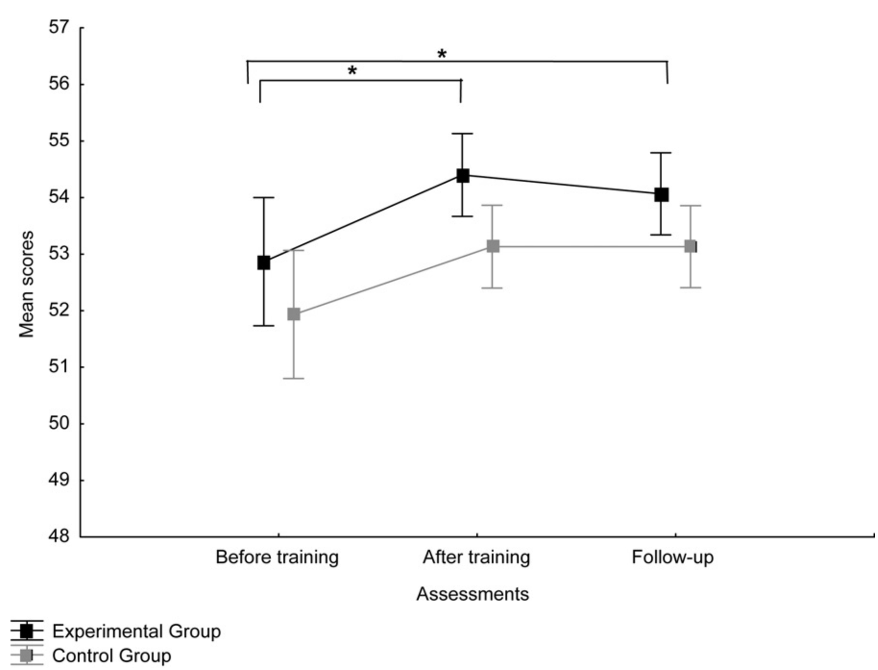

Fig. 2. Mean scores and standard error bars for the Berg Balance Scale before training, after training and at follow-up in the experimental and control groups. *Post-hoc Tukey test; $P<0.005$.

assessment and parameter selection of the next movement [23–25]. The presence of motivating stimuli, such as the reinforcing stimulus of optimal performance, as well as the novelty aspect of the games, can be particularly important in patients with Parkinson's disease who have reduced motivation [26]. Finally, training with Wii Fit promoted a high number of repetitions of various movements, which may have favoured learning [6,7,11,12].

The second important finding of this study was that the improvement in the skills trained through Wii Fit was not restricted to games, but had a positive impact on independent performance of activities of daily living, balance and cognition. As many activities of daily living require stability and cognitive skills in order to be performed efficiently and independently, balance and cognitive improvement could be associated with the improved independent performance of activities of daily living [27–29].

The third finding of this study was that training of the same motor skills in a real environment, dissociated from complex tasks, provided improvements equivalent to those obtained by the Wii-based motor and cognitive training. This equivalence of results can be explained by the similarity of the motor demands, purposely imposed for both types of training. Several studies have indicated that physiotherapy-based balance exercises, in many aspects similar to those proposed by this study and present in both types of training, can contribute to the improvement of postural instability of patients with Parkinson's disease [5,30–32].

Regarding the positive effects of both groups for cognition, it was assumed that, due to the low cognitive demand of balance exercise therapy compared with the Wii-based motor and cognitive training, the improvement could only be attributed to the beneficial effects of physical activity. Some studies have shown that exercise can promote cognitive improvement in elderly people [33] and patients with Parkinson's disease [31,34]. It is therefore plausible to assume that moderate physical activity developed over 7 weeks could provide an improvement in cognitive functions. It was assumed that cognitive skills trained by Wii Fit did not promote superior effects than motor stimulation alone, or the cognitive test was not sufficiently sensitive to identify the domains in which possible improvement could have occurred. In fact, some studies have discussed the difficulties in transferring cognitive skills trained by video games to real tasks [35,36].

Another finding of this study was that neither type of training led to an improvement in balance in the dual task. Improvement in this type of performance can occur by two mechanisms: (1) repetition of movements leading to automation which allows the release of attentive resources to the resolution of another task [37]; or (2) training of simultaneous tasks that would lead to better management of attentive resources [38,39]. Thus, the balance exercise therapy could only have led to an improvement by repetition, while the Wii-based motor and cognitive training could have led to an improvement by two mechanisms. The fact that no training had a positive effect on balance in the dual task strengthens the evidence that patients with Parkinson's disease have limited scope to improve their automatic control and attention management [37,40].

In conclusion, the results of this study show that both types of training promoted an improvement in the performance of activities of daily living, balance and cognition among patients with Parkinson's disease, supporting the possibility of therapeutic use of balance exercise therapy and Wii-based motor and cognitive training. Due to the chronic and degenerative nature of Parkinson's disease, physical therapy guidelines suggest that treatment should occur on a long-term basis, which could have an adverse effect on patients' adherence to treatment as the repetitive exercises could become monotonous. Thus, Wii Fit could be used as a new tool in association with physical therapy in order to improve motivation, and consequently adherence, of patients in the long rehabilitation process, contributing to functional improvement and prevention of negative consequences of immobility.

A limitation of this study was the absence of a control group that received no intervention, which could suggest the influence of a placebo effect on the results. However, this hypothesis is weakened by two facts: (1) there was no general improvement of patients in all outcomes; and (2) the positive effects were maintained for 60 days after training, during which time the patients did not receive any type of physiotherapy.

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Conflict of interest: None declared.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2012.06.004.

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