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Review article

Effectiveness of exergaming in improving functional balance, fatigue and quality of life in Parkinson's disease: A pilot randomized controlled trial

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ABSTRACT

Although motor symptoms in Parkinson's disease (PD) are well established, few studies have described the effects of exergaming on the clinical and functional outcomes of PD.

Objectives: To analyze the effectiveness of exergaming in improving functional balance, fatigue, functional exercise capacity and quality of life in PD.

Methods: The study population consisted of 20 patients (12 males and 8 females) aged 61 ± 9.11 years allocated into two groups: an exergaming group (EGG) ($n = 10$) and a conventional exercise, or control, group (CG) ($n = 10$). The following variables were evaluated: functional balance (Berg Scale), fatigue (Fatigue Severity Scale), functional exercise capacity (Six-Minute Walk Test) and quality of life (PDQ-39 Quality of Life Questionnaire).

Results: RM-ANOVA showed that balance and fatigue differed significantly between time points: balance [$F(1.29, 23.33) = 4.16$, $p = 0.043$] and fatigue [$F(2,36) = 5.96$, $p = 0.006$]. In both cases *post hoc* Bonferroni testing revealed an improvement after 12 weeks of exergaming ($p = 0.033$ and $p = 0.000$, respectively). However, this benefit was not sustained after 60 days of follow-up for either outcome. There were no differences in functional exercise capacity or quality of life between the two groups after 12 weeks of treatment.

Conclusion: Exergaming was effective in enhancing balance and reducing fatigue in PD patients after 12 weeks of treatment, but this benefit was not sustained in the long-term.

1. Introduction

Parkinson's disease (PD) is a complex disorder that combines motor symptoms (such as tremor, rigidity, bradykinesia and gait and balance dysfunction) and non-motor symptoms (such as fatigue, pain and sleep disorders) which worsen progressively over time and have a significant negative impact on the patient's exercise capacity and quality of life.

Even if they undergo surgery in addition to drug therapy [1], PD patients show continuing functional deterioration and physical problems [2]. Physical therapy (PT) interventions are currently considered an important rehabilitation tool for PD patients, and various studies using PT have reported positive outcomes, including maximization of patients' functional ability and minimization of secondary complications such as inactivity [3] and social withdrawal [4], thereby improving patients' quality of life [5] [6]. Interventions that promote the integration of multi-sensory, cognitive and motor abilities may be more effective in motivating PD patients to be more active for longer periods despite their limitations [6]. However, there is little evidence of the actual effectiveness of therapies that promote this interaction.

The use of technology, including virtual reality and exergaming software, is rapidly increasing in neurological rehabilitation [7]. Exergames (videogame-based physical activities) involve tasks in virtual environments that combine physical and cognitive demands in an attractive and challenging way. The player is encouraged to achieve goals and overcome limits during the games, which

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provide immediate feedback on his performance. In addition, exergaming can be fun, is inexpensive and can be used with patients who live in remote or rural settings, increasing adhesion to physical activity [8].

Exergaming could thus be used as another tool for preventing or slowing the pace of functional losses and have a positive impact on PD patients' quality of life.

Although there is some evidence of the effectiveness of virtual reality and the use of video games in enhancing balance [9], there is still little evidence of their effectiveness in reducing fatigue and increasing exercise capacity, particularly in a randomized controlled trial (RCT) design.

We hypothesize that virtual reality-based exercise improves or maintains balance and exercise capacity, reduces fatigue and has a more positive impact on perceived quality of life in PD than conventional exercise.

The aim of this study was to assess the effectiveness of exergaming in improving PD patients' functional balance, fatigue, functional exercise capacity and quality of life.

2. Methods

This pilot randomized controlled trial was conducted at the *Associação Paranaense de Portadores de Parkinson (*APPP) (Paraná State Parkinson's Disease Association) in Curitiba, Paraná, from January through December 2013. The trial design followed the recommendations of the Consolidated Standards of Reporting Trials *(*CONSORT) [10]. The study, which was carried out in accordance with the Declaration of Helsinki, was reviewed and approved by the UFPR Committee for Ethics in Human Research (ref no. 173.719/2012) and registered with ClinicalTrials.gov (clinical trial identifier: NCT02023034). All participants provided voluntary written informed consent.

Inclusion criteria were a clinical diagnosis of PD according to the UK Parkinson's Disease Society Brain Bank criteria for idiopathic Parkinson's disease (UK-PDSBB) [11] confirmed by a neurologist; age 40–80 years; disease stage I, II or III based on the modified Hoehn & Yahr scale [12]; low risk of falls (Berg score > 45); and being recruited from the APPP between August 2013 and December 2013.

Exclusion criteria were any type of dementia or cognitive deficit (assessed by the Mini-Mental State Examination using a cutoff of 24) [13]; acute pain or comorbid conditions (e.g., orthopedic disease, severe or unstable heart disease and other neurologic diseases); visual impairment; use of any assistive device that could prevent the patient performing the exercises correctly; having attended any other rehabilitation program (PT or OT, occupational therapy) in the last three months; and having used a Wii balance board at any time in the past.

Once participants were included in the study, their demographic, anthropometric and clinical data were recorded and they were evaluated for functional balance, fatigue, functional exercise capacity and quality of life.

Following baseline testing, patients were randomly allocated into two treatment groups: an exergaming group (EGG) [14] and a conventional exercise, or control, group (CG). The activities performed in both groups exercise various elements of the balance control system, including musculoskeletal components, sensory systems, neuromuscular strategies and anticipatory control mechanisms. Interventions were conducted with both groups in 30 min sessions twice a week over a 12-week period during the ON time of the dopaminergic medication. This was considered to be 1 h after the patients took a supra-threshold dose of their morning medication [15]. Interventions were carried out at the APPP and supervised by two physiotherapists, who provided immediate physical assistance when necessary during both the exergaming and conventional exercise programs. Patients were allowed to miss up to two sessions.

2.1. Interventions

The exergaming intervention consisted of seven Wii Fit games: Table Tilt, Tilt City, Penguin Slide, Soccer Heading, Basic Run, Obstacle Course and Basic Step. The choice of games was based on Mendes et al. [14].

Before the beginning of the intervention, patients practiced the movements and positions required for each game twice. A description of the exergames in the order in which they were performed is given in Table 1.

The device used was a Nintendo® video game console with a Wii Balance Board®. The latter consists of a platform with four force transducers that generate information related to force distribution as the player displaces his center of gravity in real time [14].

The conventional exercise program used was chosen following Pompeu et al. [16]. and consisted of the following activities: warming, stretching and active exercises (10 min); resistance exercises for the limbs (10 min); and diagonal exercises for the trunk, neck and limbs (10 min).

Patients were tested at baseline, after 12 weeks of sessions and 60 days after the sessions had finished (follow-up). They were instructed to maintain their normal activities of daily living without doing any physical exercise for 60 days after the last session. The outcome assessor was blinded to group allocation.

2.2. Primary outcome

The primary outcome evaluated was functional balance, which was assessed using the Berg Balance Scale. This comprises 14 progressively more challenging tasks of balance and postural control [17], each of which is rated from 0 to 4, where 0 denotes “unable to perform the task” and 4 “fully able to perform the task”. The maximum score is 56, and the fall-risk cutoff is 45 [17].

2.3. Secondary outcomes

The secondary outcomes evaluated were fatigue, exercise capacity and quality of life. Fatigue is an important non-motor symptom affecting approximately 58% of PD patients [18]. Present from the earliest stages of the disease, it is one of the three most disabling symptoms and has a significant negative impact on the patient's quality of life [19]. Fatigue was assessed using the Brazilian version of the Fatigue Severity Scale (FSS-BR), which includes nine statements. Patients are instructed to rate each statement from 1 to 7, where 7 indicates full agreement with the statement. The total FSS-BR score is the mean of the scores for all nine items; a score ≥4 indicates fatigue [20,21].

Functional exercise capacity was estimated using the Six-Minute Walk Test (6MWT) according to the American Thoracic Society guidelines [22]. The 6MWT measures the maximum distance (in meters) that a patient can walk in 6 min. The test was performed along a 30 m-long indoor corridor on a flat surface marked every meter; the start and finish of the test was marked with a traffic cone.

Quality-of-life was measured using the PDQ-39 Parkinson's Disease Questionnaire, which consists of 39 items covering eight domains: mobility, activities of daily living, emotional well-being, stigma, social support, cognition, communication and body discomfort. Total score ranges from 0 to 100, and lower scores denote a perception of better health status [23].

Table 1
Description of the exergames.

Game	Description
Table Tilt	The screen shows a platform with holes and balls rolling on the platform. The player has to make the balls go through the holes within a predetermined time (defined by the game) by tilting the virtual platform and shifting his body weight to make the balls roll into the holes. In the first level, the platform has one hole and one ball, and as the game progresses to higher levels other balls and holes appear, increasing the level of difficulty. Every time a ball falls off, the platform turns at random so that the hole is in a different position.
Tilt City	Three on-screen platforms are controlled by the player, one with the Wii Remote® and the other two by means of the player's body movements on the WBB. The platform controlled by the Wii Remote® controller is above the other two, which are in line. At the bottom of the screen there are three colored pipes under the platforms. The goal is to steer each ball into the pipe of the same color. The balls drop onto the top platform and the player has to direct them to the correct side and then lean his body toward the pipe of the matching color.
Penguin Slide	The player controls the movements of a virtual penguin on an iceberg while fish leap over the iceberg. The goal is to catch as many fish as possible. When the penguin tries to move to one side, the iceberg tilts and the penguin slides quickly to that side. At this point the player should shift his body weight in the opposite direction to prevent the penguin from falling into the sea.
Soccer Heading	The goal is for the on-screen player to head as many balls as possible when these are thrown toward him in several directions. The virtual (on-screen) player mimics the real-life player. Sometimes teddy bear heads and cleats are thrown toward the virtual player instead of balls, in which case the real-life player should tilt quickly to dodge those.
Basic Run	The player has to alternate steps to allow the virtual player to follow an on-screen cat and finish a run on a course shown on the screen. After completing the run, the player is required to answer three questions about details of the course.
Obstacle Course	The virtual player has to move along a course with obstacles consisting of, for example, large swinging spheres. The real-life player has to alternate steps to control the speed the virtual player moves at and make him dodge the balls by jumping, which the virtual player does when the real-life player bends and straightens his legs. The virtual player is thrown off course if one of the spheres hits him. The score is proportional to the distance covered by the player.
Basic step	A virtual player has to step on and off a virtual platform to the rhythm of the soundtrack in a sequence determined by the visual cues. The game requires lower-limb coordination and anticipatory body posture adjustments for the constant weight transfers the player has to make.

3. Sample and randomization

The sample-size calculation showed that 20 patients would be sufficient for a power greater than 80% (5 points as the minimal detectable change [24], and $\alpha = 0.05$). All patients who agreed to participate in the study were assigned a number and randomly allocated to one of the two groups using simple randomization procedures (computer-generated random numbers). Allocation was concealed using sequentially numbered and sealed opaque envelopes that were only opened when each subject was admitted to the study. An independent physiotherapist performed both procedures.

4. Statistical analysis

The data were analyzed using Statistical Package for the Social Sciences (SPSS) for Windows version 16.0.

The Shapiro-Wilk and Levene tests were used to assess normality and homogeneity of variance, respectively, for all measures. Baseline characteristics of the EGG and CG patients were compared using the unpaired *t*-test and Mann-Whitney test depending on the type of variable and data distribution.

The results of primary and secondary outcomes were assessed by repeated-measures analysis of variance (RM-ANOVA) using group (EGG and CG) and assessment (before the intervention, at the end of the intervention and after 60 days of follow-up) as factors.

To ensure systematic progression of variance across pre and post measures, test-retest reliability was determined in a secondary analysis by calculating the intraclass correlation between pre and post assessment values for each test parameter.

The level of statistical significance was set at $p < 0.05$.

5. Results

Thirty individuals with PD agreed to participate in the study; of these, only twenty [age 61 ± 9.11 years, 12 (60%) males, 8 (40%) females] fulfilled the inclusion criteria. Ten patients were assigned to the EGG group and ten to the CG group (Fig. 1). There were no statistically significant differences between the two groups, and all participants completed the study. Demographic, anthropometric and clinical data for the study population are shown in Table 2.

5.1. Primary outcome

RM-ANOVA (Table 3) showed a significant effect of assessment between and within factors on balance [$F(1.29, 23.33) = 4.16$ $p = 0.043$, $\omega^2 = 0.188$], and *post hoc* Bonferroni testing revealed an increase in balance after 12 weeks of the exergaming program ($p = 0.033$). However, this benefit was not sustained after the 60-day follow-up ($p = 0.001$).

5.2. Secondary outcomes

As with balance, RM-ANOVA (Table 3) revealed a significant difference in fatigue between assessment time points [$F(2, 36) = 5.96$, $p = 0.006$, $\omega^2 = 0.249$], and *post hoc* Bonferroni testing revealed a reduction in fatigue after 12 weeks of the exergaming program ($p = 0.002$). However, this benefit was not sustained after the 60-day follow-up ($p = 0.002$).

In contrast, RM-ANOVA showed a non-significant effect of assessment on functional capacity (Table 3) and quality of life (Table 4) without a group effect.

6. Test-retest reliability

Because of the relatively small sample size, estimates of test-retest reliability were computed to assess the reliability of all the measures. This analysis was carried out for both groups combined (Table 5).

7. Discussion

The European Physiotherapy Guideline for Parkinson's Disease identifies five core areas in which a rehabilitation program should lead to improvements depending on the patient's cognitive condition and the stage of the disease: physical capacity; weight transfer; manual activities; balance; and gait. Improvements in these areas can be expected to lead to improved performance in activities of daily living and better quality of life.

Exergames combine real-time motion detection with engaging video games that can help motivate people to exercise [25]. The challenge of fulfilling the goals defined in the game, achieving high scores and moving to the next level of difficulty seems to motivate participants.

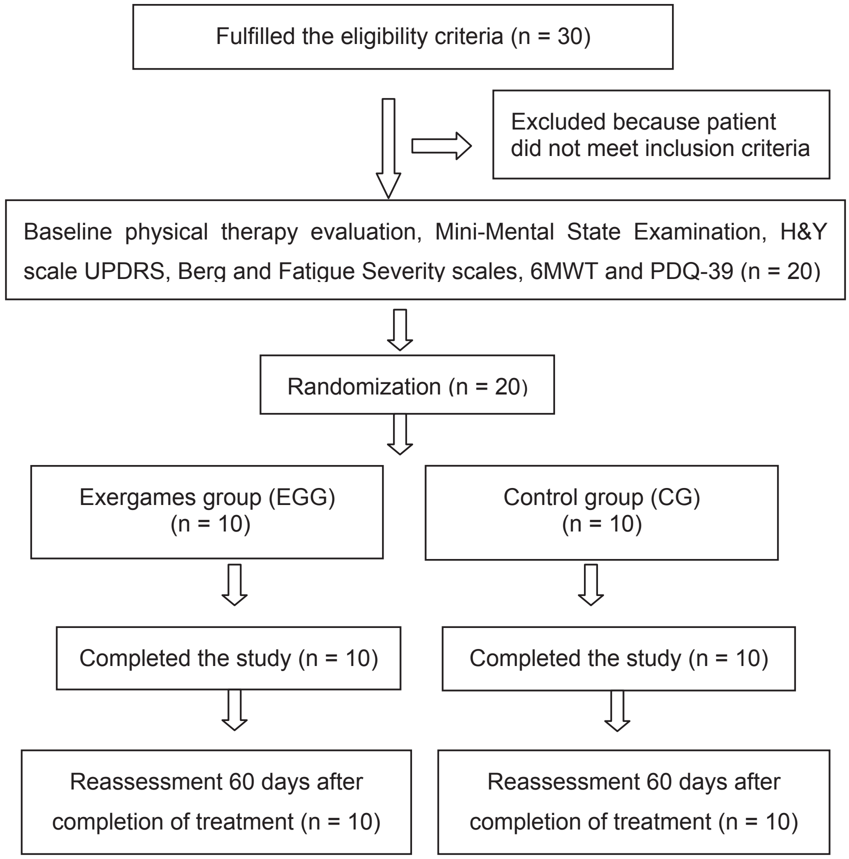

Fig. 1. Data collection flowchart based on the CONSORT guidelines.

Table 2
Demographic, anthropometric, and clinical data for the study sample.

Characteristics	EGG (n = 10)	CG (n = 10)	*p*-value
Age, years (mean ± SD)	61.70 ± 6.83	60.20 ± 11.29	0.72
Sex, M/F (n)	4/6	4/6	1.00
BMI, m/kg^2 (mean ± SD)	24.85 ± 3.08	25.01 ± 2.73	0.90
MMSE (median, p25–p75)	27.5 (23–29)	27.5 (26–29)	0.85
Disease duration in years (mean ± SD)	6.5 ± 4	7 ± 2.79	0.75
H&Y (median, p25–p75)	1.25 (1–2)	1.5 (1–2)	0.63
H&Y, n (1/1.5/2/2.5)	5/2/2/1	3/4/2/1	0.76
UPDRS (median, p25–p75)	22.5 (11.5–32)	20.5 (13.5–27.5)	0.74

EGG: exergaming group; CG: control group; BMI: body mass index; MMSE: Mini-Mental State Examination; H&Y: Hoehn & Yahr Scale; UPDRS: Unified PD Rating Scale; p25: 25th percentile; p75: 75th percentile.

A recent systematic review analyzed the safety, feasibility and effectiveness of exergaming in PD and showed not only that PD patients enjoy playing exergames, but also that the games induce some improvements in motor symptoms in these patients [25]. In the present study, we examined the effectiveness of a new rehabilitation tool in reducing fatigue and improving balance, exercise capacity and quality of life in PD patients. The study yielded some interesting results: (1) after 12 weeks of treatment, the patients in the exergaming group showed a statistically significant improvement in balance and fatigue; (2) this benefit was not sustained after 60 days of follow-up. There were no complications, falls or adverse effects during the interventions in either group.

Our results showed a significant improvement in balance, as evidenced by increased post-exergaming Berg scores in the intervention group, agreeing with several studies that have reported the beneficial effects of exergaming on balance in older adults. Bruin et al. [26] point out that physical exercise based on virtual reality games is more effective than conventional balance training. According to the authors, physical exercise using video games is beneficial because settings and therapy protocols can be tailored to each individual's therapeutic requirements and interests, enabling gains in balance and motor coordination. In addition, exergaming improves motor learning by inducing changes in brain architecture, which in turn help to increase the individual's independence and motivation to exercise. Furthermore, Yamada et al. [27] regard exergaming as a dual task, since the player needs to concentrate on the screen and execute movements, stimulating balance mechanisms and consequently reducing the risk of falls. Nevertheless, to date there is only one study, by Pompeu et al. [16], that examines the effects of exergaming on PD patients' balance. The findings of the study indicated that exergaming led to an increase in PD patients' Berg balance scores.

To our knowledge, the present study is the first to investigate the possible benefits of exergaming for fatigue in PD patients.

Table 3
Comparisons of functional parameters between the two groups.

Exergaming Group	Before treatment	After treatment	Follow-up
Balance (Berg)[a]	50.40 ± 2.79	52.30 ± 2.26	47.70 ± 4.80
Fatigue (FSS)[b]	3.80 ± 1.66	1.83 ± 0.57	3.05 ± 1.11
6MWT (m)[c]	352 ± 91.99	408 ± 97.27	376 ± 98.68
Control Group			
Balance (Berg)	48.40 ± 2.63	48.20 ± 2.89	46.90 ± 2.72
Fatigue (FSS)	3.55 ± 1.68	3.02 ± 1.22	3.23 ± 1.31
6MWT (m)	384 ± 86.43	437 ± 89.69	392 ± 80.24

Data expressed as mean ± SD; FSS: Fatigue Severity Scale; 6MWT: Six-Minute Walk Test.
Post hoc Bonferroni test: Before *vs* After, p = 0.033; Before *vs* Follow-up, p = 0.022 and After *vs* Follow-up, p = 0.001.
Post hoc Bonferroni test: Before *vs* After, p = 0.000; Before *vs* Follow-up, p = 0.037 and After *vs* Follow-up, p = 0.002.
[a] Repeated-measures analysis of variance [F(1.29, 23.33) = 4.16, p = 0.043, $\omega^2 = 0.188$].
[b] Repeated-measures analysis of variance [F(2,36) = 5.96, p = 0.006, $\omega^2 = 0.249$].
[c] Repeated-measures analysis of variance [F(2,36) = 0.42, p = 0.656, $\omega^2 = 0.023$].

Table 4
Comparisons of quality-of-life scores (PDQ-39) between the two groups.

Exergaming Group PDQ-39	Before treatment	After treatment	Follow-up
Mobility[a]	32.51 ± 24.12	28.01 ± 22.53	32.41 ± 18.27
ADLs[b]	16.74 ± 15.51	16.91 ± 13.42	20.49 ± 14.39
Social well-being[c]	32.49 ± 24.51	31.24 ± 22.15	30.13 ± 22.37
Stigma[d]	15.83 ± 25.37	7.08 ± 10.40	14.99 ± 25.68
Social support[e]	12.49 ± 24.60	12.49 ± 24.29	13.33 ± 22.97
Cognition[f]	30 ± 16.62	27.50 ± 17.23	32.27 ± 15.86
Communication[g]	28.33 ± 31.95	17.49 ± 17.32	19.99 ± 28.10
Discomfort [h]	54.16 ± 27.28	44.99 ± 26.70	46.23 ± 27.95
Control Group PDQ-39	**Before treatment**	**After treatment**	**Follow-up**
Mobility	17.50 ± 11.78	16.20 ± 12.08	18.25 ± 11.36
ADLs	10.82 ± 10.70	10.61 ± 10.87	13.56 ± 9.58
Social well-being	24.99 ± 20.87	22.63 ± 21.04	21.79 ± 20.07
Stigma	11.45 ± 14.34	9.16 ± 10.40	9.91 ± 13.61
Social support	4.15 ± 7.06	3.32 ± 7.01	1.88 ± 4.01
Cognition	6.71 ± 16.47	14.81 ± 15.87	15.23 ± 17.17
Communication	19.99 ± 18.08	19.09 ± 20.44	22.42 ± 17.15
Discomfort	25.82 ± 23.72	23.31 ± 15.62	29.99 ± 17.21

Values expressed as mean ± standard deviation; ADLs: activities of daily living.
[a] Repeated-measures analysis of variance [F(2,36) = 0.54, p = 0.582, $\omega^2 = 0.030$].
[b] Repeated-measures analysis of variance [F(2,36) = 0.031, p = 0.908, $\omega^2 = 0.002$].
[c] Repeated-measures analysis of variance [F(2,36) = 0.012, p = 0.988, $\omega^2 = 0.001$].
[d] Repeated-measures analysis of variance [F(1.16,21.04) = 0.610, p = 0.468, $\omega^2 = 0.033$].
[e] Repeated-measures analysis of variance [F(2,36) = 1.279, p = 0.291, $\omega^2 = 0.066$].
[f] Repeated-measures analysis of variance [F(1.15,20.79) = 0.444, p = 0.541, partial eta squared = 0.024].
[g] Repeated-measures analysis of variance [F(2,36) = 1.621, p = 0.212, $\omega^2 = 0.083$].
[h] Repeated-measures analysis of variance [F(2,36) = 1.144, p = 0.330, $\omega^2 = 0.060$].

Fatigue is one of the three most disabling symptoms in PD and affects roughly 58% of patients with this condition [18,28]. According to Valko et al. [29], fatigue in PD can be influenced by multiple factors, including the motor symptoms themselves, and is likely to be reflected in the patient's physical capacity, which in turn affects the underlying psychological dimension of this symptom.

Although our results showed no significant differences in functional capacity between the groups, after 12 weeks of sessions the walking distance for both groups had increased. Functional exercise capacity is dependent on an individual's ability to perform activities that demand sustained aerobic metabolism [30]. The exercises in the present study did not require this level of aerobic metabolism, and the results therefore did not show any differences in functional capacity between the two types of interventions.

Table 5
Test-retest reliability between values obtained before the intervention, after the intervention and after 60 days of follow-up.

	CCI	CI 95%
Balance	0.76	0.50–0.89
Fatigue	0.86	0.70–0.94
TC6	0.96	0.92–0.98
PDQ-39–Mobility	0.97	0.94–0.98
PDQ-39–ADLs	0.90	0.78–0.95
PDQ-39–Social well-being	0.89	0.76–0.95
PDQ-39–Stigma	0.81	0.60–0.92
PDQ-39–Social support	0.99	0.97–0.99
PDQ-39–Cognition	0.93	0.84–0.96
PDQ-39–Communication	0.91	0.81–0.96
PDQ-39–Discomfort	0.90	0.79–0.95

CCI: intraclass confidence coefficient; CI: confidence interval.

No significant improvement in the quality-of-life domains was reported by patients in either of the groups. According to Camargos et al. [31], physical handicaps represent an emotional burden on individuals with PD, as such individuals are unable to perform their daily activities the way they would like to and become less self-reliant, developing a tendency to social withdrawal. Hence, it is reasonable to suggest that the improvements observed here are to some extent due to increased motivation.

We acknowledge, however, that the study has certain limitations, the main one being the small sample size. Although the number of individuals registered at the APPP was high, the majority were already having conventional PT, which excluded them from the study. Another limitation was the lack of data on the number of falls before and after the intervention, an important factor that should have been evaluated. In addition, objective and subjective measures of safety and the participants' ability to play the games should have been reported. Despite these shortcomings, the study addresses key outcomes for PD. Furthermore, the results are consistent and can be generalized to clinical practice.

Some considerations, nevertheless, are necessary when prescribing exergaming for PD patients. While there were no adverse events in this study, we believe that the main challenge is to ensure the exercises are suitable for the patient's cognitive level and disease severity. In addition, when activities of this kind are carried out in a home setting, the risk of falls must be monitored, which requires direct supervision by a qualified professional.

The results of this study show that exergaming-based activities are an effective treatment option as far as balance and fatigue are concerned and could therefore become an additional tool for the treatment of PD and other neurodegenerative diseases.

Author contributions

CGR: Coordinating investigator. Conception of the study design; organization of the study; execution of the study; review and critique of the statistical analysis; review and critique of all drafts.

LAS: Coordinating investigator. Conception of the study design; organization of the study; execution of the study; review and critique of the statistical analysis; review and critique of all drafts.

MRC: Coordinating investigator. Conception of the study design; organization of the study; execution of the study; review and critique of the statistical analysis; review and critique of all drafts.

HGT: Medical expert. Conception of the study design; organization of the study; review and critique of the statistical analysis; writing of the first draft; review and critique of all drafts.

SV: Coordinating investigator. Conception of the study design; organization of the study; review and critique of the statistical analysis; writing of the first draft; review and critique of all drafts.

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