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Tomasz Zalecki[1], Agnieszka Gorecka-Mazur[2], Wojciech Pietraszko[2],
Artur D. Surowka[3], Pawel Novak[4], Marek Moskala[2], Anna Krygowska-Wajs[5]

VISUAL FEEDBACK TRAINING USING WII FIT IMPROVES BALANCE IN PARKINSON'S DISEASE

Abstract: Postural instability including imbalance is the most disabling long term problem in Parkinson's disease (PD) that does not respond to pharmacotherapy. This study aimed at investigating the effectiveness of a novel visual-feedback training method, using Wii Fit balance board in improving balance in patients with PD. Twenty four patients with moderate PD were included in the study which comprised of a 6-week home-based balance training program using Nintendo Wii Fit and balance board. The PD patients significantly improved their results in Berg Balance Scale, Tinnet's Performance-Oriented Mobility Assessment, Timed Up-and-Go, Sit-to-stand test, 10-Meter Walk test and Activities-specific Balance Confidence scale at the end of the programme. This study suggests that visual feedback training using Wii-Fit with balance board could improve dynamic and functional balance as well as motor disability in PD patients.

Key words: Parkinson's disease, physical therapy, visual feedback, balance training.

INTRODUCTION

Parkinson's disease (PD) is one of the most common neurodegenerative diseases, with a prevalence of 100–200/100000 people worldwide [1–5], clinically characterized by slowly progressive bradykinesia, rigidity, resting tremor and postural instability [6]. The pathological definition of PD includes the loss of dopaminergic cells in the substantia nigra (pars compacta) with the subsequent lack of the neurotransmitter dopamine [7] and the presence of histopatological markers, called Lewy bodies [8].

Dopamine substitution therapy provides symptomatic relief, but even with optimal pharmacological and surgical treatment the disease and symptoms progress further and the treatment loses its efficacy [9]. In addition there are symptoms, such as postural instability with falls, autonomic failure, gait disturbance and freezing which are not responsive to dopaminergic stimulation.

It has been shown that postural instability including imbalance, as a major axial disorder in PD, is associated with cholinergic neurons of the pedunculopontine nucleus [10, 11]. Also, the involvement of other non-dopaminergic systems has

been shown [11, 12]. Thus, these studies may explain the resistance of postural instability to levodopa treatment. Furthermore, postural instability and other axial disorders are the most disabling long-term problems of PD that do not respond to levodopa. Therefore the management of PD requires the development of new therapeutic strategies.

Recently, the physical treatment has gained in importance as a method of supporting pharmacotherapy. Several studies have shown that physiotherapy including limb strength, endurance, flexibility and balance training may improve the balance of patients with PD [13–17].

Biofeedback training of balance has shown to be effective for posture control [18]. The use of virtual reality (VR) and visual feedback training has been offered to improve functional balance, gait speed and mobility in older adults, and post-stroke patients [19–21]. Several studies support the use of virtual reality and video gaming programmes in physiotherapy of older adults [19, 21–25]. VR is technology that allows the user to directly interact with computer simulated environment. VR is defined as a real-time computerized simulation in two or three dimensions [19] that is in real time and interactive. Virtual reality balance training requires participants to perform discrete, controlled movements beyond their base of support in response to visual impulses.

The Wii console and balance board is a modern system providing virtual reality balance training [21]. The Wii Fit balance system interacts with the user by collecting data from body movements as a result of a specific action in the game, constantly re-sending visual feedback to the user, using a sensory-enriched environment. A recently performed pilot study of Wii Fit training of patients affected by PD has shown improvement in static and dynamic balance, mobility and functional abilities [26].

This study aimed to investigate the effectiveness of a novel visual-feedback training method, using Wii Fit balance board in improving balance in patients with PD.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Jagiellonian University Medical College. All patients signed a written informed consent form. Twenty four patients (7 female 17 males) aged 68.8 ± 1.9 years (range: 43–80 years) (Table 1) with idiopathic PD, were recruited from the Outpatient Movement Disorders Unit of the Department of Neurosurgery Jagiellonian University and the Cracow Parkinson's Disease Association.

Inclusion criteria included diagnosis of idiopathic PD established according to UK Parkinson's Disease Society Brain Bank Criteria. Severity of parkinsonism was assessed using the Hoehn&Yahr scale (H&Y) [27] and Unified Parkinson's Disease Rating Scale (UPDRS) [28]. Cognitive dysfunction was evaluated by the Mini Mental State Examination (MMSE) [29]. Exclusion criteria were severe con-

Table 1

Patients characteristics.

	PD patients n = 24 7 Woman, 17 Men
Patients	Mean (SD) Min-Max
Age, years	61.8 (1.9) 43–80
Duration of the disease, years	9.21 (0.94) 3–20
Mini Mental State Examination	27.6 (1.89) 24–30
UPDRS part II before training	13.29 (0.47) 10–18
UPDRS part II after training	8.58 (0.44) 513
UPDRS part III before training	22.42 (0.63) 18–27
UPDRS part III after training	16.21 (0.69) 10–21

comitant disease, which limits physical performances and could impact gait or balance, clinically significant hearing or vision problems that may hinder the ability to hear the feedback sound, cognitive inability that limits cooperation with this system (according to Mini Mental Status Examination score <24), major depression, surgical treatment for PD.

Clinical evaluations, including a detailed history and physical examination, were performed by a movement disorder neurologist. Medical treatment was optimized prior to the study. It was aimed at keeping medication stable during the study. At least 2 month prior to–the study all patients were on a stable dose of levodopa.

The Nintendo Wii and Wii Fit game with balance board using video techniques was used for a balance training program of patients with idiopathic PD. The installation of the Wii console in the patient's home, as well as detailed instruction about the program was carried out by a physiotherapist. Furthermore, all patients received an instruction and guidelines booklet describing the exercise plan.

Eighty four sessions of up to 20 minutes of therapy per session was provided two times a day every day over a 6 week period. All sessions were scheduled to coincide with the "on period" for dopaminergic therapy.

The program of exercises consisted of 20 minutes training with Wii Fit game (using the balance board) and 20 minutes exercises with a Wii Sports game. The Wii Fit game consisted of the "Ski Slalom" and "Balance Bubble". For these exercises there is a marker on the screen that tracks the user's movement and the challenge is to keep it within a certain area to win points. The patient stood on a platform and viewed himself/herself in the VR on the television monitor and interacted in real-time with virtual objects appearing inside the virtual environment.

Wii Sports consisted of exercises on flexibility, upper and lower limb strength, motor coordination and balance. The program was identical for all patients. A motivational telephone call to each patient was made by a physiotherapist every week, and-to ensure that he/she performed training regularly and correctly. Also the patients were reminded to always train during the "on period", which means the time when their pharmacotherapy was effective.

ASSESSMENTS

- ***The Berg-Balance Scale (BBS)*** — consists of 14 different balance tasks such as standing, reaching, bending, and transferring abilities. This scale has an overall score range from: 0 points (severely impaired patient) to 56 points (excellent) [30].
- ***Tinnet's Performance-Oriented Mobility Assessment (POMA)*** — containing several static and dynamic tasks with a maximum score of 28 [31].
- ***The Timed Up-and-Go (TUG)*** — was used to assess the ability to perform a sequence of movements of functional mobility, like to stand up from a chair, walk for a distance of 3 meters at comfortable speed, turn, walk back, and sit down on the chair [32]. The time of realization was measured using a stopwatch and the average of the two trials was taken into account.
- ***The sit-to-stand test (STST)*** — in this manner, the patient was asked to stand up and sit back down on the chair as many times as possible in 30 second [33].
- ***10-Meter Walk Test (10MWT)*** — the patient was asked to walk as fast as possible for a distance of 10 m (mean of 3 trials). The mean time of reaching this goal was being measured [34].

Disease severity was measured using **Unified Parkinson's Disease Rating Scale (UPDRS)** and Hoehn and Yahr staging (H&Y). The UPDRS test was carried out by a PD specialist (trained in performing the UPDRS evaluation) at baseline (before the training program) and after completion of the training program.

The Activities-specific Balance Confidence (ABC) was used for the assessment of subjective perception of balance level and fear of falling. The ABC scale is a 16 item questionnaire that allows participants to rate their confidence when performing certain daily activities such as walking in a crowded place and picking up an object off the floor [35].

The scale is rated from 0% (no confidence) to 100% (absolute confidence).

The cognitive status for all patients was assessed by means of the Mini-Mental — State Examination (MMSE).

During the study, a physiotherapist visited and observed-at least one session of each patient. The assessments were performed at baseline (before the beginning of exercise), after 3 weeks of exercises and after 6 weeks from the initial session.

STATISTICAL ANALYSIS

In order to perform the valuable statistical data analysis both parametric (t-test for dependent variables) and nonparametric tests (Wilcoxon's test) were employed. Furthermore, to verify the normality of distribution of each variable, the Shapiro-Wilk test was carried out. In case of normally distributed variables the t-test for dependent variables was applied. Otherwise, the Wilcoxon's test was used. Overall statistical analysis was prepared by means of STATISTICA 10.0 package.

RESULTS

The results of the BBS test are shown in Figure 1. A clear improvement of the BBS scores was achieved, i.e. from 46 points before training, through 49 points after three weeks of the training to 50.5 points after six weeks of Wii Fit training. Moreover, the difference between the BBS score obtained before the training and after three weeks of the training was statistically significant at the p value much lower than 0.05. The comparable result was obtained for the BBS scores corresponding with the beginning of the study and after six weeks of the Wii Fit training. The difference between the BBS scores obtained after three weeks of the training and after the six weeks duration was also statistically significant (p = 0.0001).

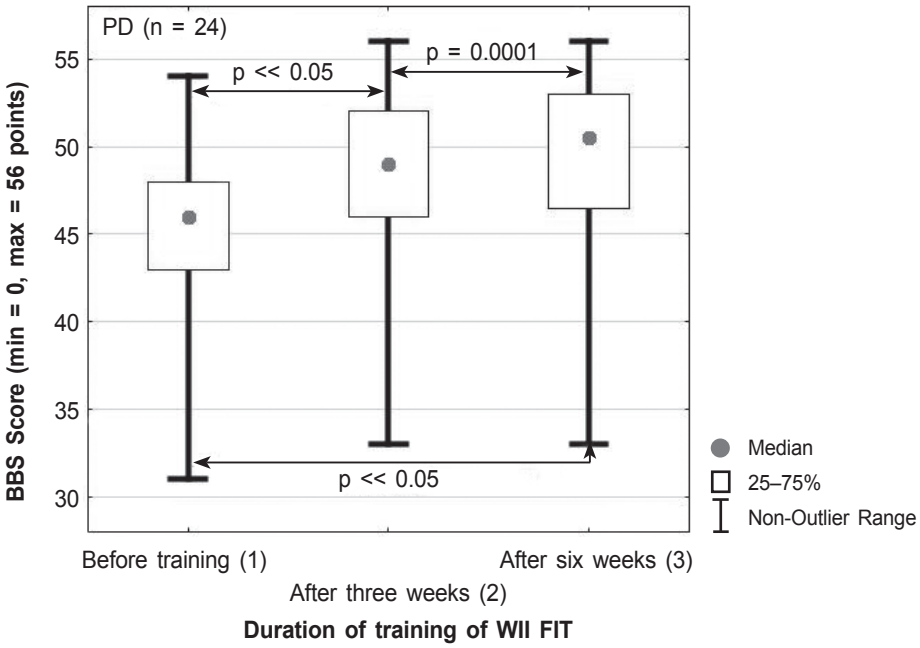

Fig. 1. Scores for PD patients on the Berg Balance Scale (BBS).

The scores for PD patients on the Tinnet's Performance Oriented Mobility Assessment are presented in Figure 2. The POMA scores change from 20 points before the training, through 22 points after three weeks of the training to 24 points after six weeks of the training Statistically differences were noticed between the POMA scores obtained before the study and after three weeks of the training as well as between the POMA results achieved at the beginning and after six weeks of the study. In both cases p value was much lower than 0.05. Statistically significant differences of the POMA scores were also found for the PD patients after three and six week's duration of the Wii Fit training (p = 0.001).

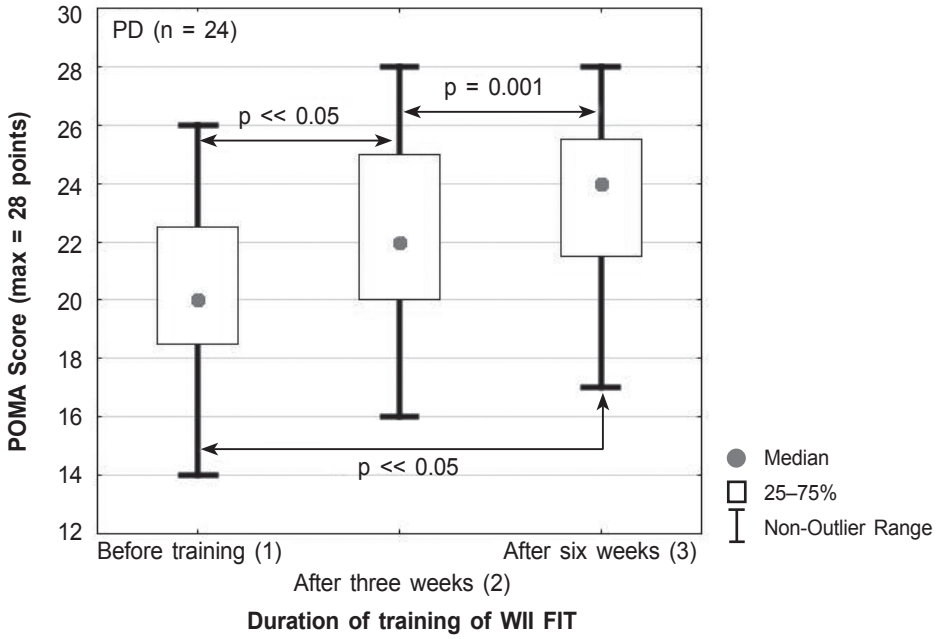

Fig. 2. Scores for PD patients on the Tinnet's Performance Oriented Mobility Assessment (POMA).

The results of the Timed- Up- and- Go test by PD patients are shown in Figure 3. At the beginning of the training the mean time to complete the TUG test by PD patients was equal to 8.14 ± 0.37 s. This score was improved to 7.38 ± 0.36 s after three weeks of the training and to 7.17 ± 0.38 s after six weeks of the training. Moreover, it was found that statistically significant differences ($p << 0.05$) are observed both between the results obtained at the beginning of the TUG test and after three weeks of the training and between the initial results and the scores obtained by PD patients after six weeks of the Wii Fi training.

The results of 10MTW test are presented in Figure 4. The 10MTW scores show that the time to complete the 10- m walk test was 4.03 s at the beginning of the study. The patients completed the 10MTW test in 3.08 s after three weeks

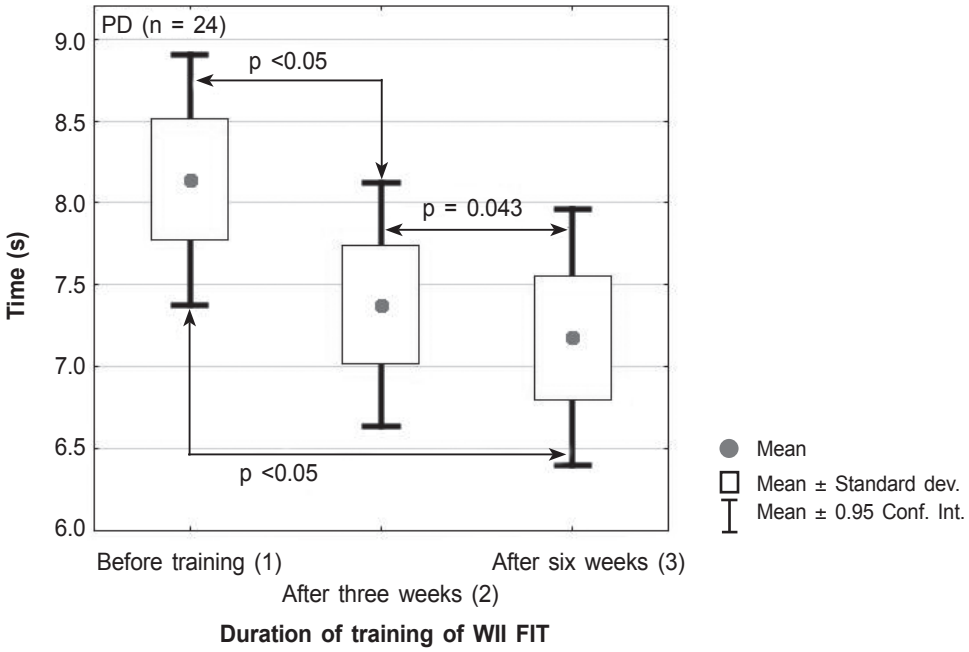

Fig. 3. Time to complete the Timed- Up- and- Go test by PD patients.

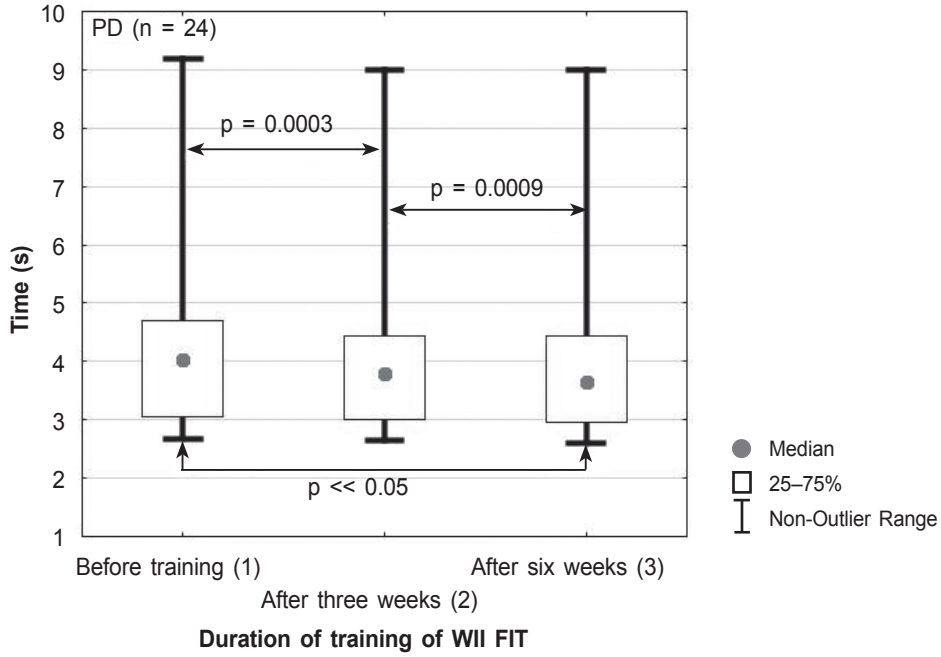

Fig. 4. Time to complete 10- m walk test by PD patients.

training and in 3.65 s after six weeks. We have also found that there exist statistically significant mutual differences between all median values. For all cases p values do not exceed 0.05.

The results of the Sit- to- Stand Test are presented in Figure 5. We have found that the number of repetitions performed by PD patients on the STST significantly increased with the duration of the training. Before the Wii Fi training the median value of the repetitions performed by PD patients on STST was equal to 11. This result improved to 12.5 repetitions after three weeks of the training and to 13.5 repetitions after six weeks. We have noticed statistically significant differences between all calculated median values for this test. Particularly, the difference between the results obtained after three and six weeks of the training was statistically significant at p = 0.06. For other cases the differences were statistically significant at p value much lower than 0.05.

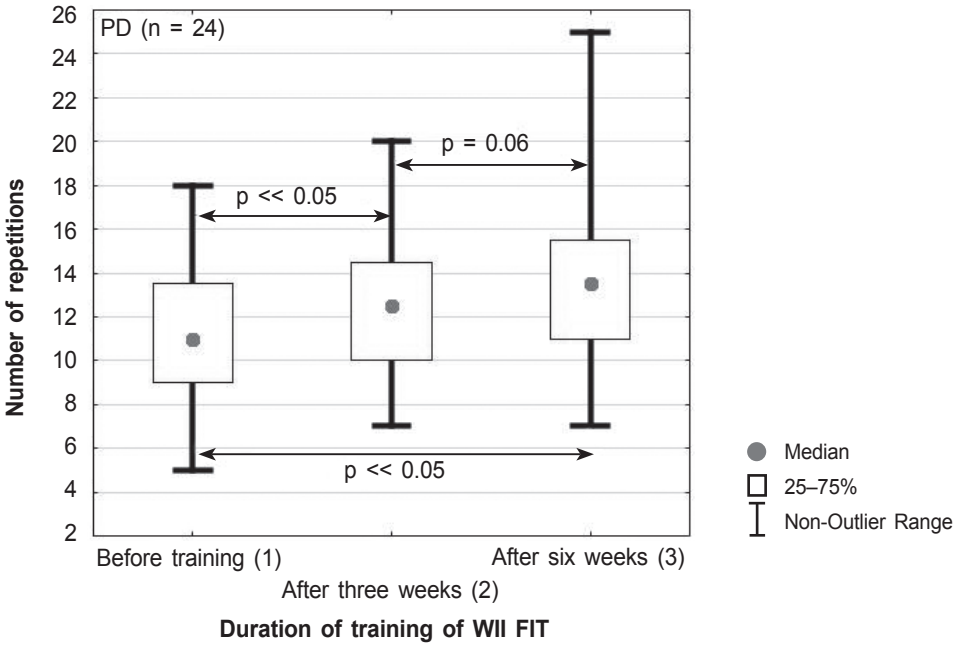

Fig. 5. Repetitions performed by PD patients on the Sit- to- Stand Test (STST).

The scores for the Activities — specific Balance and Confidence test are shown in Figure 6. An increase of the median value of the test score from 73.5% before the Wii Fi training to 80% after the training was observed. The difference was statistically significant at a very low p-level (p = 0.003).

Furthermore, the scores of UPDRS (part II) Activity of Daily Living were analyzed and are presented in Figure 7a. Mean value of the UPDRS (part II) scores was equal to 13.29 ± 0.47 before and 8.58 ± 0.44 after the training. The differ-

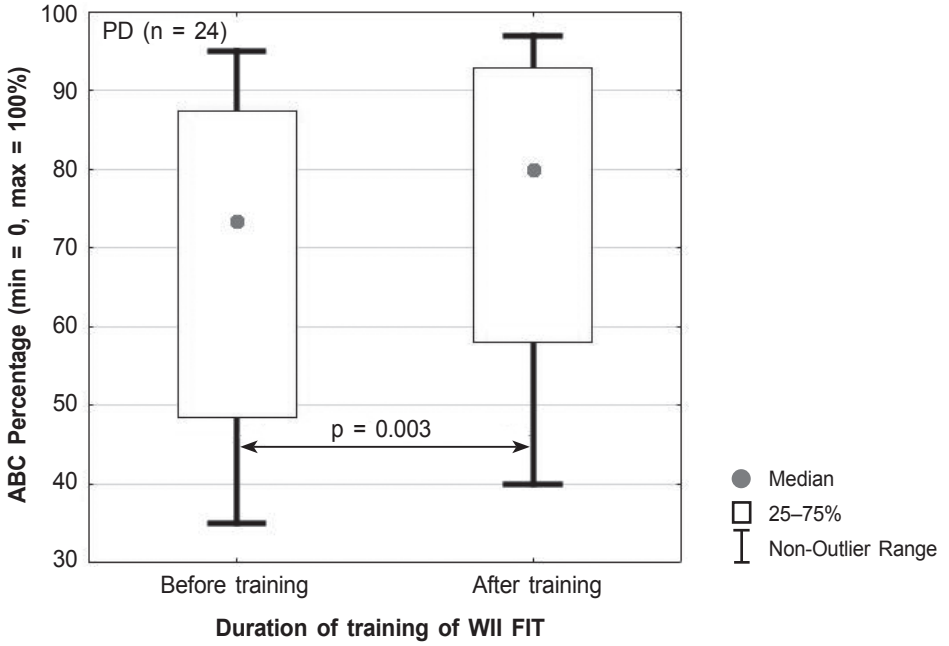

Fig. 6. Scores for the Activities — specific Balance and Confidence (ABC) (Assessment of subjective perception of balance).

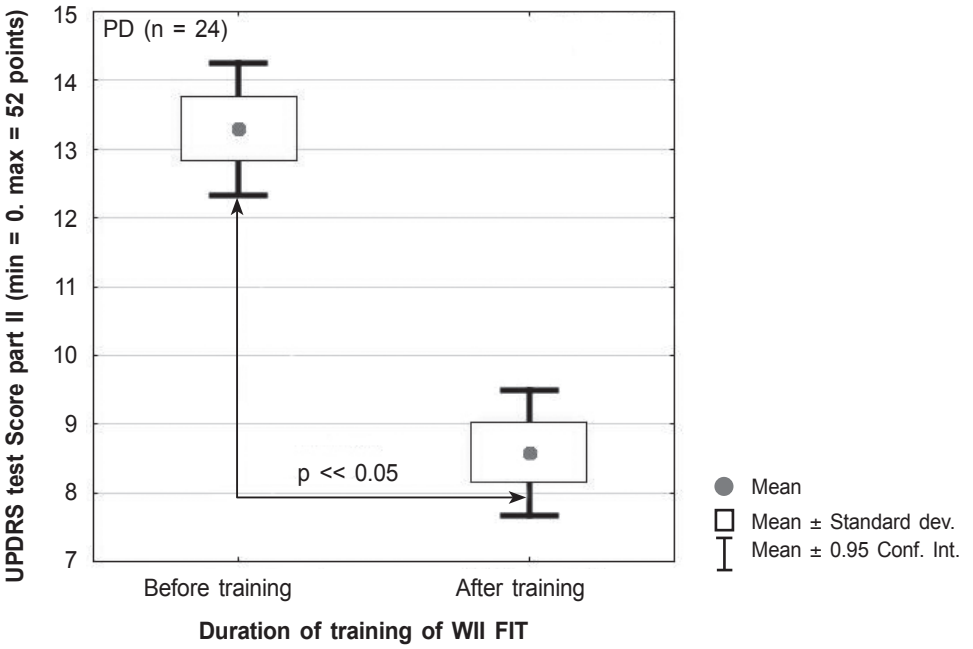

Fig. 7a. Scores for UPDRS (part II) Activity of Daily Living.

ence between both scores was statistically significant ($p < 0.05$). For the UPDRS (part III) Motor Examination the median values changed from about 23 points before the study to about 17 points after the Wii Fi training (Fig. 7b). For both UPDRS tests the differences between the initial and final scores was statistically significant, i.e. p values were much lower than 0.05.

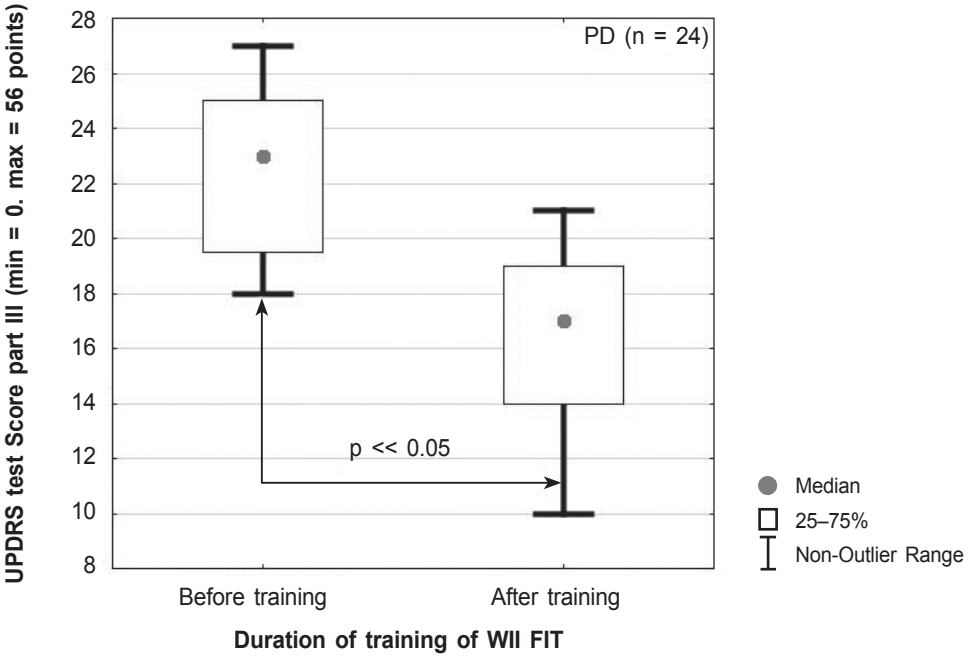

Fig. 7b. Scores of parkinsonism according to UPDRS part III Motor Examination.

DISCUSSION

The results of this study revealed that all training programmes provided some benefits for PD patients. All individuals demonstrated an improvement in dynamic and functional balance aspects, as shown in Figures 1–7. Statistical data analysis suggests that the whole training may influence dynamic balance, functional abilities as well as patient's mobility.

The improvement in the BBS, POMA and TUG provide indications of the increased balance and functional mobility of PD patients. The median values of the TUG test score were below 7.17 s after six weeks of the physical training. According to the mean decreased time to complete the TUG (2.11 s, median 1.9 s) this is a notable change .Our mean values for TUG time were quite a bit higher that those reported by Steffen and Seney as clinically significant (minimal detectable change is 2–5 s for PD patients) [36]. The TUG test combines sequential motor

actions. These motor actions require components of functional capacity such as strength, flexibility, and agility. Similarly, the higher number of repetitions observed on STST suggest that the Wii Fit programme improved not only balance, but also functional strength of the lower limbs [33]. Our mean values of Berg's BBS post training program was close to 50.5 points.

Also changes to the ABC scale were significant. PD patients reported increased balance and stability, and reduced fear of falling. Consequently, they have higher scores on UPDRS (II part) scale.

Although changes to the 10-m walking test were not clinically significant [36], PD patients increased their performance walking speed by 0.20 m/s. This change indicates that all training sessions improved mobility, fitness and dynamic balance [37].

In this study, we found a clinical relevant improvement on the UPDRS score. Schrag et al. [38] have shown that a reduction of the UPDRS motor scale by 5 points is clinically relevant. Neurological symptoms rarely served as outcome measures for exercise programmes, and only a few studies found significant improvement of motor disability compared to baseline [39].

Very few studies have assessed the effect of Wii Fit programme on PD. Recently a pilot study suggest that a home based balance program using Wii Fit with balance board could improve static and dynamic balance, mobility and functional abilities in PD patients [26].

We demonstrated that Wii Fit training in patients with PD is feasible and that it appears to be well accepted. All patients reported satisfaction and enjoyment during the training programme. Patients commented that they felt comfortable during the home session and they could foresee a need for such training in the future. Patients also reported improved mood after training which was visible according to ABC.

It has been suggested that a restricted range of motion of axial structures might contribute to loss of postural control and gait impairment [40]. Several studies have shown that physical exercises designed to improve axial range of motion were shown to improve functional reach distance. This might explain that improvement of balance was observed in all patients.

According to Esculier et al. [26] the hypothesis for the good results achieved using Wii Fit is that its exercise programme offers a rich environment of sensory impulse combining visual, auditory and proprioceptive feedback. It may also provide PD patients more ways to enhance attention and focus on the required moves in the game by the stimulation of the motor, oculomotor, cerebellar and limbic loop [40]. Visual feedback is enhanced by the signal sent from the proprioceptive system depending on weight shifting on the balance board during the game. Also, there may be the activation of the reward circuitry and releasing of dopamine in the ventral striatum by the results obtained in the game as well as the expectation of clinical benefits [41].

In recent years there is growing evidence that central mechanisms play an important role contributing to beneficial effects of physical exercise. Experimental and clinical studies indicate that physical exercise enhances brain plasticity [42]. Physical activity modifies the release of dopamine and dopamine turnover and enhances the release of brain-derived neurotrophic factor (BDNF). BDNF improves neural plasticity and promotes axon outgrowth and development of synapses [43].

Training with the Wii device teaches participants new strategies of movement that could be applied in real life situations. A limitation of this study is the small group of patients. Future studies should include a larger group of patients and compare them to an active control group. The absence of follow-up evaluation should also be noted as a limitation of this study.

In conclusion the results presented here demonstrate that Wii Fit training for balance in PD is associated with quantitative improvements. This study suggest that programmes aimed at improving or slowing the deterioration of balance and mobility should consider visual feedback training using Wii Fit in PD. Training with the Wii Fit may provide this needed addition to the pharmacological treatment of PD patients.

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[1] Higher Vocational State School
Health Care Institute
ul. Mickiewicza 8, 33-100 Tarnów, Poland

[2] Department of Neurosurgery
Jagiellonian University Medical College
ul. Botaniczna 3, 31-503 Kraków, Poland

[3] Faculty of Physics and Applied Computer Science
AGH University of Science and Technology
al. Mickiewicza 30, 30-059 Kraków, Poland

[4] Department of Dental Diseases
Jagiellonian University Medical College
ul. Montelupich 4, 31-155 Kraków, Poland

[5] Department of Neurology
Jagiellonian University Medical College
ul. Botaniczna 3, 31-503 Kraków, Poland

Corresponding author:
Anna Krygowska-Wajs
krygowska@neuro.cm-uj.krakow.pl