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Original Article

Virtual Reality-Based Wii Fit Training in Improving Muscle Strength, Sensory Integration Ability, and Walking Abilities in Patients with Parkinson's Disease: A Randomized Control Trial☆

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SUMMARY

Background: Virtual reality (VR) systems have been proven to increase motor performance in stroke and elderly patients. However, the effects have not been established in patients with Parkinson's disease (PD). The aim of this study was to examine the effects of VR-based training in improving muscle strength, sensory integration ability, and walking abilities in patients with PD through a randomized controlled trial.
Methods: Thirty-six individuals who have been diagnosed with PD were randomly assigned to one of three groups ($n = 12$ for each group). Participants performed VR-based Wii Fit exercise (VRWii group) or traditional exercise (TE group) for 45 minutes, followed by treadmill training for another 15 minutes for 12 sessions in 6 weeks. Participants in the control group did not undergo the structured exercise program, but received fall-prevention education instead. The study outcomes included lower extremity muscle strength, sensory integration ability, walking velocity, stride length, and functional gait assessment. All outcomes were assessed at baseline, after training, and at 1 month follow-up.
Results: Both the VRWii and TE groups showed more improvement in level walking velocity, stride length, functional gait assessment, muscle strength, and vestibular system integration compared with the control group after training and at 1 month follow-up. The VRWii training, but not the TE training, resulted in greater improvement in visual system integration than the control.
Conclusion: VRWii training is as beneficial as TE in improving walking abilities, sensory integration ability, and muscle strength in patients with PD, and such improvements persisted for at least for 1 month. VRWii training is thus suggested to be implemented in patients with PD.

1. Introduction

With the progression of Parkinson's disease (PD), patients may develop a festinating gait with decreased gait speed and stride length in level walking. The slow walking speed and reduced stride length limit the independence and quality of life of these patients. In addition, PD patients also showed impairments in functional walking tasks such as turning, obstacle crossing, and stair climbing. The impairments in level walking and functional walking can lead to a fall. It has been reported that more than two-thirds of community-dwelling individuals with PD experience falls once per year[1]. Therefore, improvement of walking abilities is recognized as an important goal of treatment. Previous studies stated that muscle strength correlated with gait velocity, stride length, and functional ambulation ability[2]. Reduced muscle power is associated with slower walking velocity and falls[3]. In addition to muscle strength, impaired central integration of vision, somatosensation, and vestibular systems are reported in patients with PD[4]. These deficits in integrating sensory inputs contribute to postural instability and decreased gait performance[5]. Previous studies further stated that deficit in sensory integration ability correlated with freezing of gait, turning deficit, and unstable obstacle crossing performance[6].

☆ Conflicts of interest: The authors have no conflicts of interest to declare.

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Traditional exercises (TEs), such as stretching, strengthening, balance exercise, and treadmill training, are found to improve muscle strength, balance, gait performance, and motor function in patients with PD[7,8]. Virtual reality (VR) training has been used in elderly and stroke patients to improve postural control and mobility because of the interaction with a computer-generated scenario[9,10]. Recently, the gaming industry has developed a variety of affordable and accessible VR systems such as Wii Fit. Wii Fit balance board detects the user's body movements to transform a specific action in the game, thus providing a visual feedback to the user in real time. Some studies reported that Wii Fit training can exert beneficial effects on functional activities, balance, quality of life, and Unified Parkinson's Disease Rating Scale in PD patients[11]. However, whether such training can also exert beneficial effects in muscle strength, sensory integration ability, and walking ability in patients with PD is not immediately known.

Therefore, the purpose of this study was to establish the effects of VR-based Wii Fit exercise (VRWii) on improving muscle strength, sensory integration ability, and walking abilities by comparing the TE and the control groups. Our results can provide suggestions for the possible use of VRWii training for patients with PD.

2. Materials and methods

2.1. Participants

Participants were recruited from medical centers in Taiwan and were diagnosed with idiopathic PD by a neurologist. The diagnostic criteria were as follows: (1) at least two of the following features were present: resting tremor, bradykinesia, rigidity, and asymmetric onset; and (2) at least one feature was tremor or bradykinesia. All participants met the following inclusion criteria: (1) Hoehn and Yahr Stages I–III, (2) ability to walk independently without any walking aids, (3) stable medication usage, (4) with or without deep brain stimulation, and (5) a score of 24 or higher in the Mini-Mental State Examination. The exclusion criteria were as follows: (1) unstable medical condition; (2) history of other neurological, cardiopulmonary, or orthopedic diseases known to interfere with the study; and (3) use of cardiac pacemaker. A total of 43 individuals were identified as potential participants for this study. Of these, 36 participants provided informed consent. This study was approved by the Institutional Human Research Ethics Committee of Chang Gung Medical Foundation, Linkou, Taiwan (Figure 1).

2.2. Experimental design

This study was designed as a single-blinded, stratified, randomized controlled trial. The participants were stratified using the Hoehn and Yahr scale: Stages 1–1.5, Stages 2–2.5, and Stage 3. An individual independent of the study selected one of a set of sealed envelopes to assign participants to the VRWii group, TE group, or control group prior to the intervention. Participants in the VRWii group performed 45 minutes of VRWii exercise followed by 15 minutes of treadmill training. Participants in the TE group performed 45 minutes of TE followed by 15 minutes of treadmill training. Participants in the control group, who did not undergo a structured exercise program, received fall-prevention education. The exercise programs were administered for a total 12 sessions (2 sessions per week) over a 6-week period. All outcomes were measured the day prior to the intervention (pre), the day after completing the intervention (post), and the 30th day after completing the intervention (follow-up) by a physical therapist blinded to the group assignment. The measurement and intervention were conducted with the patients in the “on” state when they were moving freely and easily without excessive rigidity or tremor.

2.3. Sample size and power calculation

GPower 3.1 was used to calculate the sample size and statistical power. Sample size was calculated by a given α error (0.05), power ($1 - \beta$ error $= 0.8$), and effect size (calculated by mean and standard deviation of the variables). Statistical power was calculated by effect size, α error, and sample size.

2.4. Interventions

2.4.1. VRWii exercise

The Wii Fit Plus gaming system and Wii Fit balance board (Nintendo Phuten Co., Ltd, Taipei, Taiwan) were used for VRWii exercise. The Wii Fit balance board is a novel system that tracks changes in the center of pressure during an exercise game. A virtual environment was displayed on a 230-cm (width and height) screen in front of the participant. Through avatar technology, images were projected on the screen through a projector. The virtual character provides instantaneous visual or auditory feedback. Participants can initiate the virtual character and adjust their own movements according to the feedback in real time. At the end of the game, the Wii Fit system also provides the total score on the screen. In each Wii Fit exercise session, participants underwent 10 minutes of yoga exercise, 15 minutes strengthening exercise, and 20 minutes of balance game.

(1) *Yoga exercises*. The yoga exercises were a combination of stretching, strengthening, and balance exercises. The yoga program includes sun-salutation modified lunges, chair pose, tree pose, and table top in standing position.
(2) *Strengthening exercises*. This exercise program was similar to that in the TE group but set in a VR-based environment. Ankle weights for each leg were also used, starting from 1 kg and gradually increased to 2 kg for each leg.
(3) *Balance games*. The balance games included the football game, marble balance, ski slalom, and balance bubble. When performing these games, participants needed to shift their COM as quickly and accurately as possible to hit the football, make the rolling marble in the hole, ski without hitting the obstacles, and navigate the bubble through the maze without popping it.

2.4.2. TE

The TE program included 10 minutes of stretching exercises, 15 minutes of strengthening exercises, and 20 minutes of balance exercise training in each session.

(1) *Stretching exercises*. The stretching exercise focused on the upper body and the upper and lower extremities with gentle joint extension and flexion and trunk rotation in a standing position. Deep breathing was emphasized during the exercise.
(2) *Strengthening exercises*. The strengthening exercise focused on the lower extremity muscles that are important for posture, balance, and gait. Participants performed exercises including bilateral alternate: (i) hip and knee flexion/extension, (ii) forward/sideward steps, (iii) heel and toe raises, and (iv) squatting. Participants performed three sets of 10–15 repetitions for each activity. Ankle weights for each leg started from 1 kg and gradually increased to 2 kg for each leg. Natural breathing was emphasized during the exercise.