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ORIGINAL ARTICLE

Home-based virtual reality balance training and conventional balance training in Parkinson's disease: A randomized controlled trial

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balance training;
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Background/Purpose: Virtual reality has the advantage to provide rich sensory feedbacks for training balance function. This study tested if the home-based virtual reality balance training is more effective than the conventional home balance training in improving balance, walking, and quality of life in patients with Parkinson's disease (PD).
Methods: Twenty-three patients with idiopathic PD were recruited and underwent twelve 50-minute training sessions during the 6-week training period. The experimental group ($n = 11$) was trained with a custom-made virtual reality balance training system, and the control group ($n = 12$) was trained by a licensed physical therapist. Outcomes were measured at Week 0 (pretest), Week 6 (posttest), and Week 8 (follow-up). The primary outcome was the Berg Balance Scale. The secondary outcomes included the Dynamic Gait Index, timed Up-and-Go test, Parkinson's Disease Questionnaire, and the motor score of the Unified Parkinson's Disease Rating Scale.
Results: The experimental and control groups were comparable at pretest. After training, both groups performed better in the Berg Balance Scale, Dynamic Gait Index, timed Up-and-Go test, and Parkinson's Disease Questionnaire at posttest and follow-up than at pretest. However, no significant differences were found between these two groups at posttest and follow-up.

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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Conclusion: This study did not find any difference between the effects of the home-based virtual reality balance training and conventional home balance training. The two training options were equally effective in improving balance, walking, and quality of life among community-dwelling patients with PD.

Introduction

Patients with Parkinson's disease (PD) demonstrate progressive impairments in balance and walking function.[1] In standing, patients exhibit delayed, reduced postural response to regain stability from balance disturbances. In walking, patients take small, shuffling steps with increased stride-to-stride variability.[2] The impaired balance and walking function increase the patients' fall risk and have a substantial impact on their quality of life.[3]

In the recent decade, virtual reality (VR) has become generally accepted as a therapeutic tool for neurological patients to interact with simulation from the environment via multiple sensory channels.[4,5] VR training can be applied using commercially available devices (e.g., Wii with balance board) or the prototype developed by the researchers,[6] such as Esculier et al[7] using Wii Fit with a balance board for 6 weeks of home-based balance training in patients with PD. Their results indicated that Wii Fit with VR programs could improve the static balance (i.e., one-leg stance), dynamic balance (i.e., center of pressure weight shift), mobility (i.e., timed Up-and-Go test, TUG), and functional abilities (i.e., Community Balance and Mobility scale) of patients with PD. However, they only recruited 11 PD patients and nine healthy controls without randomization. Pompeu et al[8] investigated the effect of 7 weeks of Nintendo Wii-based motor cognitive training versus balance exercise therapy in patients with PD via a randomized controlled trial, with the training taking place at the Brazilian Parkinson Association. The results indicated both groups showed a significant improvement on the Berg Balance Scale (BBS), Unipedal Stance Test (with open and closed eyes), and Montreal Cognitive Assessment after training, and the effects were maintained at follow-up (i.e., 60 days).[8] However, no group effect (Wii vs. exercise) was found. Thus far, it is still unclear how effective home-based VR balance training is compared to conventional balance training.

Hsieh et al[9] reported that patients with PD were impaired on tasks with internal cues but performed normally on tasks with external cues. Furthermore, an external visual cue was commonly used to compensate for impaired kinesthetic feedback and attentional processing to bypass the deficit of internal cueing.[10] It was suggested that VR could provide the visual and/or cognitive cues to facilitate motor learning, retention, and transfer in patients with PD.[11] Thus, the aim of the present study was to examine the effect of our developed prototype VR balance training for patients with PD living at home. The research hypotheses of this study are: (1) VR balance training can improve balance and other related tasks and (2) the VR balance training might be superior to conventional balance training in patients with PD living at home.

Methods

Participants

Community-dwelling patients with idiopathic PD based on the UK Parkinson's Disease Society Brain Bank criteria[12] were recruited from the neurological department of a university-based medical center. The inclusion criteria were (1) age 55–85 years; (2) intact cognitive function (Mini-Mental State Examination score > 24)[13]; (3) Hoehn–Yahr Stages II–III; (4) not engaged in balance or gait training in the past 6 months; (5) no untreated medical conditions (e.g., knee arthritis) that might affect balance and walking function. The exclusion criteria were those with untreated depression or underlying significant visual/auditory impairments. The informed consent form approved by the center's research ethics committee was signed by all participants prior to physical screening.

Procedure

The trial was registered on ClinicalTrials.gov (identifier: NCT01301651) and the CONSORT (Consolidated Standards of Reporting Trials)-type flow diagram is shown in Figure 1. Eligible participants were assigned to the experimental or control group using a dynamic randomization algorithm written in MATLAB (version 7.10.0; The Mathworks Inc., Natick, MA, USA).[14] All participants received twelve 50-minute sessions of balance training, twice per week for 6 weeks. The training of the experimental and control groups was conducted separately by two physical therapists. The pretest (Week 0), posttest (Week 6), and follow-up (Week 8) assessments were conducted by an independent assessor who was blinded to the group allocation. Participants underwent the three assessments during their medication ON period (1 hour after drug intake), and it took 40–60 minutes to complete all measurements.

VR balance training system

As shown in Figure 2, the VR balance training system included a 22-inch all-in-one touchscreen computer (Micro-Star International Co., Ltd., New Taipei City, Taiwan) and a wireless balance board. The VR balance training system was developed by the Cycling and Health Center of Taichung, Taichung, Taiwan. The balance board measured the center of pressure by embedded load cells, and transmitted the signals wirelessly to the computer via Bluetooth. The center of pressure was used for controlling the virtual objects (e.g., a virtual car or human avatar) in the VR software. The sensitivity of the balance board could be set to different

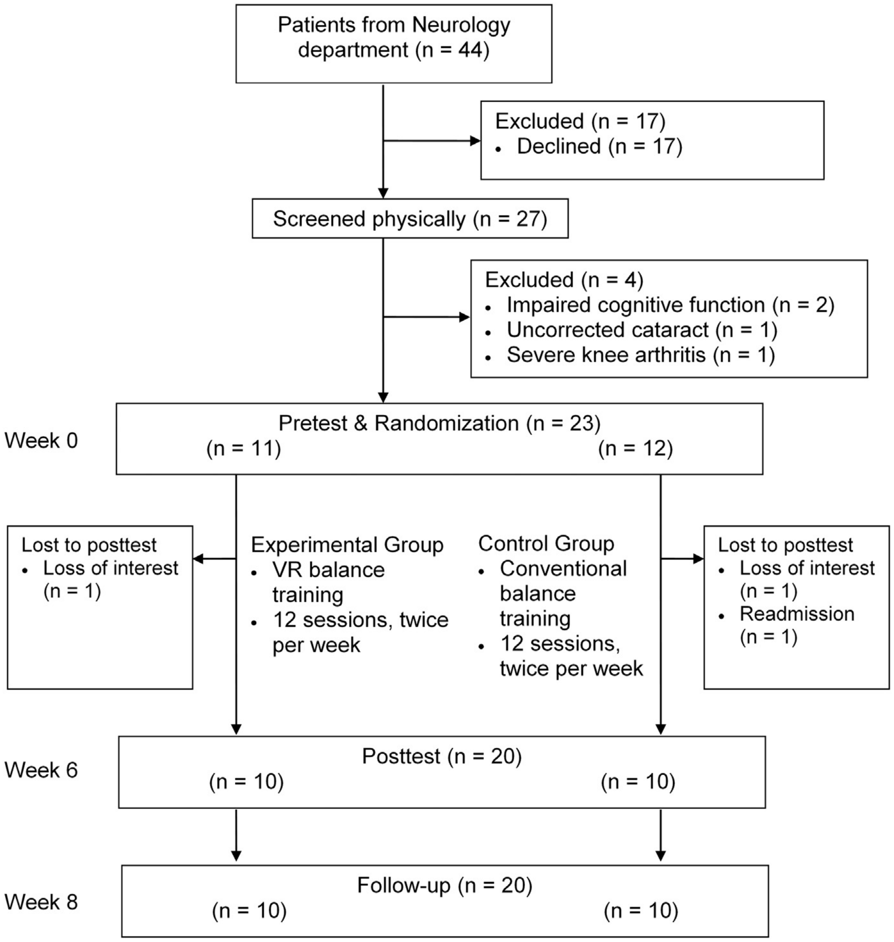

Figure 1 Design and flow of participants through the study.

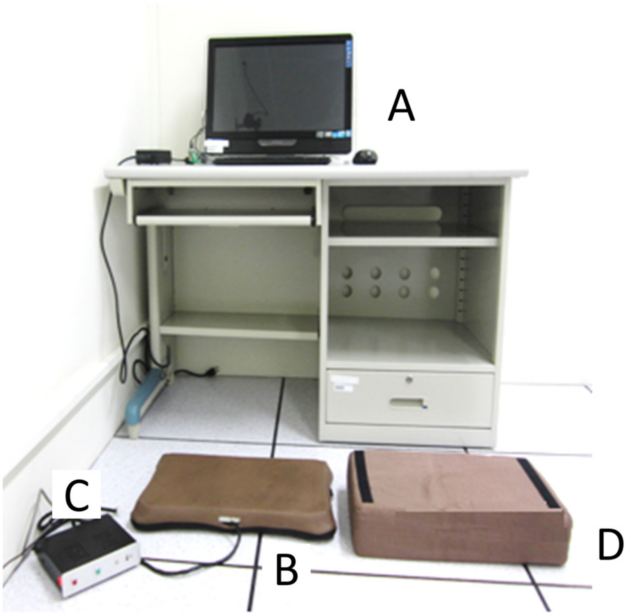

Figure 2 The virtual reality (VR) balance training system includes (A) an all-in-one touchscreen computer, and (B) a balance board with a (C) receiver box to trigger the balance board. (D) A spongy foam could be placed on top of the balance board to add extra training difficulty.

levels to modify the training difficulty. For example, moving a virtual object would be easy when the sensitivity was set to high, and vice versa. The VR software had three programs: *basic learning*, *indoor daily tasks*, and *outdoor daily tasks* (Table 1, Figure 3). The basic learning program helped users get familiar with the VR training system through gaming tasks such as a ball maze. The indoor and outdoor programs simulated daily tasks in indoor and outdoor environments respectively.

Training protocol

Overview

The training programs in both the experimental and control groups aimed to improve weight shift control. All 12 training sessions (50 minutes per session, for 6 weeks) were conducted during the medication ON period at the participants' home. Each session included a 10-minute warm-up stretching, three 10-minute blocks of balance training, and two 5-minute breaks between blocks.

VR balance training

In the experimental group, training was conducted with the VR balance training system. In each session, participants practiced the static posture maintaining (10 minutes) and dynamic weight shifting (2 × 10-minute blocks; Appendix

Table 1 Tasks of the virtual reality balance training system.

Program	Task name	Task type	Task description
Basic learning	Star excursion	Static posture maintaining	Stand on the balance board. Control the virtual ball to roll into the target area by leaning body to the specified extent, and maintain that posture for 5 s.
	Ball Maze	Dynamic weight shifting	Stand on the balance board. Control the virtual ball to escape from the maze by shifting body weight.
	Table tilt	Dynamic weight shifting	Stand on the balance board. Control the tilt of a virtual board by shifting body weight. The task is to make all balls on the tilting board to fall into the hole on the board, not fall out of the board.
Indoor	Home Yoga	Static posture maintaining	Stand on the balance board. Control the virtual character to do Yoga exercise by leaning body to the specified extent, and maintain that posture for 5 s.
	Cooking	Dynamic weight shifting	Standing on the balance board. Control the virtual character to add flavoring by shifting body weight.
	Cloth washing	Dynamic weight shifting	Standing on the balance board. Control the virtual character to collect laundries by shifting body weight.
Outdoor	Car racing	Dynamic weight shifting	Stand on the balance board. Control the virtual car to cruise around the streets by shifting body weight.
	Park walking	Dynamic weight shifting	The balance board is placed in front of the user. Control the virtual character to walk around the park by alternatively stepping onto the balance board.
	Apple catching	Dynamic weight shifting	Standing on the balance board. Control the virtual basket to catch the falling apples by shifting body weight.

1). The indoor and outdoor tasks were designed to simulate daily activities. The sensitivity of the balance board was adjusted (static posture maintaining tasks: low to high; dynamic weight shifting tasks: high to low) to increase training difficulty, and reset to default value every three sessions as a foam/manipulative task was added. The therapist in the experimental group guided warm-up stretching and supervised for safety.

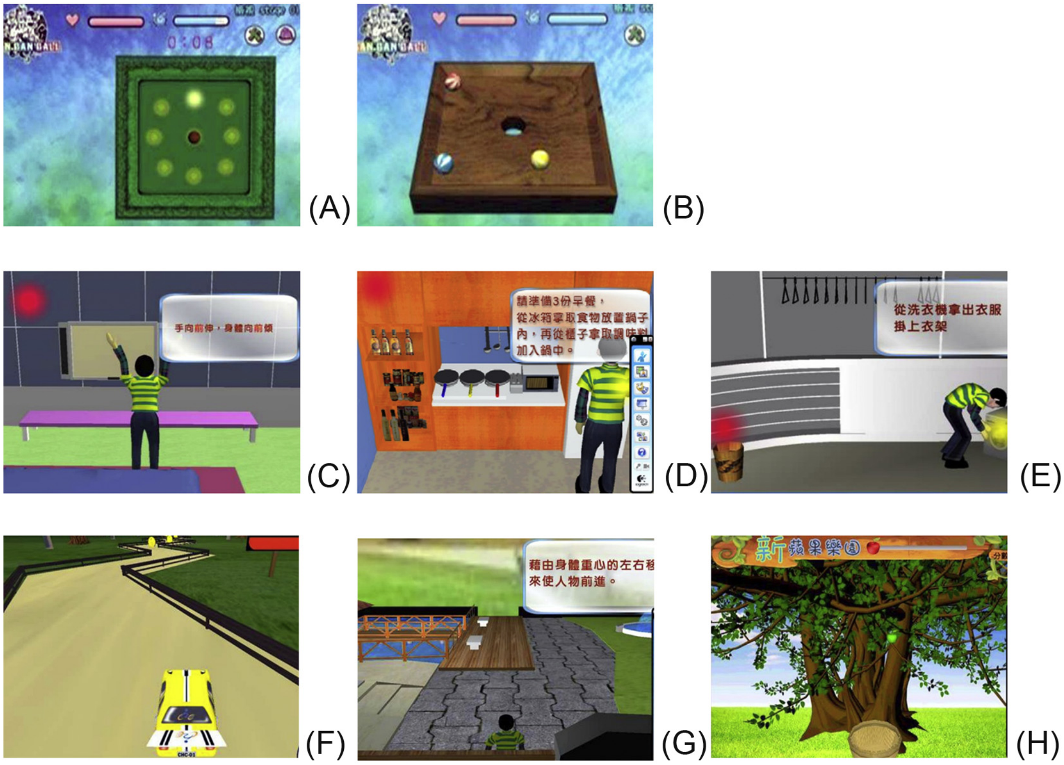

Figure 3 Tasks of the virtual reality (VR) software: (A) Star excursion, (B) Table tilt, (C) Home Yoga, (D) Cooking, (E) Cloth washing, (F) Car racing, (G) Park walking, and (H) Apple catching.

Conventional balance training

In the control group, training was conducted under the instruction of a therapist. In each session, participants practiced the static posture maintaining (10-minute block) and dynamic weight shifting (2 × 10-minute blocks; Appendix 2). The therapist in the control group guided the training and provided verbal instructions to correct the participants' movements.

Outcome measures

The primary outcome in this study was the BBS. The BBS is a 14-item performance-based balance measure with scores ranging from 0 to 56. The BBS score is moderately associated with motor deficits and capacity of activity of daily living, with a higher score indicating better balance function.[15]

The secondary outcomes included the Dynamic Gait Index (DGI), the TUG test, the 39-item Parkinson's Disease Questionnaire (PDQ-39), and the motor score of the Unified Parkinson's Disease Rating Scale (UPDRS-III). The DGI is an 8-item tool used to rate a patient's stability during adaptive walking tasks. The DGI scores range from 0 to 24, with a higher score indicating better walking function.[16] The TUG measures the patient's functional mobility with a consecutive sit-to-stand, walking, turning, and stand-to-sit movements, where a shorter completion time indicates better functional mobility.[17] The PDQ-39 is a self-report questionnaire that uses a 5-point Likert scale to grade the quality of life, including severity of symptoms in mobility, activities of daily living, emotional well-being, stigma, social support, cognitions, communication, and bodily discomfort.[18] The PDQ-39 summary index was rescaled to 0—100, with a higher score indicating a poorer quality of life. Finally, we measured the severity of motor deficits using the motor score of UPDRS.[19] The motor score measures the deficits in speech, facial expression, tremor, rigidity, limb coordination, mobility, gait, and postural stability. The motor scores range from 0 to 108, with higher scores indicating more severe deficits.

Data analysis

The calculation of the sample size was based on the BBS. We sought a difference between the two groups of five on BBS (score from 0 to 56), and the variance was set to 25.[20] Power analysis showed that 13 patients in each group were needed as the statistical power at 0.7 and significance level at 0.05. The intention-to-treat analysis with the last observation carried forward method was used to treat the data of the dropout participants.[21] That is, the values of posttest and follow-up for the dropout participants were substituted by the values at pretest.

To account for the dependency of the observations in time, generalized estimating equations with a longitudinal linear regression technique were used to analyze the treatment effects at posttest and follow-up. Generalized estimating equations were used because of the dependency of observations across time within participants and because the time frames between pretest and posttest and between posttest and follow-up were not equal. The levels of the group factor and time factor were two (experimental and control) and three (pretest, posttest, and follow-up) respectively. Pairwise comparisons with least significant difference adjustment were conducted if the time main effect or group × time interaction reached significance level ($p < 0.05$). All statistical calculations were conducted using SPSS (version 17; SPSS Inc., Chicago, IL, USA).

Results

Participants

Forty-four patients were contacted and 27 of them were physically screened between March 2011 and July 2011. Twenty-three patients were enrolled and randomized into the experimental ($n = 11$) or control ($n = 12$) group. One experimental participant and two control participants dropped out during the intervention period (Figure 1). One participant in the experimental group stopped (at the 4th session) because she preferred conventional balance training. One participant in the control group stopped (at the 8th session) because of personal reasons. The baseline characteristics of the participants are shown in Table 2.[31,32] No participants reported a change in drug prescription during the 8-week study period.

Effect of intervention

Table 3 shows all the outcome measures at pretest, posttest, and follow-up (mean and standard deviation), as well as the within-group differences (mean difference and standard deviation) and between-group differences (mean difference and 95% confidence interval). In the primary outcome, the BBS, a significant time main effect ($p < 0.001$) was found despite the group main effect ($p = 0.893$) and group × time interaction ($p = 0.786$) not being significant. In the secondary outcomes of walking function, the DGI and TUG, a significant time main effect (DGI, $p < 0.001$; TUG, $p < 0.001$) was found despite the group main effect (DGI, $p = 0.970$; TUG, $p = 0.684$) and group × time interaction (DGI, $p = 0.614$; TUG, $p = 0.955$) not being significant. In the quality of life, the PDQ-39, a significant time main effect ($p = 0.007$) was found despite the group main effect ($p = 0.762$) and group × time interaction ($p = 0.806$) not being significant. In the motor deficits, the UPDRS-III, none of the time main effect ($p = 0.345$), group main effect ($p = 0.345$), and group × time interaction ($p = 0.121$) were significant.

Pairwise comparisons between pretest, posttest, and follow-up showed that BBS and DGI at posttest and follow-up were significantly higher than at pretest in the VR and control groups ($BBS_{posttest} > BBS_{pretest}$, $p = 0.001$; $BBS_{followup} > BBS_{pretest}$, $p = 0.003$; $DGI_{posttest} > DGI_{pretest}$, $p < 0.001$; and $DGI_{followup} > DGI_{pretest}$, $p < 0.001$). In addition, TUG and PDQ-39 at posttest and follow-up were significantly lower than at pretest in the VR and control groups ($TUG_{posttest} < TUG_{pretest}$, $p = 0.001$; $TUG_{followup} < TUG_{pretest}$, $p = 0.001$; $PDQ\text{-}39_{posttest} < PDQ\text{-}39_{pretest}$, $p = 0.047$; and $PDQ\text{-}39_{followup} < PDQ\text{-}39_{pretest}$, $p = 0.022$). In summary, both the VR and control groups showed improved balance, walking, and quality of life after

Table 2 Baseline characteristics of participants ($n = 23$).

Characteristic	Randomized ($n = 23$)		Lost to posttest & follow-up ($n = 3$)	
	Experimental ($n = 11$)	Control ($n = 12$)	Experimental ($n = 1$)	Control ($n = 2$)
Participants				
Age (y)	72.5 ± 8.4	75.4 ± 6.3	83	70 ± 9.9
Sex (female/male)	4/7	5/7	1/0	1/1
Disease duration (y)	9.4 ± 3.6	8.3 ± 4.1	12	10.6 ± 3.2
Hoehn—Yahr scale	3 (3, 3)	3 (3, 3)	3 (—)	3 (3, 3)
MMSE	27.5 ± 4.0	27.2 ± 2.5	29 (—)	27.0 ± 2.7
Berg Balance Score < 40[a]	2	2	0	1
Dynamic Gait Index < 19[b]	4	4	0	1

Statistics are presented as mean ± SD or median (interquartile range).
MMSE = Mini-Mental State Examination; SD = standard deviation.
[a] Number of participants with Berg Balance Scale < 40 at pretest, a criterion for assisted walking.[31]
[b] Number of participants with Dynamic Gait Index < 19 at pretest, a criterion for gait instability and fall.[32]

training, and the effects were retained in the follow-up phase. However, no significant differences were found between the two groups on any outcome measure at any assessment point.

Discussion

Most studies related to VR application in patients with PD indicated that VR positively affected movement velocity and time, balance, gait, postural control, and upper extremity functions, compared to healthy controls.[8,22] This was the first study to compare home-based VR balance training and conventional home balance training in community-dwelling patients with PD. The results of the present study supported our research hypothesis that VR balance training could improve balance and other related tasks with retention and transfer effects, except the UPDRS-III. Similar results were reported in previous studies, where UPDRS-III demonstrated smaller changes than the mobility measures.[23,24] It was possible that the UPDRS-III included items other than balance and walking function, thus making UPDRS-III less responsive to the effect of balance training.

We hypothesized that home-based VR balance training was superior to conventional balance training in improving balance and walking function. However, the results showed that the experimental and control groups had comparable improvements in balance and walking function after training. One possible explanation for this was that the two programs used the same design rationale, thus leading to similar training effects. This notion was supported by Baltaci et al,[25] who reported that Wii Fit training and conventional exercise training had the same effect on muscle strength, dynamic balance, and functional performance for patients after anterior cruciate ligament reconstruction. It was also possible that our outcome measures were not sensitive enough to detect the subtle difference between VR and conventional balance training. We acknowledged the possibility that a force platform (e.g., the balance board in the VR balance training system) might provide extra information, but it was not assessed in this study. Therefore, the difference in training effect between VR and conventional balance training, if exists, could be too minor to be clinically important.

We developed our own VR balance training system rather than using commercial products to serve our specific needs: (1) training tasks mimic common daily tasks; (2) each task has a wide, adjustable range of difficulty; and (3) avoid unnecessary wire connections. However, our weight-shift controlling method was closely similar to that of the Wii device to produce similar training effect in patients with PD at home.[7] Furthermore, the retention effect of Wii balance training was also observed in the study of Pompeu et al[8] with PD patients trained in the community association. The retention effects of our VR balance training on balance and the transfer effect on walking function might be attributable to several factors. First, VR provided ample visual feedback, which patients heavily relied on during skill learning.[26] Our VR balance training system enabled the participants to visualize the shift of body weight, thus facilitating the learning of weight shift control. Second, the VR balance training system provided varied practice to enhance attention focus on learning. In our VR software, the location of targets and navigation routes would vary from trial to trial, so participants practiced the task repeatedly. Last, the videogame-like reward billboard in the VR software encouraged users to gain points and higher scores, thus increasing the practice motivation.

The characteristics of the present study design were as follows: (1) the VR programs for patients with PD at home was supervised by a home physiotherapist to ensure the appropriate execution of VR programs; (2) the control group received conventional balance training by direct manual management from a home physiotherapist; and (3) both groups received similar principles of progression. Thus, the VR group focused on visual/sound feedback from the screen, whereas the conventional group focused on hepatic/verbal feedback from the therapist. In terms of the learning mechanisms, knowledge of performance (KP) is the information about the pattern and quality of an action, whereas knowledge of results (KR) is the information about the outcome of an action with regard to the goal.[27] In VR balance training, the feedback included both KP and KR.[28] For example, in the car racing task, KP included the trajectory of the virtual car, and KR included the number of

Table 3 Mean (SD) of groups at three assessment points, mean (SD) difference within groups, and mean (95% CI) difference between groups for all outcomes, for all patients (intention-to-treat analysis).

Outcome	Groups						Difference within groups				Difference between groups[b]	
	Pretest (Week 0)		Posttest (Week 6)		Follow-up (Week 8)		Posttest minus Pretest		Follow-up minus Pretest		Posttest minus Pretest	Follow-up minus Pretest
	VR ($n = 11$)	Control ($n = 12$)	VR ($n = 11$)[a]	Control ($n = 12$)[a]	VR ($n = 11$)[a]	Control ($n = 12$)[a]	VR	Control	VR	Control	VR minus Control	VR minus Control
Berg Balance Scale	46.9 (6.5)	46.9 (6.6)	50.3 (5.4)	51.1 (5.9)	49.6 (5.9)	49.8 (6.3)	3.36 (2.38)	4.17 (5.01)	2.73 (3.07)	2.83 (3.76)	−0.80 (−4.26–2.65)	−0.11 (−3.10–2.89)
Dynamic Gait Index	16.9 (4.2)	17.4 (4.3)	21.0 (2.6)	20.6 (4.5)	20.0 (4.4)	20.1 (4.8)	4.09 (2.98)	3.17 (2.86)	3.09 (3.39)	2.67 (2.61)	0.92 (−1.61–3.46)	0.42 (−2.18–3.03)
Timed Up-&-Go test	22.9 (12.1)	21.1 (12.2)	19.6 (8.9)	18.0 (9.8)	20.7 (11.4)	18.8 (10.7)	−3.34 (3.67)	−3.07 (3.15)	−2.26 (1.96)	−2.26 (2.91)	−0.28 (−3.24–2.68)	0.00 (−2.17–2.17)
PDQ-39	29.2 (16.3)	31.7 (17.9)	23.8 (15.5)	26.4 (19.1)	24.6 (14.9)	25.2 (17.4)	−5.34 (11.96)	−5.27 (11.96)	−4.60 (8.66)	−6.49 (9.18)	−0.07 (−10.40–10.27)	1.90 (−5.86–9.65)
UPDRS-III	22.5 (12.1)	21.7 (14.4)	25.1 (12.8)	18.5 (11.0)	22.5 (14.7)	16.9 (9.0)	2.55 (5.96)	−3.17 (8.73)	0.00 (6.72)	−4.75 (9.98)	5.71 (−0.83–12.25)	4.75 (−2.70–12.20)

CI = confidence interval; PDQ-39 = 39-item Parkinson's Disease Questionnaire; SD = standard deviation; UPDRS-III = Unified Parkinson's Disease Rating Scale; VR = virtual reality.

[a] Intention to treat with the last observation carried forward method.

[b] A 95% CI crossing zero indicates insignificant between-group difference.

collisions and the running time. By contrast, the feedback in the conventional balance training was primarily KP from the therapist's instruction. Furthermore, the weight shift training was a learning process that might involve explicit and/or implicit learning. The degeneration of basal ganglia circuitries in patients with PD suggests a deficit in implicit learning.[29] Indeed, a recent systematic review on serial reaction time tasks supports the notion that implicit acquisition is affected in PD.[30] Fortunately, there were several ways to shift the learning process toward the explicit end of the implicit—explicit continuum. Auditory pacing, visual targets, visual feedback, and KR were useful clinical tactics to facilitate motor learning in patients with PD.[26] Thus, both VR and conventional training would be helpful.

We acknowledge that the small sample size is a key limitation of this study. The target population in this study was community-dwelling patients with PD. We unexpectedly found that patients and their family members frequently felt it inconvenient to receive regular home visits, and thus declined to join this study. Second, the 2-week follow-up might be too short to justify the retention of training effects. However, all participants in this study visited the outpatient clinic every 10—12 weeks, so the total length of the study was set to 8 weeks to avoid drug change during the study period. Future investigations with a longer follow-up period are suggested to justify the delayed retention and transfer of training. Third, this study did not monitor freezing of gait; therefore, the effect of VR and conventional balance training on freezing were unclear. Finally, the VR programs could be made more simple and usable by patients or family members, so as to reduce the manpower requirement of the physiotherapist during home visits.

This study compared the effect of VR balance training and conventional balance training in participants' home setting. The control group in this study took conventional balance training supervised by a physical therapist. However, we did not include a general-exercise control group (i.e., taking general stretching/strengthening exercise at home without supervision), nor a no-treatment control group. Therefore, the effect of VR balance training in respect of general exercise or no exercise remains unanswered. Future studies with rigorous design are required to further compare the difference between VR balance training and general exercise.

In conclusion, we did not find differences between home-based VR balance training and conventional home balance training. The results suggested that home-based VR might be a viable option for patients with PD, especially those living in areas with limited access to rehabilitation services. It is also plausible that VR balance training could be an interesting alternative to home exercise prescription. Future studies with greater sample sizes are recommended to explore more applications of home-based VR.

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Appendix 1. Protocols of the virtual reality balance training.

	1—3 sessions	4—6 sessions	7—9 sessions	10—12 sessions
Supporting surface	Solid floor	Solid floor	Compliant foam	Compliant foam
Manipulative task	No	Holding a volleyball with arms extended	No	Holding a volleyball with arms extended
Static posture maintaining (10 min)	Sensitivity: low to high • Star excursion (learning) • Home Yoga (indoor)	Sensitivity: low to high • Star excursion (learning) • Home Yoga (indoor)	Sensitivity: low to high • Star excursion (learning) • Home Yoga (indoor)	Sensitivity: low to high • Star excursion (learning) • Home Yoga (indoor)
Dynamic weight shifting (10 min + 10 min)	Sensitivity: high to low • Ball maze OR Table tilt (learning) • Cooking OR Cloth washing (indoor) • Car racing OR Park walking OR Apple catching (outdoor)	Sensitivity: high to low • Ball maze OR Table tilt (learning) • Cooking OR Cloth washing (indoor) • Car racing OR Park walking OR Apple catching (outdoor)	Sensitivity: high to low • Ball maze OR Table tilt (learning) • Cooking OR Cloth washing (indoor) • Car racing OR Park walking OR Apple catching (outdoor)	Sensitivity: high to low • Ball maze OR Table tilt (learning) • Cooking OR Cloth washing (indoor) • Car racing OR Park walking OR Apple catching (outdoor)

The parentheses specify the program type, including basic learning (learning), indoor daily tasks (indoor) and outdoor daily tasks (outdoor).

Appendix 2. Protocols of the conventional balance training.

	1–3 sessions	4–6 sessions	7–9 sessions	10–12 sessions
Supporting surface	Solid floor	Solid floor	Compliant foam	Compliant foam
Manipulative task	No	Holding a volleyball with arms extended	No	Holding a volleyball with arms extended
Static posture maintaining (10 min)	Stance width from wide to narrow, including: • Shoulder width • Narrow width • Partial tandem • Tandem • 1 leg	Stance width from wide to narrow, including: • Shoulder width • Narrow width • Partial tandem • Tandem • 1 leg	Stance width from wide to narrow, including: • Shoulder width • Narrow width • Partial tandem • Tandem	Stance width from wide to narrow, including: • Shoulder width • Narrow width • Partial tandem • Tandem
Dynamic weight shifting (10 min + 10 min)	Speed: Low to high Step size: Small to big • Choice stepping • Rope crossing (forward/backward) • Rope crossing (rightward/leftward)	Speed: Low to high Step size: Small to big • Choice stepping • Rope crossing (forward/backward) • Rope crossing (rightward/leftward)	Speed: Low to high Step size: Small to big • Choice stepping • Rope crossing (forward/backward) • Rope crossing (rightward/leftward)	Speed: Low to high Step size: Small to big • Choice stepping • Rope crossing (forward/backward) • Rope crossing (rightward/leftward)

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