Virtual reality exercise to improve balance control in older adults at risk of falling

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KEY MESSAGES

1. Playing Wii Fit games can improve the Berg Balance Scale score and stability limits of institutionalised and frail older adults with a history of fall.
2. The Wii Fit balance training was more effective than conventional balance training in this regard.
3. The Wii Fit balance training can enhance the management of fall prevention in older adults (especially for those living in aged care facilities) and may reduce health care costs and suffering in older adults.

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Introduction

It is estimated that 28% to 35% of older adults (age 65 years) experience at least one fall each year; fall is the second leading cause of accidental death worldwide.[1] Risk factors of fall include intrinsic and extrinsic factors. Balance control is intrinsic and modifiable. Virtual reality (VR) simulates daily life activities by presenting an illusion of three-dimensional vision and direct visual and auditory feedback.[2] Interventions using the Nintendo Wii Fit force-sensing platform and its built-in VR games for balance, yoga, aerobic, and strength training have been reported.[2]

The effectiveness of Wii Fit exercise versus conventional exercise on balance control has been studied. In a study of 36 community living older adults, the Wii Fit balance training group achieved better balance control post intervention, based on the Tinetti test and the Wii Fit centre of gravity test.[3] In another study of 32 community living older adults, the Wii-fit group, the traditional exercise group, and the control group achieved significant but comparable improvement in Berg Balance Scale (BBS) score of 3.55, 3.45, and 2.99, respectively.[4] However, scientific evidence on the effects of VR exercise using Wii Fit on balance control among institutionalised older adults with a fall history is still lacking. Hence, this randomised clinical study aimed to compare Wii Fit balance training with conventional balance training in this group of older adults.

Methods

Approval was obtained from the nursing homes prior to the study. Ethical approval was obtained from the ethics committee of the nursing home and The Hong Kong Polytechnic University. Informed consent was obtained from each participant. A total of 79 older adults aged over 65 years who were nursing home residents with a functional ambulatory category (FAC) of 2 (walking with one person assistance) or 3 (walking without assistance but needed a standby guard for safety) were recruited in this single-blinded, randomised clinical trial. Subjects were randomised to a Wii Fit balance training group or a conventional balance training group. Each group received three 1-hour sessions of training per week for 6 weeks. The Wii Fit balance training games included Soccer Heading, Table Tilt, and Balance Bubble. The conventional balance training regimen was led by a physiotherapist and included leg strengthening exercises, tandem standing exercise in parallel bars, tandem walking in parallel bars, sideways walking and turning around in parallel bars, stepping exercises, sit-to-stand exercises, and mini-squats.[5] Outcome measures included BBS, timed-up-and-go test, and limits of stability test.

Independent t-test was used to compare the two groups in terms of age, height, weight, body mass index, and number of falls in the previous year. Chi-squared test was used to compare the distribution of genders and functional ambulation categories. Two-way repeated measures analysis of variance was used to test the group and time effects and any interaction of group and time with intent-to-treat. Post-hoc analysis was conducted using the independent t-test to compare between-group measurements and the paired t-test to compare within-group measurements. The alpha level was set at 0.05 with Bonferroni correction.

Results

Of the 79 subjects, 39 were randomised to Wii Fit balance training and 40 to conventional balance training. All subjects completed the 6 weeks of training and post-intervention assessment. The two groups were comparable in terms of gender distribution, age, height, weight, body mass index, FAC, and number of falls in the previous year (Table 1).

Repeated measures analysis of variance was used to assess the group-by-time interaction, which was significant in the BBS score, and two of the four balance components in the limits of stability test (the end-point excursion and the maximum excursion).

Pre-test values of the two groups were comparable, but post intervention the Wii Fit

TABLE 1. Demographics of the Wii Fit and conventional balance training groups

Parameter	Wii Fit balance training (n=39)	Conventional balance training (n=40)	P value
Mean±SD age (years)	82.3±3.8	82.0±4.3	0.806
No. of males:females	16:23	15:25	0.820
Mean±SD height (m)	1.54±0.1	1.57±0.1	0.139
Mean±SD weight (kg)	52.6±4.6	55.9±8.5	0.183
Mean±SD body mass index (kg/m^2)	22.3±2.1	22.8±2.8	0.625
No. of subjects in the functional ambulatory category 2:3	22:17	20:20	0.654
Mean±SD No. of falls in the previous year	2.4±1.0	2.2±1.1	0.312

TABLE 2. Outcome measures of the Wii Fit and conventional balance training groups

Outcome measures	Mean±SD				P value		
	Wii Fit balance training (n=39)		Conventional balance training (n=40)				
	Pre-test	Post-test	Pre-test	Post-test	Pre-test (group effect)	Post-test (group effect)	Group-by-time effect
Berg Balance Scale score	37.0±3.0	40.7±3.2*	37.1±1.8	37.8±1.8*	0.804	<0.001†	<0.001‡
Timed-up-and-go time (s)	19.7±3.1	17.0±2.8*	18.9±3.1	18.2±2.4*	0.290	0.061	0.434
Limits of stability reaction time (ms)							
Anterior	696.3±166.9	605.8±144.2	716.0±137.6	706.9±133.0	0.599	0.003†	0.145
Posterior	703.1±165.1	648.9±139.3	667.4±155.8	646.5±137.3	0.412	0.710	0.540
Left	635.3±245.2	658.5±225.7	577.4±238.2	651.9±196.4	0.286	0.976	0.483
Right	640.2±282.2	772.2±273.4	697.8±299.9	710.4±266.0	0.318	0.382	0.258
Limits of stability end-point excursion (mm)							
Anterior	93.1±27.0	121.2±29.1*	90.3±24.8	78.8±13.4	0.667	<0.001†	<0.001‡
Posterior	87.3±30.2	103.3±23.9*	81.8±20.3	70.7±11.5	0.391	<0.001†	0.001‡
Left	93.6±29.7	105.3±28.4*	88.6±24.6	82.6±19.2	0.467	<0.001†	0.048‡
Right	92.4±37.5	113.0±32.6*	87.1±29.5	76.1±19.8	0.532	<0.001†	0.007‡
Limits of stability maximum excursion (mm)							
Anterior	121.8±26.0	158.8±22.1*	118.4±21.8	102.3±12.4	0.572	<0.001†	<0.001‡
Posterior	112.6±27.7	136.1±18.9*	108.3±26.4	91.7±11.4	0.524	<0.001†	<0.001‡
Left	123.4±30.8	135.8±25.7*	116.5±25.1	105.1±15.9	0.330	<0.001†	0.011‡
Right	118.5±31.8	142.3±34.7*	108.9±27.7	97.5±15.5	0.200	<0.001†	0.001‡
Limits of stability directional control (%)							
Anterior	89.8±1.9	91.0±3.5	90.2±2.4	88.2±6.0	0.389	0.026	0.055
Posterior	86.5±3.5	86.7±4.3	86.6±3.8	84.8±5.5	0.967	0.136	0.212
Left	90.3±4.0	89.0±5.5	90.8±3.8	90.6±4.7	0.620	0.220	0.538
Right	90.2±4.7	89.2±5.5	89.9±5.4	90.8±4.0	0.812	0.190	0.292

* P≤0.01 after Bonferroni correction (0.05/4=0.0125) within group (time effect)
† P≤0.01 after Bonferroni correction (0.05/4=0.0125) between groups (group effect)
‡ P≤0.05 between and within groups (group-by-time effect)

balance training group achieved better balance performance than the conventional balance training group, namely a significantly better BBS score, faster reaction time in the anterior direction, and further end-point excursion and maximum excursion in all four directions of the limits of stability test ($P \leq 0.01$, Table 2).

Within the Wii Fit balance training group, the BBS score, timed-up-and-go test, end-point and maximum excursions in all four directions in the limits of stability test improved significantly (Table 2). Within the conventional balance training group, only the BBS score and the timed-up-and-go test improved significantly (Table 2).

Discussion

The improvement in BBS score was significantly more in the Wii Fit than the conventional balance training group (3.7 vs 0.7). This may be attributed to the real-time performance feedback and cuing stimuli in the VR training to support error-free learning. The results of this study are comparable with other studies conducted in community in which Wii Fit intervention significantly improved older adults' BBS score.[6-8]

The improvement in the timed-up-and-go test for the Wii Fit and conventional balance training groups was 2.7 and 0.7 seconds, respectively. Both groups focused on training standing balance and neither the Wii Fit nor the conventional balance training emphasised walking speed. Nonetheless, the static balance training could enhance a more dynamic balance control in our institutionalised and frail (FAC 2 or 3) subjects as reflected by the timed-up-and-go test.

The reaction times of the limits of stability test of the two groups were comparable. In a cross-sectional study, experienced Tai Chi practitioners achieved significantly better reaction time than non-Tai Chi practitioners.[9] In contrast, another study by the same research group in 2004 reported that there was no significant difference in reaction time between subjects who received 8 weeks of Tai Chi training and controls who received health education.[10] One possible explanation for these contrasting results is that it may require a longer training period to improve the reaction time in older adults, particularly those who are institutionalised and with low mobility status (FAC 2 or 3). Thus, the training duration may need to be longer than the present protocol.

Only the Wii Fit group achieved significant improvement in end-point (20.8%) and maximum (20.3%) excursion in all four directions of the limits of stability test ($P \leq 0.01$), and was significantly better than the conventional balance training group ($P \leq 0.01$). In a study measuring the functional reach test (also known as the voluntary limits of stability - anterior direction) in 16 older adults without a history of fall,[11] Wii Fit intervention for 4 weeks achieved a significant increase of 2.48 inch (from 10.92 to 13.40 inch); the percentage change was 22.7%. The Wii Fit balance training resembles the body movements of the limits of stability test, which quantifies the maximum distance by which a person can intentionally displace their centre of gravity by leaning without assistance, losing their balance or stepping. Such body-weight-shifting practice was not included in the control balance training. In this connection, Tai Chi practitioners had significantly better reaction time, maximum excursion and directional control than non-Tai Chi practice controls.[9] Such enhanced balance performance as reflected by the limits of stability test might be due to the weight-shift involved in Tai Chi practice, which is similar to the Wii Fit training.[12,13] Better end-point and maximum excursion may be related to the better performance of functional activities, which might, in turn, minimise the risk of fall.

The directional control of the limits of stability test of the two groups was comparable. In the balance control perspective, Tai Chi training seems more effective in improving directional control than Wii Fit balance exercises, as Tai Chi practitioners improved more than controls after 8 weeks of Tai Chi practice.[10] This might be due to the nature of the exercise. The Wii Fit balance training required the individual to shift body weight to random target positions. This constantly challenged the balance control system to maintain the body's centre of mass within the base of support. However, such erratic movements might not develop smooth and coordinated weight shifting. Yet, to prevent falls, smoothness and continuous weight shifting is less important than a quick response to perturbation. Therefore, further kinematic and kinetic study of centre of mass movement during falls and during Wii Fit training is warranted.

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