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The Effect of a Virtual Reality Game Intervention on Balance for Patients with Stroke: A Randomized Controlled Trial

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Abstract

Objective: The aim of this study was to investigate the effects of virtual reality (VR) balance training conducted using Kinect for Xbox® games on patients with chronic stroke.
Materials and Methods: Fifty patients with mild to moderate motor deficits were recruited and randomly assigned to two groups: VR plus standard treatment group and standard treatment (ST) group. In total, 12 training sessions (90 minutes a session, twice a week) were conducted in both groups, and performance was assessed at three time points (pretest, post-test, and follow-up) by a blinded assessor. The outcome measures were the Berg Balance Scale (BBS), Functional Reach Test, and Timed Up and Go Test (cognitive; TUG-cog) for balance evaluations; Modified Barthel Index for activities of daily living ability; Activities-specific Balance Confidence Scale for balance confidence; and Stroke Impact Scale for quality of life. The pleasure scale and adverse events were also recorded after each training session.
Results: Both groups exhibited significant improvement over time in the BBS ($P = 0.000$) and TUG-cog test ($P = 0.005$). The VR group rated the experience as more pleasurable than the ST group during the intervention ($P = 0.027$). However, no significant difference was observed in other outcome measures within or between the groups. No serious adverse events were observed during the treatment in either group.
Conclusions: VR balance training by using Kinect for Xbox games plus the traditional method had positive effects on the balance ability of patients with chronic stroke. The VR group experienced higher pleasure than the ST group during the intervention.

Keywords: Stroke, Virtual reality therapy, Videogames, Postural balance, Activities of daily living

Introduction

Neurological symptoms occurring after stroke include abnormal reflex, muscle hypertonicity, attention deficiency, hemineglect, and sensorimotor functional impairment. Although patients demonstrate functional improvement followed by recovery, most of them still experience stroke symptoms. Stroke affects independence in activities of daily living (ADL) by reducing postural control, resulting in slow walking speed and short stride length.[1–3]

Common balance problems caused by stroke are decrease in muscle strength and proprioception, higher loads on the nonparetic extremity, and increased postural oscillation.[4] Moreover, stroke leads to loss of balance and falls in 56% and 18% of patients every month, respectively[5]; this may cause traumatic brain injury, fracture, and fall fear and affect ADL independence and quality of life (QOL).[6] Stroke imposes huge economic and social burden in the long term and is among the top three diseases responsible for high medical expenditures in the National Health Insurance.[7] Balance recovery helps patients with stroke to become independent in ADL and reduces the burden of medical costs.

Nonimmersive virtual reality (VR), which has been used in stroke rehabilitation,[8] can improve balance ability through the provision of multisensory feedback and repeat practices. Compared with traditional methods, the VR method can greatly increase motivation. Commercial games such as Sony ''EyeToy®'', Nintendo® Wii™, and Microsoft Kinect have been used in nonimmersive VR rehabilitation. Specifically, Microsoft Kinect does not require a controller and it

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captures movements by using a sensor; thus, patients can see movements in real time and provide feedback immediately. Rajaratnam et al. demonstrated the static and dynamic balance effects of VR-related games by using the Wii balance board or Microsoft Kinect for patients with subacute stroke.[9]

Subramaniam and Bhatt reported that the introduction of Microsoft Kinect (''Just Dance 3'') games to 11 patients after stroke improved the reaction time, movement velocity, maximum excursion, and number of steps during dance intervention.[10] Although studies have supported the effectiveness of these commercial games, the study designs and evidence have been vaguely studied. A game is designed for leisure goals and not for treatment goals.[11] No standard treatment (ST) integrating rehabilitation and home care is available. Furthermore, few studies have investigated the effects of these games on long-term retention.[12]

In this study, we investigated the effect of the Microsoft Kinect function for Xbox training plus traditional training on the balance ability of patients with chronic stroke. We hypothesized that the use of Microsoft Kinect games plus traditional balance training was feasible and enjoyable for patients and it would show improvements in balance and participation performance after 6 weeks of intervention, which are the same as those obtained using traditional methods; moreover, the effects could be maintained after 3 months.

Materials and Methods

Participants

The patients were recruited from February 2015 to January 2016. All outpatients of the Neurorehabilitation Unit of Hospital presenting with residual hemiparesis after stroke were eligible to participate in this study. The inclusion criteria were as follows: (1) age between 20 and 75 years; (2) having chronicity >6 months; (3) ability to understand game instructions; (4) ability to stand for 15 minutes; and (5) having Brunnstrom stage $\geq$III. The exclusion criteria were as follows: (1) having a Montreal Cognitive Assessment score <16; (2) having visual or auditory impairment with the inability to clearly see or hear the feedback from the game; (3) having severe spasticity of lower extremity (Modified Ashworth Scale $\geq$3); and (4) having other medical symptoms that could affect movement.

Individuals who met all criteria and agreed to participate in the study were provided detailed information. Written informed consent was obtained from all patients. The study

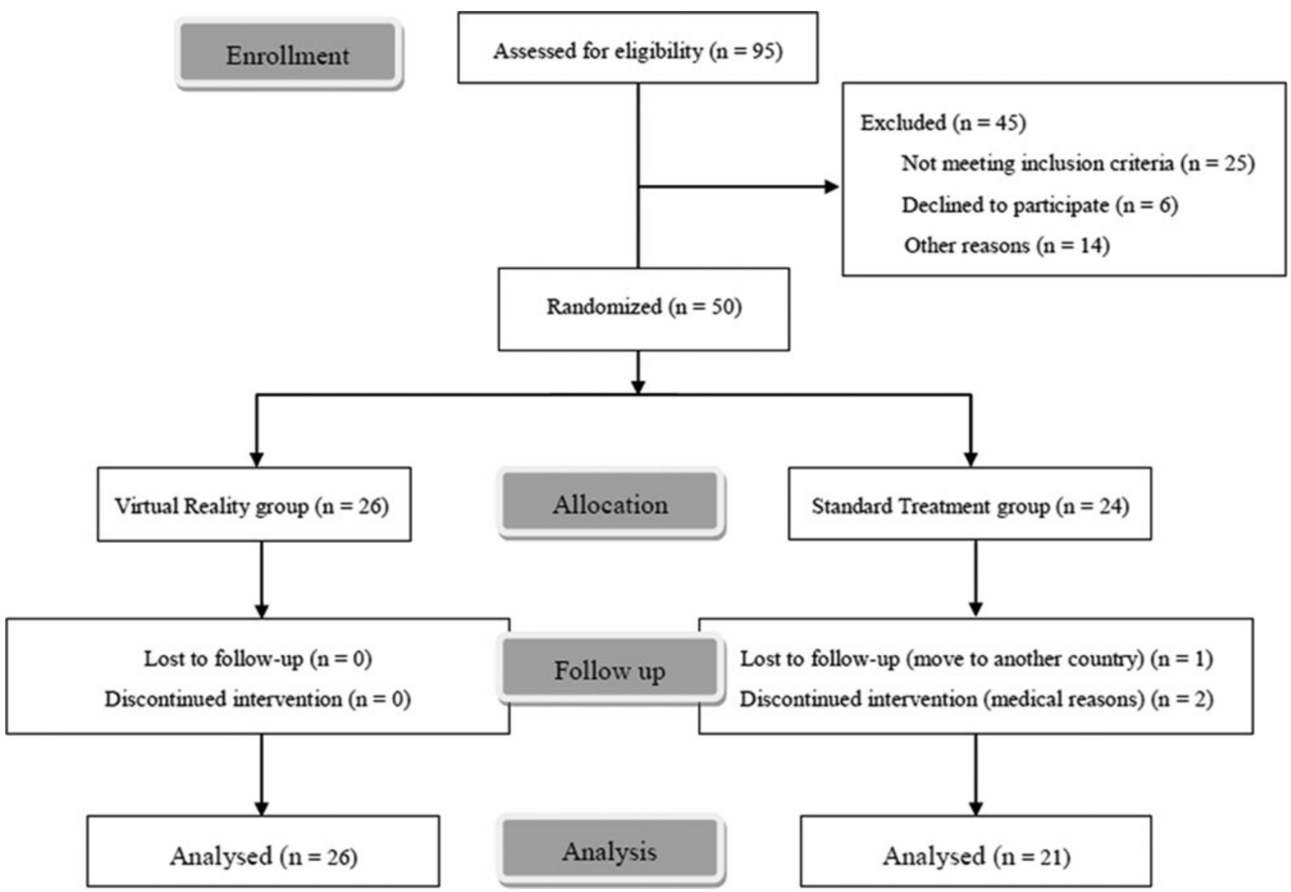

FIG. 1. Flowchart of the experimental protocol. During the recruitment process, a total of 95 outpatients were assessed. Of these, 25 were excluded, 6 rejected the invitation to participate, and 14 could not meet the time. A total of 50 (52.63%) patients from the remaining sample met the inclusion criteria and were randomly allocated into the VR group ($n=26$) or ST group ($n=24$). After 12 training sessions, the patients' performance was assessed by a blinded assessor. Three patients in the ST group dropped out during the study because of relocation to another country ($n=1$) and medical reasons ($n=2$). Consequently, data from 47 patients, 26 in the VR group and 21 in the ST group, were included in this study. ST, standard treatment; VR, virtual reality.

was approved by the Institutional Review Board of Taipei Medical University Hospital (No.: 201412023). The protocol was registered in ClinicalTrials.gov PRS (No.: NCT02735265).

Design

A prospective, randomized controlled design was used. We randomized 50 patients into the VR group or ST group through simple random sampling by using a computer generator. After 12 training sessions, the patients' performance was assessed by a blinded assessor (Fig. 1). An independent occupational therapist who was not blinded to the intervention explained the training procedure to the participants and provided technical support.

Intervention

Both interventions were administered twice a week for 6 weeks under the supervision of a qualified occupational therapist. The VR group received 45 minutes of ST and 45 minutes of interactive VR balance-related games. The ST group received ST for 90 minutes.

VR group. The VR game training system comprised a television (50LB5800 WiFi Smart TV; LG, Seoul, Korea), Microsoft Kinect (Microsoft, Inc., Redmond, WA), and a commercial game. The system was applied in the clinical setting.

Nine games were selected from the Kinect Sports, Kinect Adventures, and Your Shape™ Fitness Evolved packages that are based on common balance problems experienced after stroke (Table 1). We analyzed the tasks on the basis of the motor learning theory of Gentile and selected the game according to body stability and stationary conditions for initial practice (Fig. 2).[13]

The regulatory conditions indicate relevant environmental features that constrain movement execution and may either be stationary (stationary regulatory conditions) or moving (in-motion regulatory conditions). With the indicator, intertrial variability is used to differentiate between regulatory conditions that change between trials (intertrial variability) and those that do not (no intertrial variability). Body orientation indicates whether an action requires the performer to move from one location to another (body transport) or not (body stability). Object manipulation indicates whether an object has to be controlled during the action performance (object manipulation) or not (no object manipulation). According to Gentile, the easiest skill category can be found at the top left position. Moving either rightward or downward in the table renders the skill category more difficult; thus, the most difficult skill category can be found at the bottom right of the table.

In each session, 15 minutes of warm up and 15 minutes each for two selected games were set for patients according to their ability, requirements, and choice. The therapist demonstrated the game control and instructions to ensure that the patients understood the controlling of the system, which prevented compensatory movements through oral feedback. For safety, we placed a handrail in front of the participant if required. We graded the difficulty by modifying movement challenges, endurance time, and feedback frequency during the session. The patients were asked to rest and stretch muscles for a short time when their hypertonicity interfered with the game control. The

Table 1. Game Analysis in the Virtual Reality Group

Game name	*Description*	*Requirement*
"Darts" (Kinect Sports: Season 2)	Small missiles are thrown at a circular dartboard. The player throws three darts per visit at the board with the goal of reducing 501 to 0.	Unilateral upper limb movement with static standing.
"Golf" (Kinect Sports: Season 2)	The golf club is swung to hit the ball into the hole.	Slight bilateral knee squat, bilateral hand swing with trunk rotation to one side, weight shifting.
"Bowling" (Kinect Sports)	Players are required to reach to their left or right to pick up a ball before swinging their arm forward to bowl, exaggerating the arm motion to add a spin if required.	Unilateral upper limb movement with weight shifting, stepping to lunge.
"Virtual smash" (Your Shape™: Fitness Evolved)	Virtual bricks are randomly displayed from various directions, and a punch or kick across the body must be performed to hit them.	Unilateral upper limb movement with weight shifting, single-limb weight bearing.
"Light race" (Your Shape: Fitness Evolved)	There are five buttons on the ground, and each button randomly lights up. The player is required to step onto the button to darken it and score.	Stepping to four directions, single-limb weight bearing.
"Space Pop" (Kinect Adventures!)	Players attempt to pop the bubbles by touching them, earning adventure pins. To move upward, the players flap their arms, and to stay at their current height, they hold their arms out to the sides.	Bilateral upper limb movement with locomotion and weight shifting.
"Rally Ball" (Kinect Adventures!)	A ball floats in the air in front of the player. The player can use any body part to reach out and whack it.	Bilateral upper limb movement, trunk leaning for weight shifting.
"Table Tennis" (Kinect Sports)	A lightweight ball is tossed up and hit back and forth across a table by using a small paddle.	Unilateral upper limb movement with weight shifting.
"River rush" (Kinect Adventures!)	The players control the raft with their bodies by moving from side to side and jumping.	Unilateral upper limb movement with trunk lean and weight shifting or stepping.

score was recorded after the game for the next goal, and feedback was obtained at the end of the therapy.

ST group. Both groups performed 45 minutes of the ST rehabilitative protocol, focusing on strengthening, endurance training, ambulation, and ADL training on the following: (1) hip flexor and knee extensor strengthening with resistance progression by using weight bags or a Thera-band; (2) cycle ergometer riding with an increase in speed and resistance; (3) gait pattern and speed correction through a treadmill and parallel bar; and (4) hand functional training and strategy teaching for feeding, dressing, and toileting.

In addition, the ST group participated in 15 minutes of warm-up exercises for stretching to increase soft tissue flexibility and range of motion and 30 minutes of functional balance exercises that included the following programs: (1) to facilitate the balance reaction through weight shifting exercises by standing on an even to uneven surface, such as a tilting board; (2) postural transition, including sit-to-stand, sit down, reaching to different directions, stepping to different directions with weight transfer, and bending the trunk forward and side to side; (3) change in the standing requirement, such as a single-legged stance or lunge stance; and (4) increased perception complications through cognition or upper extremity tasks to improve dual-task attention.

The difficulty level of the exercises was adjusted according to the progression of each participant. The number of repetitions, height of the exercise step, and the weight were progressively modified. Each set lasted for 15 minutes.

Outcome measures

The outcome measures were assessed at three time points (before intervention, postintervention, and at 3-month follow-up) by a therapist who was blinded to the training allocation.

The primary outcome measure was the Berg Balance Scale (BBS).[7,14–16] Other balance outcomes included the Functional Reach Test (FRT)[16,17] and Timed Up and Go-cognition (TUG-cog) test. In the TUG-cog test, patients were asked to complete the test while counting backward by 3 from a randomly selected number between 20 and 100.[18] Participation outcomes included the Modified Barthel Index (MBI)[19] for ADL, Activities-specific Balance Confidence (ABC) scale-Taiwan[20,21] for balance confidence, and Stroke Impact Scale (SIS)[22] for QOL. Feasibility outcomes that were recorded after each session included the modified Physical Activity Enjoyment Scale (M-PAES)[23] and the incidence of adverse events, namely soreness, motor sickness, pain, injury, and fall accident.

Data analysis

Data were analyzed using IBM SPSS statistics (version 20.0). The significance level was set at 0.05. Descriptive analysis was used, and all data are presented as mean ± standard deviation. Demographic and baseline characteristics were evaluated using the chi-square test or independent samples *t*-test. Repeated-measures analysis of variance (ANOVA) with time as a within-participant factor and group as a between-participant factor was performed for the balance, ADL, balance confidence, and QOL outcome measures. The Bonferroni post hoc test was used to investigate differences between groups at the three time points. For each repeated-measures ANOVA, we present the partial η^2 as a measure of the effect size. Feasibilities reported in both groups were compared using independent sample *t*-tests.

Data were assessed by using the Kolmogorov–Smirnov test to confirm the normality. If the data were not normally distributed, the Friedman two-way ANOVA test was used for time effect and the Mann–Whitney *U* test was used for group effect. Wilcoxon signed-rank test was used for post hoc analysis.

Results

Patients

A total of 50 patients were recruited and randomly allocated into the VR ($n = 26$) and ST ($n = 24$) groups. Three

		Action function			
		Body stability		Body transport	
Environmental context		No object manipulation	object manipulation	No object manipulation	object manipulation
Stationary regulatory conditions	No intertrial variability		Darts		Bowling
	Intertrial variability		Golf		
In-motion regulatory conditions	No intertrial variability		Virtual smash	Light race	Rally ball
	Intertrial variability		Table tennis	River rush	Space pop

FIG. 2. VR games corresponding to Gentile's skill categories. The task was analyzed based on motion (body stability or transport) and condition (stationary or in-motion regulatory conditions). According to Gentile, the easiest skill category can be found at the top left position. Moving either rightward or downward in the table renders the skill category more difficult; thus, the most difficult skill category can be found at the bottom right of the table.

patients in the ST group dropped out during the study. The reasons for exclusion and dropping out are presented in Figure 1. Finally, we included a total of 47 patients (VR group: 26; ST group: 21). Before treatment, demographic characteristics and clinical data did not significantly differ between the VR and ST groups (Table 2).

Clinical data

The clinical data are listed in Table 3. A significant time effect was observed in both groups in BBS ($P=0.000$) and TUG-cog ($P=0.009$). The post hoc analysis revealed significantly improved BBS scores from the pre- to post-intervention ($P=0.000$) and follow-up test ($P=0.003$). TUG-cog significantly decreased from the pre- to post-intervention ($P=0.003$) and follow-up test ($P=0.006$). A nonsignificant time effect was observed in both the groups in the FRT ($P=0.187$). Although both groups exhibited partial improvement in scores, no significant group-by-time interaction was observed in any scale.

Feasibility

The M-PAES scores significantly differed between the two groups ($P=0.027$). Furthermore, the incidence of adverse events did not differ significantly between the two groups (6% vs. 10%, $P=0.267$; Table 4). The details of adverse events in both groups are presented in Figure 3.

Discussion

In this study, we observed that both groups exhibited partial balance improvement in the BBS and TUG-cog test after 12 sessions of balance training and this improvement was maintained at the 3-month follow-up; however, no significant improvement was observed in balance confidence, ADL, or QOL. In addition, no significant group effects or group-by-time interactions were observed in all outcome measures. A higher level of pleasure was experienced in the VR group than in the ST group during the treatment.

Balance effectiveness of VR game training

The results revealed significant improvements over time in the BBS and TUG-cog test, thus supporting the effectiveness of VR-based interventions in improving balance, even for a long time after stroke. We observed an improvement of 2.84 points in the BBS and 3.03 seconds in the TUG test, which are higher than the previously established minimum detectable change of 2.5 points[24] and 2.9 seconds,[25] for the chronic stroke population.

VR-based interventions involving motor learning and plasticity principles focus on high-intensity, repetitive, and task-specific practices.[15] VR-based interventions provide multisensory feedback during the game, including proprioception, vestibular, visual, and auditory feedback. VR combines sensory and cognition stimulation that could benefit a patient's dual-task ability, similar to that in the equivalent

Table 2. Comparisons of Characteristics Between Virtual Reality-Based and Standard Therapy Groups

Characteristics	*VR group* (n=*26*)	*ST group* (n=*21*)	*Value*	P
Gender, *n* (%)				
Male	16 (61.5)	18 (85.7)	3.393	0.065
Female	10 (38.5)	3 (14.3)		
Age (year)	59.35±8.95	55.76±9.59	1.322	0.193
Education level, *n* (%)				
<High school	4 (15.4)	5 (23.8)	0.664	0.718
High school	15 (57.7)	10 (47.6)		
>High school	7 (26.9)	6 (28.6)		
Affected side, *n* (%)				
Left	11 (42.3)	11 (52.4)	0.473	0.491
Right	15 (57.7)	10 (47.6)		
Etiology, *n* (%)				
Infarction	16 (61.5)	14 (66.7)	0.132	0.716
Hemorrhage	10 (38.5)	7 (33.3)		
Site of stroke, *n* (%)				
Cerebral	22 (84.6)	17 (81.0)	1.266	0.531
Cerebellum	0 (0)	1 (4.8)		
Brain stem	4 (15.4)	3 (14.3)		
Poststroke duration (day)	839.77±719.13	653.24±589.70	0.956	0.344
First stroke, *n* (%)	23 (88.5)	21 (100.0)	2.588	0.108
Regular rehabilitation (min/weeks)	64.62±61.01	68.57±60.85	–0.221	0.826
FIM of walking ability	6.19±0.63	6.29±0.64	–0.499	0.620
MoCA	24.46±4.49	24.05±3.97	0.331	0.742
Br. Stages of LE	4.62±1.44	4.05±1.28	1.407	0.166
MAS of LE	0.85±0.93	0.95±0.74	–0.427	0.671

Data are presented as mean±standard deviation or number (%). Value indicates t or χ^2 according to independent sample t-test or chi-square test.

Br. stages, Brunnstrom stages; MAS of LE, Modified Ashworth Scale of lower extremity; MoCA, Montreal cognition assessment; ST, standard treatment; VR, virtual reality.

Table 3. Intra- and Intergroup Comparisons at Three Evaluation Time Points

Outcome measure	VR group (n=26) Mean ± SD	ST group (n=21) Mean ± SD	Pretest P	Time × group effect F	P	Partial η^2	Time effect F/χ^2	P	Partial η^2	Group effect F/U	P	Partial η^2
BBS												
Pretest	43.35 ± 6.23	43.48 ± 6.62	0.945	0.705	0.497	0.015	10.446	0.000[a]	0.188	0.117	0.734	0.003
Post-test	46.19 ± 5.57	45.71 ± 6.64										
Follow-up	46.31 ± 5.80	45.00 ± 5.06										
FRT												
Pretest	21.43 ± 7.62	22.05 ± 8.27	0.791	3.066	0.051	0.064	1.707	0.187	0.037	0.601	0.442	0.013
Post-test	22.63 ± 5.07	21.84 ± 7.46										
Follow-up	22.48 ± 5.87	18.74 ± 5.88										
TUG-cog[b]												
Pretest	27.18 ± 14.90	32.13 ± 24.63	**0.585**	—	—	—	**9.329**	**0.009**[a]	—	**251.0**	**0.637**	—
Post-test	24.15 ± 10.87	28.48 ± 21.53										
Follow-up	23.52 ± 10.96	28.67 ± 18.73										
MBI[b]												
Pretest	87.31 ± 13.80	88.10 ± 15.69	**0.684**	—	—	—	**1.411**	**0.494**	—	**247.5**	**0.575**	—
Post-test	88.27 ± 14.63	86.90 ± 12.79										
Follow-up	88.85 ± 14.58	89.05 ± 12.91										
ABC												
Pretest	57.00 ± 24.12	66.27 ± 21.32	0.175	1.269	0.266	0.027	0.038	0.963	0.001	0.644	0.528	0.014
Post-test	59.76 ± 25.87	63.96 ± 19.21										
Follow-up	57.44 ± 24.54	65.05 ± 21.30										
SIS												
Pretest	61.06 ± 16.36	61.71 ± 12.51	0.883	0.247	0.782	0.005	1.295	0.279	0.028	0.003	0.955	0.000
Post-test	62.99 ± 18.13	63.10 ± 11.61										
Follow-up	64.56 ± 17.41	63.11 ± 14.03										

Values are presented as mean ± standard deviation.

[a] $p < 0.05$ in comparison between pre- and post-treatment according to two-way ANOVA.

[b] The nonparametric test was performed because the data did not exhibit a normal distribution. The Friedman two-way ANOVA test was used for time effect and the Mann–Whitney *U* test was used for group effect.

ABC, Activities-specific Balance Confidence Scale; BBS, Berg Balance Scale; FRT, Functional Reach Test; MBI, Modified Barthel Index; SIS, Stroke Impact Scale; ANOVA, analysis of variance; TUG-cog, Timed Up and Go test-cognitive.

physical world.[26] In addition, the score performance and a supervising therapist can motivate patients to learn movements.[27] Compared with conventional training, VR training provides a more stimulating, enriching, and pleasurable environment that motivates patients to completely engage in the program.[28]

However, we observed no significant results in the FRT. Hung et al.[28] and Gil-Gómez et al.[16] have reported positive effects in the FRT executed by using the Wii balance board. The FRT requires shifting the weight forward as much as possible so that the leg cannot be moved, which is similar to the requirement of the Wii balance board training.[29] Kinect for Xbox does not restrict patients to the same place, and a patient can step forward or move to control the game. It involves whole body movement, which is similar to that in the real world, without the use of a controller or standing on a narrow board.[30] The results of this study reveal a time effect in balance outcomes, but no significant group effect or group-by-time interaction, which may suggest that both groups improved in a similar manner. The VR group focused on weight shifting and stepping, which was similar to the functional balance training of the ST group. The results support that VR training plus the traditional method and traditional method alone were not significantly different in terms of the improvement of balance effect.

In this study, although the score tended to improve, participation outcomes exhibited no significant improvement on our evaluation tool. A commercial game is designed for leisure and not for ADL function.[26] Patients with low ADL function depended on caregivers for a long time. Although the balance function could improve, the improvement is not adequate to achieve independence in ADL.[31] ABC and SIS are related to self-efficiency in patients after stroke, and balance function, anxiety, and depression may affect these scores.[20] Shin[32] investigated the effectiveness of VR training and occupational therapy in SF-36 and reported that the VR group exhibited improved scores in role limitation because of

Table 4. Feasibility Comparisons of Virtual Reality-Based and Standard Therapy Groups

Outcome measure	VR group (n=26)	ST group (n=21)	P
M-PAES	31.76 ± 2.670	29.36 ± 4.45	0.027[a]
Adverse events	0.06 ± 0.11	0.10 ± 0.13	0.267

[a] $p < 0.05$ according to independent sample *t*-test.

M-PAES, Modified Physical Activity Enjoyment Scale.

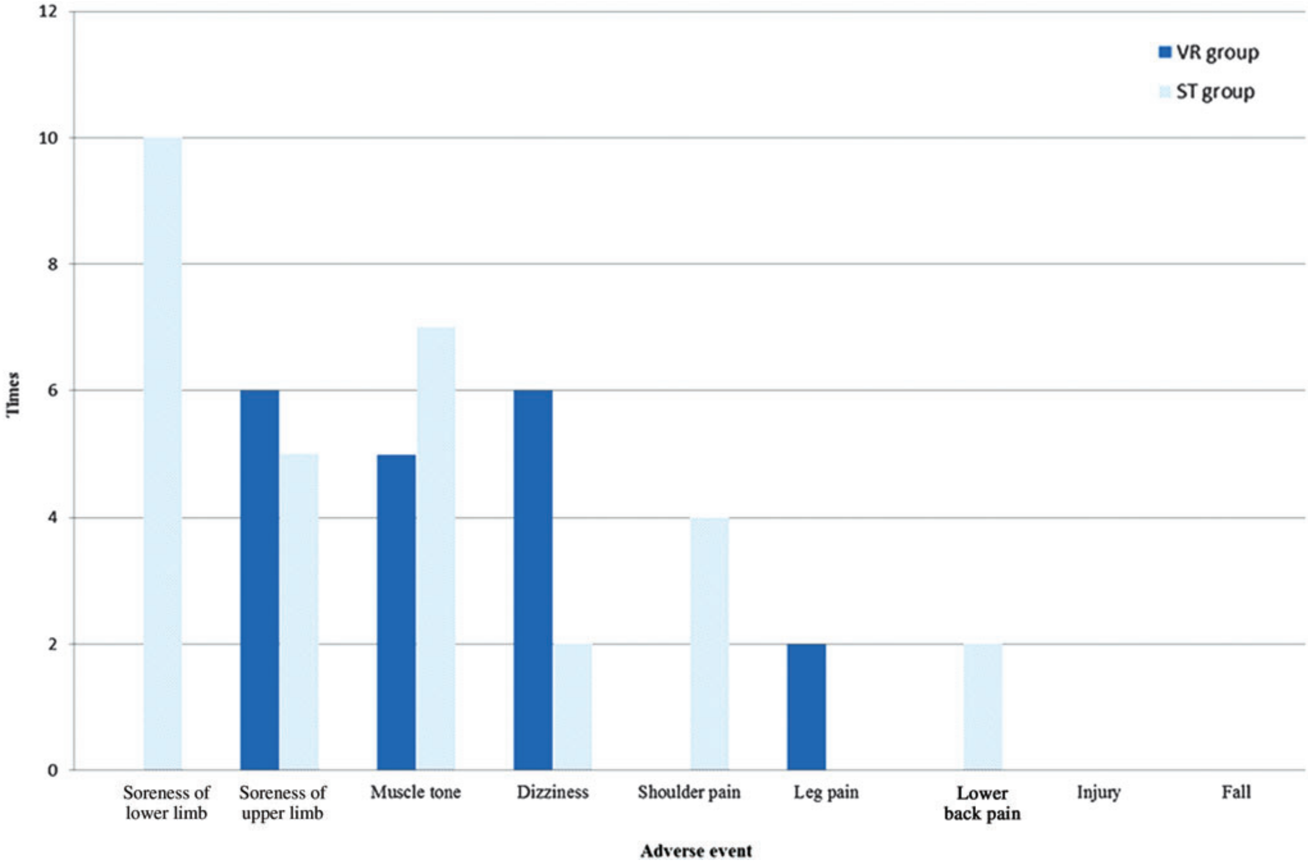

FIG. 3. Adverse events in both groups. In total, 19 adverse events were observed in the VR group and 30 adverse events in the ST group. Soreness of the upper limbs ($n=6$), muscle hypertonicity ($n=5$), dizziness ($n=6$), and leg pain ($n=2$) were observed in the VR group. Soreness of the lower limbs ($n=10$) and upper limbs ($n=5$), muscle hypertonicity ($n=7$), dizziness ($n=2$), shoulder pain ($n=4$), and lower back pain ($n=2$) were observed in the ST group.

physical function. The scores could improve because of familiarity with the game, resulting in remodeling of cognition to perceive improvement in physical function. Patients feel less stressful and engage themselves in the game.[32]

Hung et al.[28] reported that some games (e.g., the basic stepping game) may increase the spasticity and fall risk and that patients easily used compensated movements to play the game initially and then supervising therapists needed to guide them to facilitate optimal movement. Adverse events observed in our study were soreness, hypertonicity, dizziness, and shoulder pain because of task requirements or individual symptoms. All the adverse events recovered after patients took rest and did not continue with the next training session. No serious adverse events were observed in either group because a therapist supervised the safety and adjusted challenges to prevent complications.

Intervention model

Although studies have indicated the effectiveness of the VR training program, difficulties in performing the training in clinics because of space limitations, unfamiliarity of the therapist with the setting, and maintenance problems are encountered.[33] We used a commercial game that could be easily set up and was available in the market. The therapist was only required to be familiar with the characteristics of the game to select a game that matched the rehabilitation goal. Some commercial games are not suitable for patients with stroke. Therapists should be aware of the game design and should analyze the game to match the stroke rehabilitation goal. Patients with motion and cognitive impairment may feel frustrated during the game, particularly elderly people with cognitive impairment.[8] Therapists should supervise and support these patients to encourage compliance.[34]

On the basis of the motor learning theory of Gentile,[13] we analyzed the tasks and added cognition and motion demand after patients became familiar with the system control. Considering that taxonomy-based skill categories present a structure during the transition from simple to complex motor tasks, training program should involve adjusting the difficulty level, providing the adaptation method, and reducing patients' frustration.[35] For example, patients with attention impairment, slow responses, or apraxia require more demonstrations, guidance, and simplification of steps to match their abilities.

Study limitations

Stroke can cause different levels of paralysis such as hemiplegia or hemiparesis that result in a high level of heterogeneity in stroke. For ethical reasons, we did not withhold routine rehabilitation therapy. The lack of tight control on the specific tasks performed during routine therapy was another limitation. Because all the patients were in the chronic stage, they usually received maintenance exercises. Therefore, the compounding effect of routine training might be small.

Conclusions

VR balance training by using Kinect for Xbox games plus the traditional method had positive effects on the balance ability of patients with chronic stroke, and the effects could be maintained after 3 months. The level of pleasure experienced by the VR group was higher than that experienced by the ST group during intervention. Because balance function improved only partially, higher dose and frequency of rehabilitation should be used in future studies to increase the effectiveness of interventions.

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Author Disclosure Statement

No competing financial interests exist.

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