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Research

Video and computer-based interactive exercises are safe and improve task-specific balance in geriatric and neurological rehabilitation: a randomised trial

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KEY WORDS

Randomised controlled trial
Rehabilitation
Exercise
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ABSTRACT

Question: Does adding video/computer-based interactive exercises to inpatient geriatric and neurological rehabilitation improve mobility outcomes? Is it feasible and safe? **Design:** Randomised trial. **Participants:** Fifty-eight rehabilitation inpatients. **Intervention:** Physiotherapist-prescribed, tailored, video/computer-based interactive exercises for 1 hour on weekdays, mainly involving stepping and weight-shifting exercises. **Outcome measures:** The primary outcome was the Short Physical Performance Battery (0 to 3) at 2 weeks. Secondary outcomes were: Maximal Balance Range (mm); Step Test (step count); Rivermead Mobility Index (0 to 15); activity levels; Activity Measure for Post Acute Care Basic Mobility (18 to 72) and Daily Activity (15 to 60); Falls Efficacy Scale (10 to 40), ED5D utility score (0 to 1); Reintegration to Normal Living Index (0 to 100); System Usability Scale (0 to 100) and Physical Activity Enjoyment Scale (0 to 126). Safety was determined from adverse events during intervention. **Results:** At 2 weeks the between-group difference in the primary outcome (0.1, 95% CI −0.2 to 0.3) was not statistically significant. The intervention group performed significantly better than usual care for Maximal Balance Range (38 mm difference after baseline adjustment, 95% CI 6 to 69). Other secondary outcomes were not statistically significant. Fifty-eight (55%) of the eligible patients agreed to participate, 25/29 (86%) completed the intervention and 10 (39%) attended > 70% of sessions, with a mean of 5.6 sessions (SD 3.3) attended and overall average duration of 4.5 hours (SD 3.1). Average scores were 62 (SD 21) for the System Usability Scale and 62 (SD 8) for the Physical Activity Enjoyment Scale. There were no adverse events. **Conclusion:** The addition of video/computer-based interactive exercises to usual rehabilitation is a safe and feasible way to increase exercise dose, but is not suitable for all. Adding the exercises to usual rehabilitation resulted in task-specific improvements in balance but not overall mobility. Registration: ACTRN12613000610730. **[van den Berg M, Sherrington C, Killington M, Smith S, Bongers B, Hassett L, Crotty M (2016) Video and computer-based interactive exercises are safe and improve task-specific balance in geriatric and neurological rehabilitation: a randomised trial. *Journal of Physiotherapy* 62: 20–28]**

Background

Mobility limitation and balance impairment are common consequences of many acute and chronic illnesses.[1] People with mobility limitations can benefit from rehabilitation programs[2,3] particularly if a high dosage of therapy is provided.[4,5] Rehabilitation is most likely to promote re-learning of mobility tasks if it is task-specific,[6] provides feedback about performance,[7] is goal-driven,[8] and is progressive in time and challenge.[9] Unfortunately, people in inpatient rehabilitation are relatively inactive for large portions of their day rather than being engaged in therapeutic activities.[10,11]

Interactive computer or video games that are driven by gross physical movements of the player are known as 'exergames'[12–14] and may increase the dosage of exercise within and outside of therapy sessions. Exergames combine real-time motion detection, and feedback about performance, with games that can help motivate people to exercise. The games incorporated in these systems can be engaging and can provide opportunities for repetitive practice of mobility tasks. For example, the Nintendo WiiFit[a] has been suggested to be suitable for training of balanced standing in stroke rehabilitation[15] and was found to be safe and comparable to usual physiotherapy in geriatric rehabilitation.[16]

A recently updated Cochrane review[17] showed that the use of virtual reality exergames may be beneficial in improving upper limb function and function with activities of daily living when used as an adjunct to usual care. However, studies included in that review focused on the use of one technology only, which limited

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generalisability. Moreover, due to small sample sizes and the low quality of the trials, there was insufficient evidence to reach conclusions about the impact on mobility outcomes. A more recently published systematic review and meta-analysis investigating the use of virtual reality in a stroke population found that substitution of some or all of standard rehabilitation with virtual reality training resulted in improved mobility.[18] However, when data were pooled from trials that used exergames as an addition to standard therapy, there was insufficient evidence of effect due to a lack of trials that evaluated walking speed, and the heterogeneity of the participants.[18] The feasibility of exergame use in rehabilitation settings remains unclear, with one study suggesting that patients prefer traditional therapy.[19] More research is therefore required to evaluate the feasibility and impact of a range of different interactive video and computer systems to address mobility limitations in rehabilitation ward settings.

This study aimed to assess the effectiveness, feasibility and safety of physiotherapist-prescribed, tailored, video/computer-based, interactive exercises as an adjunct to usual care on mobility outcomes, compared to usual care for people undergoing inpatient geriatric and neurological rehabilitation.

Therefore, the specific research questions for this randomised, controlled study were:

1. Does adding physiotherapist-prescribed, tailored, video/computer-based interactive exercises to inpatient geriatric and neurological rehabilitation improve mobility outcomes?
2. Is prescription of a range of tailored, video/computer-based interactive exercises a feasible and safe way of increasing dosage of therapy in the rehabilitation ward setting?

Methods

Design

A randomised, controlled study[20] was undertaken from June 2013 to February 2014. Participants randomised to the experimental group received usual rehabilitation-unit care plus physiotherapist-prescribed, tailored, video/computer-based interactive exercises to usual care. Participants randomised to the control group received usual rehabilitation-unit care alone. Random allocation occurred after baseline testing and blinded outcome assessments were completed in person at Week 2 and via telephone at Weeks 6 and 12. Participants were asked not to disclose their group allocation to the assessors. The participants and intervention physiotherapists could not be blinded to group allocation.

A statistician, who was external to the study, generated the randomisation sequence in random blocks of 2 to 6 using a computer and concealed the group allocations for participants in sequentially numbered, sealed, opaque envelopes. A pharmacist, who was also external to the project, centrally managed group allocation. The pharmacist received an email notification about the completion of each participant's baseline assessment, then opened the envelope to reveal the group allocation, and then notified the intervention physiotherapist by email about group allocation.

Participants, therapists and centre

Patients were recruited following admission to the rehabilitation wards of the Repatriation General Hospital, Adelaide, Australia. A research assistant screened all patients who were admitted to these wards during the study period. Patients were eligible if they had: reduced mobility (Short Physical Performance Battery score of < 12) of recent onset, with a clinician-assessed capacity for improvement in mobility; a minimum length of stay on the rehabilitation ward of 10 days; and a likely life expectancy of > 3 months. Exclusion criteria were: the inability to participate in the study intervention due to marked cognitive impairment (Mini Mental Status Examination < 21) or insufficient English language skills; inadequate vision to use the devices; a medical condition precluding exercise (such as unstable cardiac disease, uncontrolled hypertension, uncontrolled metabolic diseases, large abdominal aortic aneurysm or a weight-bearing restriction); or a lack of interest in the use of the exergames (assessed by simply asking the patient if they would be interested in participating in the study intervention). Patients were also excluded when the treating physiotherapists or medical specialist considered the intervention to be inappropriate for the patient.

The usual rehabilitation care received by participants in both groups included assessment and management by medical specialists, nurses, physiotherapists and occupational therapists, as well as by speech pathologists, social workers and nutritionists, if required. Physiotherapists who delivered usual care did not provide the experimental intervention and physiotherapists who delivered the experimental intervention did not provide usual care to participants.

Intervention

The additional intervention received by participants randomised to the experimental group involved an additional hour of video/computer-based interactive exercises per day, delivered in a circuit class format, five times per week. It was held in a purposefully designed video/computer-based interactive exercise space, and supervised by one physiotherapist and one physiotherapy assistant. Exercise prescription in rehabilitation is always tailored in type, dose and intensity to suit each individual's needs. The present study followed a similar approach; it was not expected that one device or exergame would be suitable for every participant. Therefore, a range of devices and games were used that were individually prescribed by a physiotherapist. The games or exercises on the video and computer-based interactive systems were: functionally relevant; provided feedback about task performance; enabled individualised tailoring and progression of exercise difficulty; enabled progress to be recorded towards a functionally relevant goal; and were relatively inexpensive.

A combination of commercially available off-the shelf devices and rehabilitation-specific systems was used. The commercially available devices included Nintendo Wii[a] and Xbox Kinect[b] gaming systems, utilising movement-based input for its games. The rehabilitation-specific systems were the HUMAC[c], Modular Interactive Stepping Tiles,[21,22] and the Dance Mat Step Training System.[23,24] The HUMAC balance system couples its balance software with a balance board. The software includes balance and weight-bearing tests, exercise protocols and balance games, and provides the user with continuous real-time visual biofeedback (eg, centre of pressure display). The Dance Mat Step Training System developed by one of the authors (Smith) can be used to assess and practise stepping skills.[25] Games to practise stepping skills involve stepping in response to prompts on a screen. The mat has four step-sensitive target panels. Patients stand at the centre of the mat and make left, right, forward or backward step responses to a sequence of step instructions that are presented on the screen. The Modular Interactive Stepping Tiles was developed by one of the authors (BB) and can be arranged in different permutations, as appropriate, so that standing balance and stepping skills in all directions can be practised with integrated visual feedback about weight taken through each leg and the number of steps taken. Game prescription was based on the protocol shown in Box 1.

Additionally, participants in the intervention group wore an activity monitor[d] for the 12 weeks after randomisation. The clip-on activity monitor was portable, lightweight, and the size of a USB pen drive. It provides motivation to increase activity through real-time feedback. During the exercise classes the physiotherapist provided feedback on daily activity levels, including step count, with detailed graphs and charts displayed on a portable electronic display device when syncing the activity monitor.

Box 1. Summary of the protocol for the use of exergames during and after hospital stays.

Mobility task	Problem	Exergame	Feedback	Progression and motivation
Balance in standing	Poor strength and control of the body's postural muscles	HUMAC[a], Modular Interactive Stepping Tiles, Nintendo Wii[b], Xbox Kinect[c]	HUMAC and Modular Interactive Stepping Tiles: weight distribution (lateral, anteroposterior). Nintendo Wii and Xbox Kinect: body position in space (including arm movement).	HUMAC and Modular Interactive Stepping Tiles: increasing weight borne through more affected leg, standing for longer. Nintendo Wii and Xbox Kinect: more complex games.
Reaching while standing	Poor strength and control of postural muscles	HUMAC[a], Modular Interactive Stepping Tiles, Xbox Kinect[c]	HUMAC and Modular Interactive Stepping Tiles: weight shift. Xbox Kinect: successfully 'hitting' objects on the screen.	HUMAC and Modular Interactive Stepping Tiles: reaching further encouraged by increased weight transfer. Xbox Kinect: reaching faster and further encouraged by increased target position and speed in game.
Stepping in standing	Poor strength/ standing balance/ postural control/ difficulty weight shifting	Modular Interactive Stepping Tiles, Nintendo Wii[b], Xbox Kinect[c]	Modular Interactive Stepping Tiles: weight taken through each leg and number of steps taken. Nintendo Wii and Xbox Kinect: body position in space while walking on the spot or stepping forward/ backward/sideways.	Modular Interactive Stepping Tiles: increasing weight borne through more affected leg, increased number of steps taken. Nintendo Wii and Xbox Kinect: increased duration, speed and difficulty level of game.
Changing direction while walking	Slow reaction time to step in a different direction	Modular Interactive Stepping Tiles, Dance Mat Step Training System, Nintendo Wii[b], Xbox Kinect[c]	Modular Interactive Stepping Tiles: weight taken through each leg and number of steps taken. Dance Mat Step Training System: time to complete step sequence, score in game. Nintendo Wii and Xbox Kinect screen: body position in space while stepping in different directions.	Modular Interactive Stepping Tiles: increasing weight borne through more affected leg, increased number of steps taken. Dance Mat Step Training System: increased speed and difficulty level of game. Nintendo Wii and Xbox Kinect screen: stepping faster and further encouraged by object position and movement speed.
Physical activity throughout the day	Little activity outside structured therapy times	Fitbit[d]	Fitbit: displays number of steps taken, distance travelled, and calories burned.	Fitbit: increased number of steps, goal setting, and achievement badges.

[a] Nintendo WiiFit™, Nintendo, Kyoto, Japan.
[b] Xbox Kinect™, Microsoft Redmond Campus, Redmond, WA, USA.
[c] HUMAC balance system, CSMi solutions, Stoughton, MA, USA.
[d] Fitbit Zip™, Fitbit Inc., San Francisco, CA, USA.

Outcome measures

The primary outcome was a mobility task performance (0 to 3 points), measured 2 weeks after randomisation as part of the continuously scored version[26] of the Short Physical Performance Battery (SPPB).[27] The SPPB (0 to 12 points) is designed to measure functional status and physical performance. It is calculated from three components: the ability to stand for up to 10 seconds with feet positioned in three ways (together side by side, semi-tandem and tandem), 4-metre walk (seconds) and time to rise from a chair five times (seconds).[28]

Secondary measures included: the Maximal Balance Range test[29] (participants' ability to lean as far forward and backwards as possible, measured in mm); the Step Test[30] (stepping onto and off a 7.5-cm block as many times as possible in 15 seconds); and self-reported mobility, as measured with the Rivermead Mobility Index (0 to 15 points).[31] Physical activity was measured for 7 days with the activPAL[e] during Week 2 and with the ActiGraph GT3X[f] in Week 12.

Fall-related self-efficacy was assessed using the Falls Efficacy Scale,[32] in which level of concern about falling when carrying out a range of activities is rated on a 4-point scale (total score 7 to 28). Quality of life was assessed using the EuroQol-5D questionnaire,[33] which includes the visual analogue scale (EQ-VAS) and a self-rated health status (0 to 100%). Responses to the EuroQol-5D were converted to a utility score (0 to 1) using a scoring algorithm based on general population values for all possible health states defined by the instrument.[34] Self-report measures of activity were collected using the Activity Measure for Post Acute Care (AMPAC) Basic Mobility (18 to 72 points) and Daily Activity (15 to 60 points).[35] Participation across multiple areas of life was measured with the Reintegration to Normal Living Index (0 to 100).[36]

The physiotherapist and assistant providing the intervention kept records of treatment sessions, including the number of sessions completed, adherence and technologies used. 'System usability' and impressions of the different devices was assessed among all intervention group participants with the System Usability Scale. The System Usability Scale (0 to 100 points) is a reliable scale that allows an assessment of 'appropriateness to a purpose' of any product or service.[37] Enjoyment of the intervention was assessed at the completion of the study using a specifically designed questionnaire incorporating the Physical Activity Enjoyment Scale (0 to 126 points).[38] In addition, any adverse events

relating to a participants' emotional, psychological or physical state during their engagement in the research trial were recorded. In particular, participants were closely monitored for levels of exertion and falls during intervention.

Data analysis

A total of 58 participants (29 per group) was needed to detect a 15% between-group difference in the primary outcome measure: the continuous summary score of the SPPB with 80% power. The sample size calculation was undertaken using the *sampsi* command in Stata software[g] and data from a previous study.[39] The calculation used a mean continuous 3-point summary SPPB score of 1.6 (SD 0.41), assuming: one pre-randomisation measure; one follow-up measure; analysis using linear models with baseline scores entered as covariates; a correlation between pre and post measures of 0.7;[40] and a 20% dropout rate. This sample size was also sufficient to detect between-group differences of 10 to 15% in most of the secondary outcome measures.

To determine the effect of group allocation on continuously scored outcome measures, between-group differences were

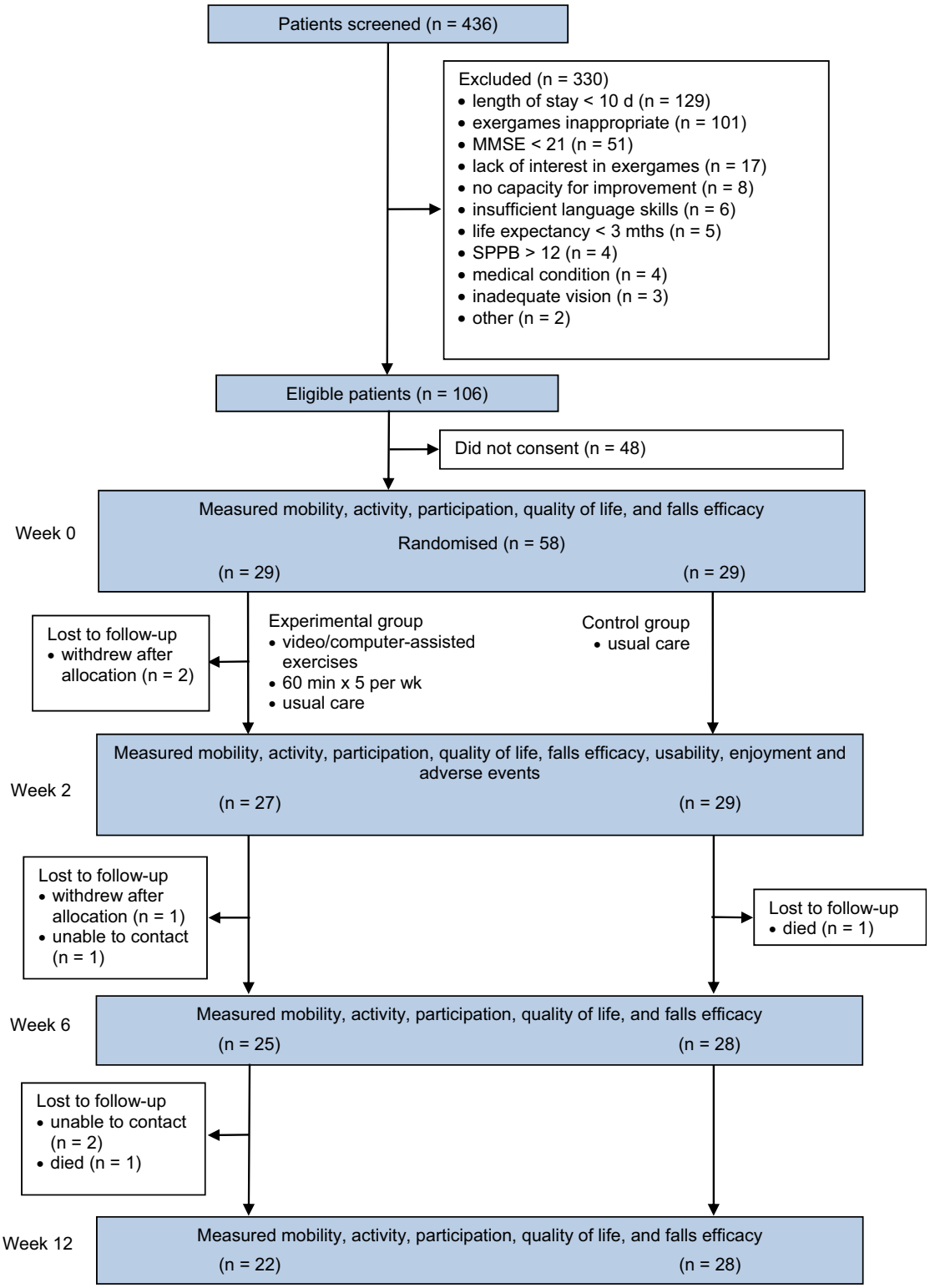

Figure 1. Design and flow of participants through the trial
MMSE = Mini Mental State Examination, SPPB = Short Physical Performance Battery.

Table 1
Participant characteristics at baseline.

Characteristic	Exp (n = 29)	Con (n = 29)
Age *(y)*, mean (SD)	78 (10)	82 (13)
Gender, n male (%)	10 (35)	12 (41)
Mini Mental State Examination *(0 to 30)*, mean (SD)	26 (3)	27 (3)
Reason for admission/primary diagnosis, n (%)		
stroke	1 (3)	2 (7)
other neurological	2 (7)	1 (3)
fracture	6 (21)	8 (28)
other orthopaedic	2 (7)	5 (17)
cardiac/pulmonary	3 (10)	2 (7)
infection	4 (14)	0 (0)
functional medical decline/reconditioning	3 (10)	5 (17)
fall	3 (10)	3 (10)
other	4 (14)	2 (7)
Use walking aid, n (%)	26 (90)	28 (97)

Con = control intervention, Exp = experimental intervention.

examined using generalised linear regression models with baseline scores entered as covariates. Statistical significance was set at $p < 0.05$ and the groups were compared at Weeks 2, 6 and 12 of follow-up, reporting mean between-group differences with 95% CI. For participants unable to undertake the SPPB tests due to physical impairment, a score of 0 was given for the timed standing balance components (as a low score is a poor score), 0 m/s for gait (as a low score is a poor score) and the maximum time for sit to stand (ie, 32.1 seconds). Individuals who were able to complete the tests, but whose sit-to-stand time was > 32.1 seconds, were also assigned a time of 32.1 seconds. Similarly, for other tests where a low score reflects poor performance, a value of 0 was assigned when a participant was unable to undertake the test due to physical impairment, and for tests where a high score reflects poor performance, a value of the mean plus three SD was assigned.

Results

Flow of participants through the study

Participant flow and reasons for dropout are presented in Figure 1. A total of 436 patients were screened for eligibility and 330 (76%) did not meet the inclusion criteria. The main reasons for ineligibility were: a length of stay < 10 days; the intervention being inappropriate, in the clinician's opinion, because of cognitive, behavioural or medical issues; and the inability to balance in standing, despite the assistance of a staff member or walking aid. Forty-eight of the 106 eligible patients (45%) declined to participate for various reasons such as 'it is too much' or 'I am happy with the care I receive'. The remaining 58 patients met the eligibility criteria and consented.

Table 1 shows the participants' baseline characteristics by treatment group. Participants were predominantly female (62%) with an average age of 80 years (SD 12), and all but four participants used a walking aid. The first two columns of data in Tables 2 and 3 show the baseline performance on the outcome

Table 2
Mean (SD) of groups and mean (95% CI) difference between groups.

Outcome	Groups				Mean difference[a] (95% CI)
	Week 0		Week 2		Week 2
	Exp (n = 29)	Con (n = 29)	Exp (n = 27)	Con (n = 29)	Exp minus Con
Summary Performance *(0 to 3)*, mean (SD)	1.4 (0.5)	1.4 (0.4)	1.7 (0.6)	1.6 (0.5)	0.1 (−0.2 to 0.3)
Short Physical Performance Battery *(0 to 12)*, mean (SD)	4.3 (1.9)	3.7 (1.8)	5.2 (2.3)	4.5 (2.0)	0.2 (−0.9 to1.2)
sit to stand *(s, 0 to 32.1)*, mean (SD)	31.2 (2.4)	30.4 (4.3)	27.9 (6.7)	28.4 (6.9)	−1.1 (−14.4 to 2.2)
gait speed *(m/s)*, mean (SD)	0.36 (0.21)	0.35 (0.13)	0.49 (0.23)	0.43 (0.15)	0.03 (−0.05 to 0.11)
standing balance *(0 to 30 s)*, mean (SD)	22 (7)	21 (8)	25 (6)	22 (8)	2 (−2 to 5)
Maximal Balance Range *(mm)*, mean (SD)	122 (64)	106 (40)	163 (68)	110 (58)	38 (6 to 69)
Step Test *(steps)*, mean (SD)	5.2 (6.3)	4.4 (5.5)	8.5 (8.4)	5.6 (5.6)	2.1 (−0.1 to 4.2)
10-m timed walk *(m/s)*, mean (SD)	0.4 (0.2)	0.4 (0.2)	0.5 (0.3)	0.5 (0.2)	0.1 (0.0 to 0.2)

Con = control intervention, Exp = experimental intervention. Rows for the primary outcomes are shaded.
[a] Adjusted for baseline.
Performance tests were administered only at baseline and Week 2. Summary performance score: 0 = worst possible severity, 3 = best; Short Physical Performance Battery: 0 = worst, 12 = best; Standing Balance: 0 = worst, 30 = best score.

Table 3
Mean (SD) of interventions and mean (95% CI) difference between interventions.

Outcome	Groups								Difference between groups[a]	
	Week 0		Week 2		Week 6[b]		Week 12		Week 2	Week 12
	Exp (n = 29)	Con (n = 29)	Exp (n = 27)	Con (n = 29)	Exp (n = 25)	Con (n = 28)	Exp (n = 22)	Con (n = 28)	Exp minus Con	Exp minus Con
Rivermead Mobility Index *(0 to 15)*	7.5 (3.4)	7.4 (2.8)	9.7 (4.4)	9.2 (2.3)	10.2 (3.1)	10.0 (2.8)	10.2 (2.8)	9.7 (3.0)	0.6 (−1.0 to 2.2)	0.3 (−1.4 to 1.9)
AMPAC Basic Mobility *(18 to 72)*	33 (9)	30 (7)	36 (9)	34 (8)	38 (8)	37 (9)	41 (9)	36 (9)	0 (−4 to 3)	3 (−3 to 8)
AMPAC Daily Activity *(15 to 60)*	33 (11)	32 (8)	34 (12)	33 (11)	32 (18)	32 (11)	34 (11)	32 (11)	1 (−4 to 5)	0 (−5 to 6)
Reintegration to Normal Living Index *(0 to 100)*	31 (8)	33 (6)	33 (10)	33 (7)	34 (8)	31 (8)	36 (8)	33 (8)	0 (−4 to 4)	3 (−1 to 8)
Quality of Life EQ5D utility score *(0 to 1)*	0.6 (0.2)	0.5 (0.2)	0.6 (0.2)	0.6 (0.2)	0.7 (0.2)	0.6 (0.3)	0.7 (0.3)	0.6 (0.2)	0.0 (−0.1 to 0.1)	0.1 (−0.1 to 0.2)
Quality of Life EQ5D VAS score *(0 to 100%)*	62 (16)	61 (17)	70 (20)	63 (19)	68 (19)	65 (24)	66 (19)	55 (17)	10 (−1 to 21)	9 (−3 to 20)
Falls Efficacy Scale *(10 to 40)*	21.4 (9.0)	26.0 (9.1)	22.3 (9.5)	24.5 (10.1)	19.9 (9.4)	20.0 (7.4)	18.5 (8.8)	20.9 (9.0)	−0.9 (−4.7 to 3.0)	−1.2 (−6.3 to 3.8)

AMPAC = Activity Measure for Post Acute Care, Con = control intervention, Exp = experimental intervention.
[a] Adjusted for baseline.
[b] Week 6 comparisons were also all non-significant; data are available on request from the authors.
Rivermead Mobility Score: 0 = worst, 15 = best; AMPAC Basic Mobility: 18 = worst, 72 = best; AMPAC Daily Activity: 15 = worst, 60 = best; Reintegration to Normal Living Index: 0 = worst, 100 = best; Quality of Life EQ5D utility score: 0 = worst, 1 = best; Quality of Life EQ5D VAS score: 0 = worst, 100 = best; Falls Efficacy Scale: 10 = best, 40 = worst.

measures. There were no marked differences between the groups at baseline.

Compliance with the study protocol

Of the 58 participants, 56 completed the assessment at Week 2, and 50 completed the telephone assessment at Week 12. Some participants were discharged prior to 14 days and so completed the Week 2 assessment before 14 days just prior to their discharge from hospital. Of the 29 participants randomised to the experimental group, 25 completed the intervention. Two withdrew from the study (one due to medical reasons and one due to lack of interest), and two participants withdrew from the intervention only (one due to medical reasons and one due to a move interstate). Lack of resources prevented the collection of additional pre-planned outcomes, including the 2-minute walk test, number of falls, and health and community service use.

Effect of the intervention

Outcomes for the experimental and control groups and between-group differences at Weeks 2, 6 and 12 are presented in Tables 2 and 3. Individual patient data are presented in Table 4, available on the eAddenda. At Week 2, the performance on the primary outcome measure, SPPB, was not significantly different between groups (MD 0.1, 95% CI −0.2 to 0.3). Performance on the Maximal Balance Range test was significantly better in the intervention than the control group at Week 2 (between-group difference after baseline adjustment 38 mm, 95% CI 6 to 69). Between-group differences were not statistically significant for other secondary outcomes but there were trends towards better walking speed (0.1 m/s, 95% CI 0.0 to 0.2) stepping (2.1 steps, 95% CI −0.1 to 4.2) and self-rated health status on the EuroQol-5D VAS (10%, 95% CI −1 to 21) in the experimental group compared with the control group at Week 2 (see Tables 2 and 3).

Table 5
Dosage of interventions received.

Characteristic of intervention received	
Dose	
total sessions *(n)*, mean (SD)	5.6 (3.3)
duration of session *(min)*, mean (SD)	47.8 (7.5)
activity *(min)*, mean (SD)	30.5 (8.5)
activity + moving between stations *(min)*, mean (SD)	34.1 (8.5)
rest *(min)*, mean (SD)	13.6 (4.8)
Attendance *(% of participants)*	
> 70% of sessions	39
> 80% of sessions	31
> 90% of sessions	19
Participants using each technology *(n)*	
Modular Interactive Stepping Tiles	25
HUMAC[a]	24
Dance Mat Step Training System	20
Wii[b]	25
Xbox Kinect[c]	8
Average time using each technology during session *(%)*	
Modular Interactive Stepping Tiles	13
HUMAC[a]	30
Dance Mat Step Training System	16
Wii[b]	31
Xbox Kinect[c]	10

[a] HUMAC balance system, CSMi solutions, Stoughton, MA, USA.
[b] Nintendo WiiFit™, Nintendo, Kyoto, Japan.
[c] Xbox Kinect™, Microsoft Redmond Campus, Redmond, WA, USA.

Feasibility and safety of the intervention

Participants received an average of 5.6 intervention (SD 3.3) sessions. The average duration of the sessions was 48 minutes, of which patients were actively engaged in exercise for about 34 minutes. About one third attended > 80% of the scheduled sessions.

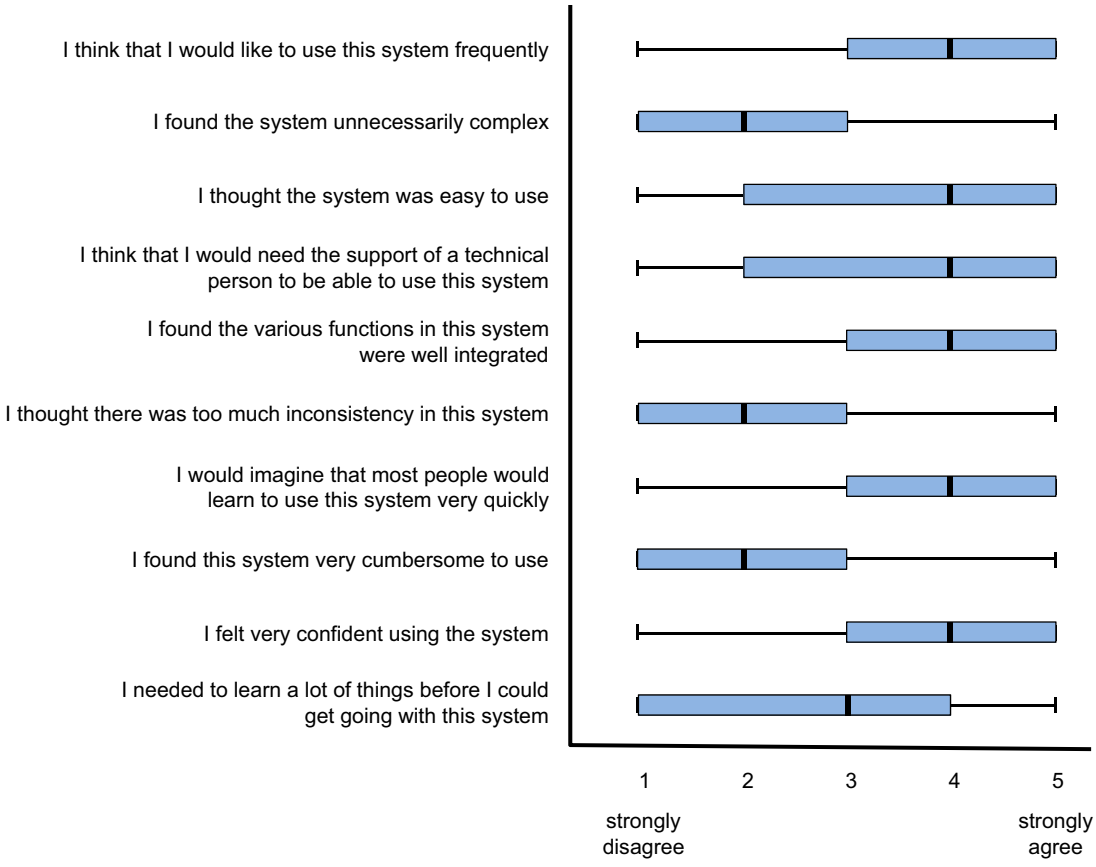

Figure 2. Boxplots of the System Usability Scale. The thick vertical line represents the median, the box the IQR, and the whiskers the minimum and maximum values.

Scores on the System Usability Scale had a mean of 62 (SD 21), indicating that participants were generally comfortable with the technology and that the equipment was easy to use once they had been trained in its use (see Figure 2). They also felt that future users would learn to use it very quickly. The scores on the Physical Activity Enjoyment Scale had a mean of 62 (SD 8), demonstrating that participants generally enjoyed the intervention.

No serious adverse events were reported. Table 5 provides details on the intervention delivery, dose and attendance rates, and the frequency and duration the various technologies that were used during intervention sessions.

Discussion

This study found that increasing the dose of repetitive exercise for people undergoing geriatric and neurological inpatient rehabilitation using individually prescribed video/computer-based interactive exercises was safe and feasible. While the approach did not impact on the primary outcome (ie, mobility task performance measured with the SPPB), statistically significant task-specific changes in balance were observed. Also, a clinically meaningful increase in walking speed was observed in the intervention group, although the between-group differences were not statistically significant. A total of 55% of eligible patients consented to take part in the trial, suggesting that this approach is not suitable for all people on rehabilitation wards. Common reasons for not consenting were feeling overwhelmed, not wishing to participate in additional intervention and being satisfied with usual care received.

A combination of commercial and purpose-built equipment was used in a population with mixed diagnoses and an average age of 80 years. Exergames could be used to supplement existing approaches for those undergoing neurological or geriatric rehabilitation, thereby giving people the opportunity for more practice. By using a variety of devices, the exergame intervention was individually tailored, addressing mobility limitations and patient goals. The findings revealed a high level of acceptance; participants generally engaged, and the majority enjoyed the experience of the exergame intervention and evaluated it positively. Participants were comfortable with the equipment and found the exergames easy to use once they had been shown how to use them. A combination of commercially available and rehabilitation-specific devices was used. It has been suggested that exergames are most practical and effective in rehabilitation settings when they have been specifically designed for therapy purposes[41] and there is some concern that commercial games are too difficult for some patients. In the present study, it was found that using off-the-shelf equipment was feasible, but appropriate game selection and careful attention to matching patients' abilities with difficulty level was essential. Previous studies have suggested that exergame-based programs can be performed independently at home.[42] Some of the commercial exergames that are too difficult or complex in the acute stage of inpatient rehabilitation may be suitable for ongoing rehabilitation in the community setting.

The SPPB is a well-established and valid measure of lower-extremity and physical functioning in the older population. Low total scores on the SPPB have been found to be predictive of disability in activities of daily living,[43] loss of mobility,[44] disability,[27,43] hospitalisation,[45] length of hospital stay,[46] admission to nursing facilities,[27] and death.[47] The lack of impact on the SPPB has several possible explanations. Participants received an average of only six intervention sessions during their inpatient stay, which may not have been sufficient to lead to a significant difference in overall mobility. In some cases, the exercise setup may not have been challenging enough to result in improvement of functional mobility. Most patients needed stand-by assistance while standing. If the therapist was not nearby, assistive devices such as walking frames were used for safety reasons and participants did not progress to performing the exercises without support.

Previous research on the effects of exergames on balance and gait has been performed in community-dwelling older adults. Similar to the present results, Wüest and colleagues[48] and Lai and colleagues[49] reported positive effects from exergames on clinical measures of balance, but an absence of overall mobility or gait-related effects. Szturm and colleagues[50] also examined an exergame-based intervention with goal-directed weight-shifting tasks and found no significant improvement in gait parameters.[48] A wider range of equipment technologies may lead to improvement in other aspects of functional mobility.

Future studies could concentrate more on mobility and activity levels outside the intervention session, by focusing more on the activity monitoring records (eg, step count) and on the activity goals, thereby reinforcing progress towards the goals. In addition, using new feedback technologies, including sensors and algorithms to quantify balance during sessions, and using this information to individualise training may optimise improvements for patients.[51]

Maximising adherence is a crucial element for the success of exercise therapy. A recent systematic review reported that 65 to 86% of older participants completed exercise programs and 58 to 77% of available intervention sessions were attended.[52] In the present study, 25 out of 29 (86%) participants completed the exercise program and an average of 65% of the sessions were attended. A practical barrier for some of the participants was the fact that they had to be transported across the hospital grounds by a porter in order to attend the sessions, as the intervention was delivered as a circuit class at a fixed time, five days a week. One-to-one sessions would have the advantage of allowing scheduling at a time that best suits the patient where possible, which may increase adherence rates. Additionally, individual semi-supervised sessions may facilitate the use of a wider range of devices and technologies, as well as the provision of more challenging exercise. Further research should also explore the suitability of independent use of the equipment.

Study strengths were: concealed allocation to groups; blinded assessors; a pragmatic intervention design; a variety of devices ensuring the exergame intervention was individually tailored; and the inclusion of a wide range of rehabilitation patients, which ensured a representative study sample. The major limitation of this study was that participants were aware of their group allocation, which may have introduced a bias to the self-report measures.

In conclusion, this study used a combination of commercially available, off-the-shelf, and purposefully developed systems. It demonstrated that the use of video/computer-based interactive exercises in inpatient rehabilitation is a safe, reasonably acceptable way to increase the dose of repetitive exercise. In this small sample there was an indication of task-specific improvements in balance, but not in overall mobility. Trends towards better walking speed, stepping and self-rated health status in the intervention group were calculated. It will be important to undertake a larger trial to investigate whether the trends in this study result in statistically significant changes in a larger sample. In addition, future trials are needed to establish whether a broader range of technologies could have a greater impact on mobility and to establish the safety, feasibility, and efficacy of home-based exergame use after discharge from inpatient rehabilitation. This study suggests that those patients who are willing to try such an intervention and who are able to play the games without physical assistance are the most appropriate candidates for the games included in this study. However, future studies should investigate the characteristics and motivations of the non-consenters (47%) and consenters, in order to understand which patients are more likely to accept this model of rehabilitation and whether the approach can be adapted to encourage greater engagement and adherence.

What is already known on this topic: People with mobility problems due to age or neurological conditions benefit from inpatient rehabilitation, especially if high doses of exercise are used. However, many of these inpatients are inactive for large portions of their day. Interactive computer or video games that are driven by the player's gross physical movements are known as 'exergames' and may increase the dosage of exercise within and outside of therapy sessions.
What this study adds: Exergames could be safely incorporated into inpatient neurological and geriatric rehabilitation. Adding exergames to usual rehabilitation led to task-specific improvements in balance but not in overall mobility. Further research should investigate the positive trends that were observed in the walking speed, stepping and self-rated health status of the participants who used exergames.

***Footnotes*:** [a]Nintendo WiiFit™, Nintendo, Kyoto, Japan, [b]Xbox Kinect™, Microsoft Redmond Campus, Redmond, WA, USA, [c]HUMAC balance system, CSMi solutions, Stoughton, MA, USA, [d]Fitbit Zip™, Fitbit Inc., San Francisco, CA, USA, [e]activPAL™, PAL Technologies Ltd, Glasgow, UK, [f]ActiGraph GT3X, ActiGraph, LLC, Fort Walton Beach, FL, USA, [g]Stata 12, College Station, TX, USA

***eAddenda*:** Table 4 can be found online at doi:10.1016/j.jphys.2015.11.005

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