Geriatrics & Gerontology International

DOI: 10.1111/ggi.14771

ORIGINAL ARTICLE
GERONTECHNOLOGY

Feasibility, safety, and effects of a Nintendo Ring Fit Adventure™ balance and strengthening exercise program in community-dwelling older adults with a history of falls: A feasibility randomized controlled trial

Wayne Lap Sun Chan,[1] Cody Wing Lam Chan,[1] Freddy Man Hin Lam,[1] Howard Ho Wing Chan,[1] Kelvin Chi Kin Chan,[1] Jerry Sai Kit Chan,[1] Oscar Lok Wang Chan[1] and Daphne Sze Ki Cheung[2]

[1]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, Hong Kong
[2]School of Nursing, The Hong Kong Polytechnic University, Hong Kong, Hong Kong

Correspondence
Wayne Lap Sun Chan, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, ST 505, 5/F, Ng Wing Hong Building, Hong Kong.
Email: wayne.ls.chan@polyu.edu.hk

Received: 24 August 2023
Revised: 7 November 2023
Accepted: 26 November 2023

Aim: This pilot study examined the feasibility, safety, and effects of a Nintendo Ring Fit Adventure™-based exercise program to enhance balance and lower limb muscle strength in community-dwelling older adults with a history of falls.

Methods: In total, 42 older adults who experienced at least one fall in the past year were randomly assigned to an experimental or control group. Participants in the experimental group performed 60-min sessions of the exercise program twice per week for 8 weeks. The control group received usual care. We assessed the feasibility (retention and adherence to the exercise program), safety (number of adverse events), and clinical outcomes: (1) balance (Mini-BESTest); (2) functional lower limb muscle strength (Five-Time Sit-to-Stand test); (3) mobility (Timed-Up and Go test); (4) dual-task ability (Timed-Up and Go test – Dual Task); (5) fear of falling (Icon-FES); and (6) executive function (Color Trails Test).

Results: Thirty-one participants (74%) completed the 8-week assessment. No adverse event associated with the exercise program was reported. There was a significant interaction in the anticipatory domain score of the Mini-BESTest between the experimental and control groups over the 8 weeks ($P = 0.019$).

Conclusions: The Nintendo Ring Fit Adventure™-based exercise program was feasible, safe, and potentially effective in improving anticipatory balance in community-dwelling older fallers. **Geriatr Gerontol Int 2024; 24: 334–341**.

Keywords: exergaming, falls, gerontechnology, rehabilitation.

Introduction

Falls affect one in three community-dwelling older adults annually[1] and can lead to numerous complications, such as hip fractures, decreased mobility, admission to nursing homes, and early mortality.[2] Balance deficits and decreased muscle strength are among the various factors strongly associated with falls in the older population.[3,4] Exercise and physical activity can effectively enhance balance and muscle strength in older individuals, making them crucial components in fall prevention interventions.[5,6] However, the participation of older adults with an increased risk of falls (e.g., having a history of falls) in exercise interventions has been suboptimal[7,8] due to barriers such as low self-efficacy, fear of falling, absence of previous exercise experience, and safety concerns.[9,10]

Technological interventions such as exergaming are being increasingly used to promote fitness and health. Exergaming, also known as active video gaming, combines exercise and video games by leveraging various technologies such as motion sensors, balance boards, dance mats, and virtual reality.[11] Players are required to use their bodily movements to control and guide the game. Several features of exergaming, such as providing immediate feedback, consistent engagement, and bringing joy to players, are regarded as potential strategies to enhance the motivation and adherence to exercise interventions among older populations.[12,13] Growing evidence indicates that exercise programs using exergaming systems have been demonstrated to be effective in improving balance, lower limb muscle strength, and gait and reducing falls in older adults.[14–18]

The Nintendo Ring Fit Adventure™ (NRFA; Nintendo) is an action role-playing exergame designed to promote fitness and physical activity. Players are required to move their body parts while holding a ring-shaped controller and complete different exercise tasks, including aerobic, resistance, and yoga exercises, to defeat opponents in the game.[19] Players are required to perform the exercise tasks based on the verbal, visual, and tactile feedback provided by the device and further improve their performance. Some preliminary studies have reported that the NRFA is feasible, safe, and effective in enhancing physical function in older individuals with musculoskeletal problems.[19,20] However, no study has been conducted to determine whether older adults with a history of falls can use the NRFA to overcome the aforementioned

barriers to participating in fall prevention exercise interventions. The feasibility and safety of using the NRFA to train balance and muscle strength in older adults with a history of falls are yet to be investigated. Moreover, the potential effects of NRFA-enhanced exercise interventions on balance, muscle strength, and other risk factors for falls in older adults remain uncertain.

The objectives of this pilot trial were to investigate the feasibility and safety of an NRFA-based exercise program and explore the potential effects of the program for community-dwelling older adults who had experienced falls in the past year. We also explored the potential effects of the exercise program on various clinical outcomes, including balance, lower limb muscle strength, general mobility, dual-task ability, executive function, and fear of falling in this population.

Methods

Study design

This study was a pilot randomized, assessor-blinded, parallel-group, controlled trial. This study was conducted in accordance with the Declaration of Helsinki[21] and approved by the Institutional Review Board of the Hong Kong Polytechnic University and participating organizations before data collection. All eligible participants provided written informed consent before the baseline assessment. The trial protocol was registered on ClinicalTrials.gov (identifier: NCT05949359). This study adheres to the Consolidated Standards of Reporting Trials (CONSORT) for maintaining reporting quality.[22]

Participants

Participants were recruited from a local community center for older adults in Hong Kong. Between September 2022 and May 2023, social workers affiliated with the participating community center reviewed and identified potential candidates who fulfilled the study inclusion criteria, i.e., (1) were aged ≥60 years, (2) had at least one fall in the past year, (3) could walk independently without a walking aid for at least 10 m, and (4) had no experience of using the NRFA.

Individuals were excluded if they (1) had a severe musculoskeletal, cardiopulmonary, or neurological condition that impeded their participation in the assessment or exercise program; (2) had a substantial visual or hearing impairment that limited their ability to follow exercise instructions; (3) scored below the age- and education-adjusted cut-offs in the Hong Kong version of the Montreal Cognitive Assessment (HK-MoCA)[23]; or (4) had participated in any structured exercise program in the past 6 months.

Randomization and blinding

Upon completion of the baseline assessment, the participants were randomly assigned to either the experimental (EG) or control group (CG) at a ratio of 1:1. Randomization was performed by asking the participants to draw a random slip of paper indicating their group allocation from a concealed plastic box. Staff members involved in the study had no control over the allocation. The assessor was blinded to the group allocation. However, the participants were not blinded to the group allocation due to the nature of the study design.

Intervention

The exercise program was conducted at a local community center. The participants in the EG were guided by an exercise instructor to play the NRFA. The NRFA captured the strength of the participants at the beginning of the exercise program using a ring-shaped controller designed for the NRFA, and tailored the strength required to perform each exergame for each participant. Each exercise session starts with asking the participants to stand up and grasp the ring-shaped controller with both hands. The participants were instructed to follow voice-over instructions, on-screen texts, and animated video demonstrations provided by the NRFA to complete each exergame.

The exercise program consisted of two 60-min sessions per week for 8 weeks. Each session consists of a 5-min warm-up exercise, 50-min core balance and muscle strengthening exercises, and a 5-min cool-down exercise. Table 1 presents the details of the exercise program. In short, each 50-min core exercise section consisted of four types of exergames: (1) yoga (Fig. 1a), (2) lower limb strengthening (Fig. 1b), (3) balance (Fig. 1c), and (4) rhythmic exergames. The exergames were selected by the team to achieve the specific objectives of this study (i.e., to enhance balance and lower limb muscle strength of the participants). The program was divided into three stages with increasing exercise repetitions, intensity, and variations. Stage 1 (easy) had 10 exercise variations. Stages 2 (medium) and 3 (hard) incorporated 14 variations. The number of repetitions of each exercise was gradually increased in Stages 2 and 3. In Stage 3, the participants were required to stand on a soft balance board when performing selected exergames to add extra balance challenge and therefore increase exercise intensity. The participants were allowed to progress to the advance stages if they could complete all the assigned exercises and achieve the target number of repetitions and intensity.

All participants were instructed to wear comfortable clothes and shoes while attending the exercise sessions. The participant was asked to notify the instructor of any discomfort they experienced during the exercise, and the participants had the right to suspend any exercise session if any discomfort restricted them from completing the exercises. The instructor was trained by the principal investigator (WC), who is a registered physiotherapist with over 10 years of experience working with older adults, to provide ongoing supervision, verbal feedback, manual support, and adjustment of exercise intensity for each participant.

The participants in the CG received advice from the exercise instructor on how to improve their physical performance and continued to receive care provided by the community center and other healthcare providers for 8 weeks.

Outcome measures

The assessor collected the following demographic data of the participants at baseline: age, sex, years of education, body mass index, history of falls, fall-related injuries and hospitalizations in the past year, medical history, and number of medications.

Feasibility

The feasibility of the exercise program was evaluated based on retention and adherence. Retention was determined by calculating the percentage of participants who completed the 8-week assessment in both groups. Adherence to the exercise program was evaluated by examining the percentage of (1) exercise sessions attended by the participants, and (2) exercises completed by the participants.

Table 1 Nintendo Ring Fit Adventure exercise program protocol

Stage	Week	Exercise routine
1 (easy)	1 and 2 (4 sessions)	Warm-up exercise Jogging in Monster Den (i.e., jogging and abdominal contraction) Core exercise Part 1: Yoga exercise • Chair pose: 10 reps • Warrior 2 pose: 16 reps Part 2: Lower limb strengthening exercise • Wide squat: 14 reps • Knee lift combo: 34 reps • Sidestep: 34 reps • Thigh squeeze: 14 reps Part 3: Balance exercise • Overhead bend: 14 reps • Overhead side bend: 14 reps • Pendulum bend: 14 reps Part 4: Rhythmic exergame: 2–3 min *Break for 5 min and repeat the core exercise* Cool-down exercise Lower limb and abdominal muscles and stretching
2 (medium)	3–5 (6 sessions)	Warm-up exercise Jogging in Monster Den Core exercise Part 1: Yoga exercise • Chair pose: 12 reps • Warrior 1 pose: 20 reps • Warrior 2 pose: 20 reps • Revolved crescent lunge pose: 20 reps Part 2: Lower limb strengthening exercise • Wide squat: 16 reps • Sidestep: 42 reps • Thigh squeeze: 42 reps • Knee lift combo: 42 reps • Hip lift: 16 reps Part 3: Balance exercise • Overhead bend: 16 reps • Overhead side bend: 16 reps • Overhead lunge twist: 20 reps • Pendulum bend: 16 reps Part 4: Rhythmic exergame: 2–3 min *Break for 5 min and repeat the core exercise* Cool-down exercise Lower limb and abdominal muscle and stretching
3 (hard)	6–8 (6sessions)	Warm-up exercise Jogging in Monster Den Core exercise Part 1: Yoga exercise • Chair po se[†]: 16 reps • Warrior 1 pose[†]: 28 reps • Warrior 2 pose[†]: 28 reps • Revolved crescent lunge pose[†]: 28 reps Part 2: Lower limb strengthening exercise • Wide squat[†]: 20 reps • Sidestep: 50 reps • Knee lift combo: 50 reps • Hip lift: 20 reps • Mini exergame: Squat goals or squattery wheel Part 3: Balance exercise • Overhead bend: 20 reps • Overhead lunge twist: 28 reps • Pendulum bend: 20 reps • Mini exergame: Gluting gallery or smack back Part 4: Rhythmic exergame: 2–3 min *Break for 5 min and repeat the core exercise* Cool-down exercise • Lower limb and abdominal muscle and stretching

[†]Participants were instructed to use one of their legs to step on a balance board when performing the exercise to increase the challenge to their balance control. The leg used to step on the balance board changed in every exercise session.

Safety

Safety was assessed by the number of intervention-related adverse events recorded during the study period. In addition, the instructor recorded any adverse event during every exercise session. The participants were instructed to inform the exercise instructor regarding any adverse events they encountered during or between exercise sessions, including dizziness, acute pain, soft tissue injury, and falls.

To determine whether a future definitive trial is indicated, several criteria were set based on feasibility and safety outcomes, i.e., (1) retention and adherence of the participants were ≥70%, and (2) <10% of the participants in EG should experience any adverse event related to the exercise program.

Clinical outcome measures

Clinical outcomes were evaluated in both the EG and CG using measures as follows: (1) Mini-Balance Evaluation Systems Test (Mini-BESTest) on dynamic balance[24]; Five-Time-Sit-to-Stand Test (FTSS) on functional lower extremity muscle strength[25,26]; Timed-Up-and-Go (TUG) single and dual tasks on general mobility and dual-task ability respectively[27,28]; Iconographical Falls Efficacy Scale (Icon-FES) on fear of falling[29]; Color Trails Test first trial (CTT-1), second trial (CTT-2), and the difference between the two trials (CTT-difference) on mental processing, executive function, and set-shifting flexibility respectively.[30]

Sample size calculation

Although a formal sample size calculation was not necessary for this pilot trial, we estimated that the number of participants required would be approximately 15% of the total required for a definitive trial. We hypothesized that the exercise program would exert medium effects on the lower limb muscle strength and balance of participants. For the definitive trial, sample size calculations indicated a need for 210 participants. We aimed to recruit 40 participants to compensate for 20% drop-out in the full trial.[31]

Statistical analysis

Descriptive statistics were used to present the participants' characteristics and feasibility outcomes. Retention and adherence rates are expressed as percentages. Means (standard deviations) are reported for continuous outcomes (e.g., age, body mass index,

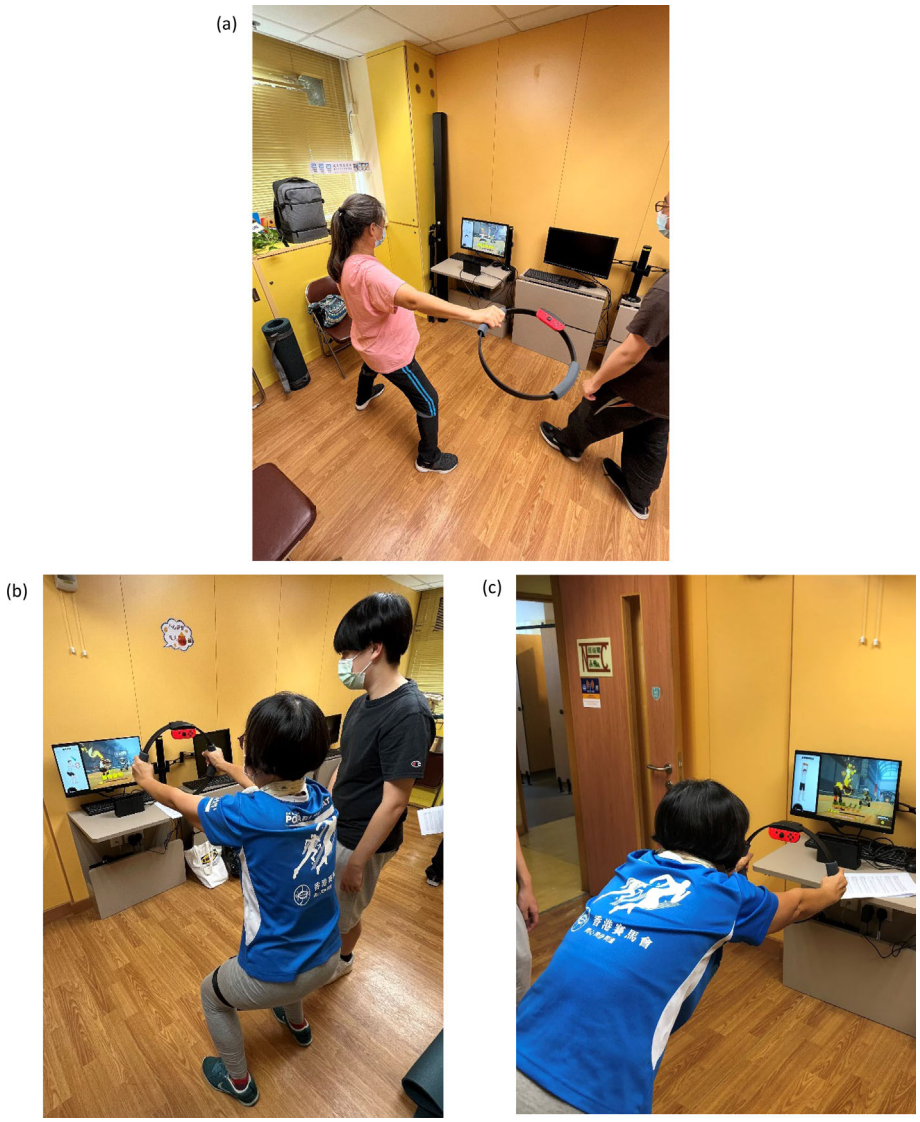

Figure 1 Scenes of the Nintendo Rig Fit Adventure™ (Nintendo, Kyoto, Japan) exercise programme. (a) yoga exergame (warrior 2); (b) muscle strengthening exergame (wide squat); and (c) balance exergame (overhead bend).

and the Mini-BESTest), and raw counts (number and percentage) are reported for categorical outcomes (e.g., sex, history of recurrent falls, and medical history). Repeated measures two-way analysis of covariance with time (baseline, 8-week) as a within-group factor and group (EG, CG) as a between-group factor was used to compare outcomes between the EG and CG after controlling for the age, body mass index, and the baseline Mini-BESTest total score. Effect sizes were calculated based on partial eta squared (η^2) of the analysis of covariance and classified as small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), or large effects ($\eta^2 = 0.14$).[32] The intention-to-treat principle using last observation carried forward was applied to the analyses for the participants who completed the baseline assessment. All data were analyzed using SPSS version 23.0 (IBM Corp.). The level of significance was set at $P < 0.05$ for all statistical analyses.

Results

Baseline characteristics

The characteristics and clinical outcomes of the participants at baseline are listed in Table 2. The participants had a mean age of 69.8 ± 5.7 years and a mean number of falls of 1.4 ± 0.6 falls in the past year. Sixteen participants (38%) had more than one fall, and seven participants (17%) had a history of injured fall in the past year.

Feasibility

Fifteen participants (71%) in the EG and 16 (76%) in the CG completed the 8-week assessment (Fig. 2). The reasons of withdrawal included personal circumstances (e.g., having frequent medical appointments) or health issues unrelated to the intervention.

The mean adherence to the NRFA exercise program was 88%. Fourteen (93%) participants attended 70% or more of the exercise sessions, whereas one participant attended 69% of the exercise sessions.

We prescribed 3480 exercises in 16 exercise sessions, and the participants completed 2988 exercises. The mean adherence of the participants to the exercise prescribed was 86%.

Safety

No adverse event was reported by the participants or recorded by the exercise instructor either during or between exercise sessions.

Table 2 Characteristics at baseline

	EG ($n = 21$)	CG ($n = 21$)	P value[†]
Characteristics			
Age, years, mean (SD)	68.2 (6.0)	71.4 (5.1)	0.08
Female sex, *n* (%)	15 (71)	17 (81)	0.47
Body mass index, kg/m^2, mean (SD)	22.53 (2.93)	26.19 (3.18)	<0.001
Number of falls, mean (SD)	1.5 (0.8)	1.3 (0.5)	0.47
Having a history of recurrent falls (≥2 falls), *n* (%)	8 (38)	8 (38)	1.00
Having a history of at least one injured fall, *n* (%)	3 (14)	4 (19)	0.68
Hypertension, *n* (%)	12 (57)	11 (52)	0.76
Type 2 diabetes, *n* (%)	6 (29)	8 (38)	0.51
Hyperlipidemia, *n* (%)	3 (14)	6 (69)	0.26

CG, control group; EG, Nintendo Ring Fit Adventure-based exercise group.

[†]Chi-squared and independent *t*-test were used to compare characteristics between the EG and CG.

Clinical outcomes

Table 3 lists the clinical outcomes and the interaction of the outcomes between the EG and CG over 8 weeks. There was a significant "time × group" interaction in the anticipatory subscore of the Mini-BESTest after adjustment for age, body mass index, and baseline Mini-BESTest total score ($P = 0.019$). No significant "time × group" interaction in other clinical outcomes were noted.

Discussion

To our knowledge, this is the first study to investigate the feasibility, safety, and potential efficacy of an NRFA-augmented exercise program aimed at improving the balance and muscle strength of community-dwelling older adults with a history of falls. Our findings show that the retention and adherence of the participants in the program and the number of adverse events met the predetermined feasibility and safety criteria. In addition, a significant improvement in anticipatory postural control was noted in the EG compared with the CG. The preliminary data indicate that the NRFA exercise program potentially improves balance in older adults who had experienced a fall.

Over 70% of the participants completed the NRFA exercise program and the post-assessment at 8 weeks. The retention of our exercise program is comparable with that of other exergaming interventions conducted in older populations[15,33,34] and exercise

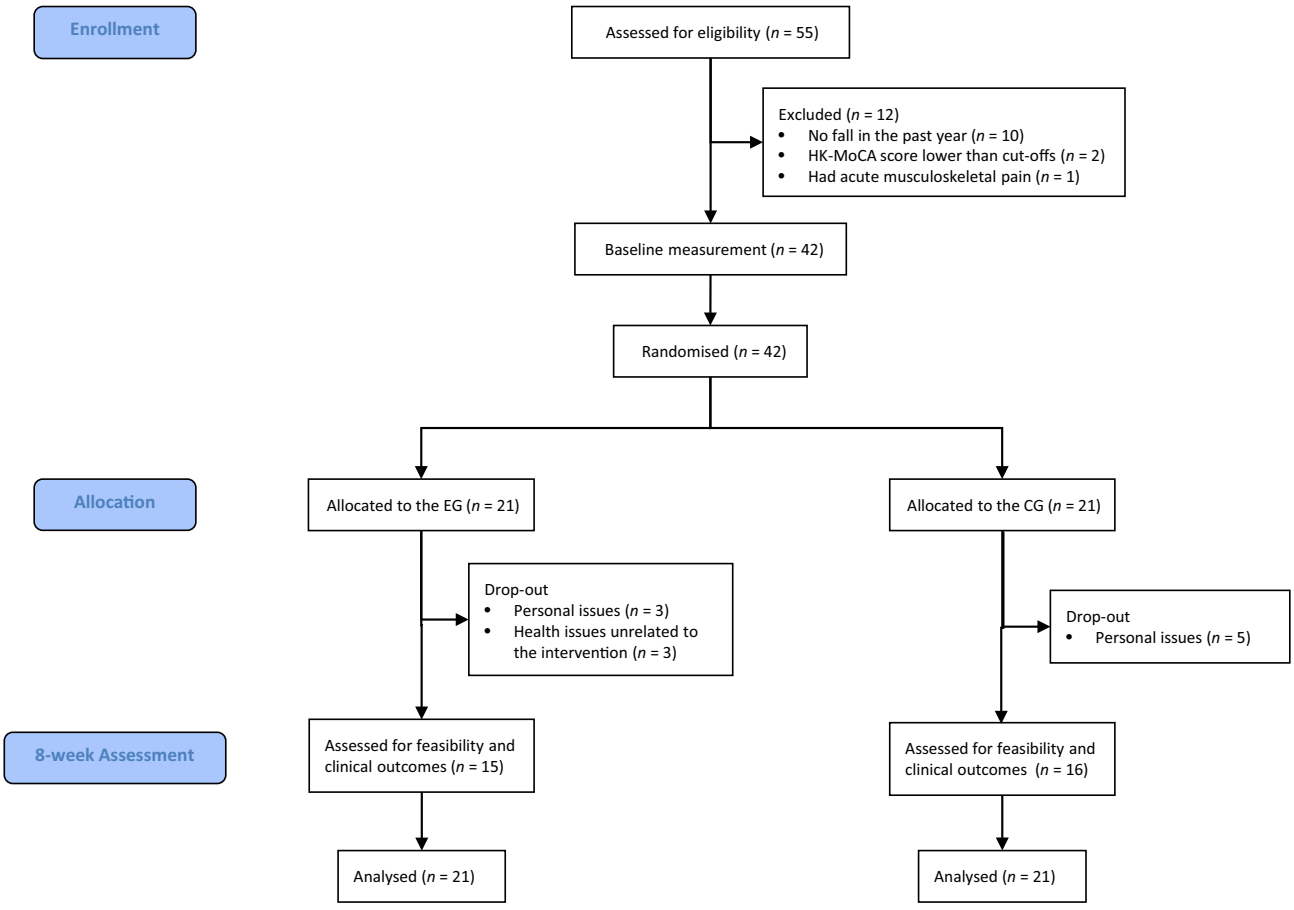

Figure 2 Flow diagram of the feasibility study.CG, control group; EG, experimental.

Table 3 Comparison of clinical outcomes within and between groups

Outcome measures	Groups	Unadjusted mean (SD)		Adjusted mean (SD)		*P* value[†]	Partial eta squared (η^2)
		Baseline	At 8 weeks	Baseline	At 8 weeks		
Mini-BESTest[‡]							
Anticipatory (0–6): score	EG ($n = 21$)	4.81 (0.98)	5.19 (0.51)	4.61 (0.65)	5.09 (0.69)	0.019	0.14
	CG ($n = 21$)	4.67 (0.73)	4.62 (0.80)	4.87 (0.65)	4.72 (0.69)		
Reactive Postural Control (0–6): score	EG ($n = 21$)	5.10 (1.00)	4.81 (1.17)	4.74 (1.20)	4.49 (1.40)	0.78	0.00
	CG ($n = 21$)	4.05 (1.63)	4.00 (1.55)	4.40 (1.20)	4.32 (1.40)		
Sensory Orientation (0–6) score	EG ($n = 21$)	5.24 (0.94)	5.62 (0.67)	5.09 (0.92)	5.62 (0.70)	0.28	0.03
	CG ($n = 21$)	5.38 (0.86)	5.71 (0.56)	5.53 (0.92)	5.72 (0.70)		
Dynamic Gait (0–10) score	EG ($n = 21$)	8.57 (0.51)	8.62 (1.07)	8.47 (0.93)	8.54 (1.33)	0.23	0.04
	CG ($n = 21$)	8.00 (1.38)	7.62 (1.53)	8.10 (0.93)	7.70 (1.33)		
Total (0–28) score	EG ($n = 21$)	23.76 (2.14)	24.29 (2.08)	23.46 (2.96)	24.11 (3.06)	0.32	0.03
	CG ($n = 21$)	22.14 (3.10)	22.00 (3.19)	22.44 (2.96)	22.18 (3.06)		
Single-task TUG, seconds	EG ($n = 21$)	11.03 (2.56)	10.52 (2.51)	11.71 (3.02)	10.77 (2.66)	0.39	0.02
	CG ($n = 21$)	12.50 (3.19)	11.68 (2.59)	11.82 (3.02)	11.43 (2.66)		
Dual-task TUG, seconds	EG ($n = 21$)	19.75 (9.74)	17.97 (9.29)	20.15 (8.94)	18.04 (8.87)	0.21	0.04
	CG ($n = 21$)	20.32 (5.07)	19.78 (5.70)	19.93 (8.94)	19.72 (8.87)		
FTSS, seconds	EG ($n = 21$)	13.14 (3.20)	11.51 (3.09)	13.61 (4.98)	11.36 (3.41)	0.70	0.00
	CG ($n = 21$)	13.69 (5.44)	11.41 (2.92)	13.22 (4.98)	11.56 (3.41)		
Icon-FES (0–40),[‡] score	EG ($n = 21$)	20.24 (5.38)	18.48 (5.83)	21.17 (6.92)	18.44 (7.27)	0.28	0.03
	CG ($n = 21$)	22.71 (6.87)	20.95 (7.08)	21.78 (6.92)	20.99 (7.27)		
CTT-1, seconds	EG ($n = 21$)	69.44 (27.09)	65.19 (27.87)	68.12 (32.34)	64.70 (28.93)	0.92	0.00
	CG ($n = 21$)	68.85 (31.14)	65.22 (24.99)	70.16 (32.34)	65.71 (28.93)		
CTT-2, seconds	EG ($n = 21$)	123.20 (43.15)	128.53 (55.68)	116.54 (46.51)	122.14 (55.46)	0.21	0.04
	CG ($n = 21$)	138.23 (45.10)	125.44 (40.79)	144.90 (46.51)	131.83 (55.46)		
CTT-difference, seconds	EG ($n = 21$)	53.76 (35.16)	63.35 (42.99)	48.41 (35.08)	57.46 (42.44)	0.18	0.05
	CG ($n = 21$)	69.38 (29.60)	60.23 (31.78)	74.73 (35.08)	66.11 (42.44)		

CG, control group; CTT, Color Trails Test; EG, Nintendo Ring Fit Adventure-based exercise group; FTSS, Five-time-sit-to-stand test; Icon-FES, Iconographical Falls Efficacy Scale; Mini-BESTest, Mini-Balance Evaluation Systems Test; TUG, Timed-Up-and-Go test.

[†]Repeated measures two-way ANCOVA was used to compare changes between the EG and CG groups after controlling for age, body mass index, and the Mini-BESTest total score at baseline.

[‡]Brackets indicate the range of score in the Mini-BESTest and Icon-FES. A higher score on the Mini-BESTest and a lower score on the Icon-FES indicate better performance.

programs focusing on fall prevention.[35] The mean attendance rate of the EG was 88%, and 14 of 15 participants completed ≥70% exercise sessions. The participants completed 86% of the exercise assigned by the program. The adherence rate of our exercise program is similar to those of other exergaming interventions, which typically surpass 90% adherence,[12] and is higher than those of traditional fall prevention exercise programs, which achieve only 66% adherence on average.[35] The high retention and adherence of our program indicate that older adults with a history of falls are willing to participate in and complete the program.

None of the participants reported any discomfort or injury during or between exercise sessions. Our findings are similar to those of previous studies reporting no major adverse events associated with exergaming interventions.[12] Although some studies have indicated that older adults participating in exergaming programs might experience minor events, such as fatigue, muscle soreness, and falls,[15,36] these events did not result in any major injury requiring medical attention. Evidence demonstrates that exergaming interventions are generally safe for older adults.

We noted that the improvement in anticipatory control in the EG was significantly superior to that among the controls with a large effect ($\eta^2 = 0.14$). Our findings are comparable with previous studies, which showed that exergaming interventions using devices such as Microsoft Kinect, Nintendo Wii, and virtual reality were effective in improving anticipatory postural control and overall balance in community-dwelling healthy older adults.[18,37,38] Highly challenging balance and yoga exercises have also been reported to be effective in improving balance and reducing falls in older adults.[5,39] The feedback given to the participants based on the motion detection function of the NRFA might enable them to perform balance exercises precisely, and therefore enhance the effects of the program on postural control.[40] The results indicated that our exercise program is challenging yet safe for older adults with a history of falls. Nevertheless, an extended duration of the NRFA exercise program following the recommended dosage (i.e., 50 h in total[41]) may be required to reduce falls in older adults.

The EG did not show an improvement in functional lower limb muscle strength despite having included several muscle strengthening exercises in the program. Our findings align with those of a systematic review indicating that exergaming interventions did not exert a significant effect on upper and lower limb muscle strength in healthy older adults.[42] However, some previous studies conducted in frail older adults and nursing home residents have found that exergaming interventions improved muscle strength,[16,33] indicating that the effect of exergames on muscle strength may be more pronounced in older adults with poor muscle strength. Future studies should consider adding resistance (e.g., free weights) to participants' body parts to enhance the potential effects of the program on functional lower limb muscle strength.

Our findings showed that the EG did not show a significant improvement in dual-task performance, fear of falling, mobility, and executive function. We expected that the NRFA exercise program may have only small effects on these clinical outcomes because the program did not specifically focus on improving these outcomes. Some preliminary studies suggested that exergaming interventions may improve these clinical outcomes in older adults when the interventions involved components that have strong effects on the outcomes concerned (e.g., incorporating cognitively stimulating games during physical exercises).[38,43–45]

We demonstrated a high retention and adherence of the NRFA exercise program in the participants. This suggests that our exercise program is potentially enjoyable and can motivate older adults to engage in exercise training. Moreover, we showed a few positive effects of our exercise program on balance in the participants. We foresee that the effects of the exercise program would be more noticeable if the duration of the program was longer and we could incorporate more balance- and strength-challenging exergames. As the gaming console and software are commonly available in many households, modifying our program into a home-based exercise program may benefit more older fallers living in the community. Nevertheless, further studies are needed to evaluate whether it is feasible, safe, and acceptable for older adults to operate the device and perform the exercise at home with minimal supervision.

This study had several limitations. The sample size was small and the power to detect changes was therefore reduced. All the participants have had at least one fall in the past year. Our findings may not be able to generalize to older adults without a history of falls. The anticipatory control of the participants was evaluated using one of the domain scores in the Mini-BESTest, which may not be able to reflect fully the anticipatory control of older adults. Future studies should therefore include measures that can specifically evaluate anticipatory control. Our exercise program was not tailored to the abilities and needs of individual participants. Adjusting the exercise parameters and progressing the exercise based on the physical function and performance of older adults in the exergames may further enhance the benefits of the exercise program.

Conclusions

The NRFA exercise program is feasible and safe and may be effective in improving anticipatory control in community-dwelling older adults with a history of falls. These findings provide support for extended research, particularly randomized controlled trials involving a larger sample of older adults with a history of falls to investigate the effects of the NRFA exercise program.

Acknowledgements

This pilot trial was supported by Undergraduate Research and Innovation Scheme (URIS) of The Hong Kong Polytechnic University (application number: 133-RS-04). We would like to thank the participants and staff at the community center for older adults of the Neighbourhood Advice-Action Council who helped to coordinate the project.

Disclosure statement

This study was supported by the Undergraduate Research and Innovation Scheme (URIS), The Hong Kong Polytechnic University (application number: 133-RS-04).

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

1 Ganz DA, Latham NK. Prevention of falls in community-dwelling older adults. *N Engl J Med* 2020; **382**: 734–743.

2 James SL, Lucchesi LR, Bisignano C *et al*. The global burden of falls: global, regional and national estimates of morbidity and mortality from the Global Burden of Disease Study 2017. *Inj Prev* 2020; **26**: i3–i11.
3 Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: a review of the literature. *Maturitas* 2013; **75**: 51–61.
4 Deandrea S, Lucenteforte E, Bravi F, Foschi R, La Vecchia C, Negri E. Risk factors for falls in community-dwelling older people. *Epidemiology* 2010; **21**: 658–668.
5 Sherrington C, Michaleff ZA, Fairhall N *et al*. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. *Br J Sports Med* 2017; **51**: 1750–1758.
6 Gillespie LD, Robertson MC, Gillespie WJ *et al*. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 2012; **2012**(9): CD007146.
7 Simek EM, McPhate L, Haines TP. Adherence to and efficacy of home exercise programs to prevent falls: a systematic review and meta-analysis of the impact of exercise program characteristics. *Prev Med* 2012; **55**: 262–275.
8 Nyman SR, Victor CR. Older people's participation in and engagement with falls prevention interventions in community settings: an augment to the cochrane systematic review. *Age Ageing* 2012; **41**: 16–23.
9 Bunn F, Dickinson A, Barnett-Page E, Mcinnes E, Horton K. A systematic review of older people's perceptions of facilitators and barriers to participation in falls-prevention interventions. *Ageing Soc* 2008; **28**: 449–472.
10 de Groot GCL, Fagerström L. Older adults' motivating factors and barriers to exercise to prevent falls. *Scand J Occup Ther* 2011; **18**: 153–160.
11 Gerling K, Mandryk R. Custom-designed motion-based games for older adults: a review of literature in human-computer interaction. *Geron* 2014; **12**: 68–80.
12 Valenzuela T, Okubo Y, Woodbury A, Lord SR, Delbaere K. Adherence to technology-based exercise programs in older adults: a systematic review. *J Geriatr Phys Ther* 2018; **41**: 49–61.
13 Skjæret N, Nawaz A, Morat T, Schoene D, Helbostad JL, Vereijken B. Exercise and rehabilitation delivered through exergames in older adults: an integrative review of technologies, safety and efficacy. *Int J Med Inform* 2016; **85**: 1–16.
14 Jeon MJ, Jeon HS, Yi CH, Kwon OY, You SH, Park JH. Block and random practice: a Wii Fit dynamic balance training in older adults. *Res Q Exerc Sport* 2021; **92**: 352–360.
15 Gomes GCV, Simões M d S, Lin SM *et al*. Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit PlusTM for frail older adults: a randomized feasibility clinical trial. *Maturitas* 2018; **118**: 20–28.
16 Fu AS, Gao KL, Tung AK, Tsang WW, Kwan MM. Effectiveness of exergaming training in reducing risk and incidence of falls in frail older adults with a history of falls. *Arch Phys Med Rehabil* 2015; **96**: 2096–2102.
17 Yang CM, Chen Hsieh J(S), Chen YC, Yang SY, Lin HCK. Effects of Kinect exergames on balance training among community older adults. *Medicine (Baltimore)* 2020; **99**: e21228.
18 Laufer Y, Dar G, Kodesh E. Does a Wii-based exercise program enhance balance control of independently functioning older adults? A systematic review. *Clin Interv Aging* 2014; **9**: 1803–1813.
19 Sato T, Shimizu K, Shiko Y *et al*. Effects of Nintendo Ring Fit Adventure exergame on pain and psychological factors in patients with chronic low back pain. *Games Health J* 2021; **10**: 158–164.
20 Takei K, Morita S, Watanabe Y, Suganami M, Inao M. Safety, feasibility, and acceptability of physiotherapy combined with strength training using active video games for older patients with musculoskeletal conditions. *Disabil Rehabil Assist Technol* 2022: 1–7.
21 World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bull World Health Organ* 2001; **79**: 373–374.
22 Eldridge SM, Chan CL, Campbell MJ *et al*. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *BMJ* 2016; **355**: i5239.
23 Yeung P, Wong L, Chan C, Leung JLM, Yung C. A validation study of the Hong Kong version of Montreal Cognitive Assessment (HK-MoCA) in Chinese older adults in Hong Kong. *Hong Kong Med J* 2014; **20**: 504–510.
24 Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the balance evaluation systems test: the mini-bestest. *J Rehabil Med* 2010; **42**: 323–331.
25 Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *J Gerontol A Biol Sci Med Sci* 2002; **57**: M539–M543.
26 Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. *Phys Ther* 2005; **85**: 1034–1045.
27 Podsiadlo D, Richardson S. The timed "up & go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; **39**: 142–148.
28 Hofheinz M, Mibs M. The prognostic validity of the Timed Up and Go test with a dual task for predicting the risk of falls in the elderly. *Gerontol Geriatr Med* 2016; **2**: 2333721416637798.
29 Delbaere K, T. Smith S, Lord SR. Development and initial validation of the iconographical falls efficacy scale. *J Gerontol A Biol Sci Med Sci* 2011; **66A**: 674–680.
30 D'Elia L, Satz P, Uchiyama C, White T. *Color Trails Test: Professional Manual*. Odessa, FL: Psychological Assessment Resources, 1996; 82.
31 Whitehead AL, Julious SA, Cooper CL, Campbell MJ. Estimating the sample size for a pilot randomised trial to minimise the overall trial sample size for the external pilot and main trial for a continuous outcome variable. *Stat Methods Med Res* 2016; **25**: 1057–1073.
32 Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol* 2013; **4**: 1–7.
33 Cuevas-Lara C, Sáez de Asteasu ML, Ramírez-Vélez R *et al*. Effects of game-based interventions on functional capacity in acutely hospitalised older adults: results of an open-label non-randomised clinical trial. *Age Ageing* 2022; **51**: 3.
34 Schwenk M, Grewal GS, Holloway D, Muchna A, Garland L, Najafi B. Interactive sensor-based balance training in older cancer patients with chemotherapy-induced peripheral neuropathy: a randomized controlled trial. *Gerontology* 2015; **62**: 553–563.
35 Osho O, Owoeye O, Armijo-Olivo S. Adherence and attrition in fall prevention exercise programs for community-dwelling older adults: a systematic review and meta-analysis. *J Aging Phys Act* 2018; **26**: 304–326.
36 Taylor ME, Close JCT, Lord SR *et al*. Pilot feasibility study of a home-based fall prevention exercise program (StandingTall) delivered through a tablet computer (iPad) in older people with dementia. *Australas J Ageing* 2020; **39**: e278–e287.
37 Donath L, Rössler R, Faude O. Effects of virtual reality training (exergaming) compared to alternative exercise training and passive control on standing balance and functional mobility in healthy community-dwelling seniors: a meta-analytical review. *Sports Med* 2016; **46**: 1293–1309.
38 Chen Y, Zhang Y, Guo Z, Bao D, Zhou J. Comparison between the effects of exergame intervention and traditional physical training on improving balance and fall prevention in healthy older adults: a systematic review and meta-analysis. *J Neuroeng Rehabil* 2021; **18**: 164.
39 Youkhana S, Dean CM, Wolff M, Sherrington C, Tiedemann A. Yoga-based exercise improves balance and mobility in people aged 60 and over: a systematic review and meta-analysis. *Age Ageing* 2016; **45**: 21–29.
40 Hatzitaki V, Voudouris D, Nikodelis T, Amiridis IG. Visual feedback training improves postural adjustments associated with moving obstacle avoidance in elderly women. *Gait Posture* 2009; **29**: 296–299.
41 Sherrington C, Fairhall NJ, Wallbank GK *et al*. Exercise for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 2019; **2019**: CD012424.
42 Viana RB, de Oliveira VN, Dankel SJ *et al*. The effects of exergames on muscle strength: a systematic review and meta-analysis. *Scand J Med Sci Sports* 2021; **31**: 1592–1611.
43 Ogawa EF, You T, Leveille SG. Potential benefits of exergaming for cognition and dual-task function in older adults: a systematic review. *J Aging Phys Act* 2016; **24**: 332–336.
44 Barcelos N, Shah N, Cohen K *et al*. Aerobic and cognitive exercise (ACE) pilot study for older adults: executive function improves with cognitive challenge while exergaming. *J Int Neuropsychol Soc* 2015; **21**: 768–779.
45 Jiang J, Guo W, Wang B. Effects of exergaming on executive function of older adults: a systematic review and meta-analysis. *PeerJ* 2022; **10**: e13194.

How to cite this article: Chan WLS, Chan CWL, Lam FMH, et al. Feasibility, safety, and effects of a Nintendo Ring Fit Adventure™ balance and strengthening exercise program in community-dwelling older adults with a history of falls: A feasibility randomized controlled trial. Geriatr. Gerontol. Int. 2024;24:334–341. https://doi.org/10.1111/ggi.14771