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RESEARCH ARTICLE

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# A randomised controlled pilot study of a Nintendo Ring Fit Adventure™ balance and strengthening exercise program in community-dwelling older adults with a history of falls

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## Abstract

**Objectives**: This pilot study examined the feasibility, acceptability, and effects of a Nintendo Ring Fit Adventure™-based balance and muscle strengthening exercise program in community-dwelling older adults with a history of falls.

**Methods:** Older adults who have had at least one fall in the past year were randomly assigned to an experimental ($n=21$) or control group ($n=21$). The experimental group performed 16 exercise sessions in total, lasting 60 min each, twice a week for 8 weeks, whereas the control group received usual care. Feasibility was evaluated based on the scores of participants in the exercises. Acceptance was evaluated using a customised questionnaire examining participants' self-perceived enjoyment, feasibility and improvements. Clinical outcomes including balance (Mini-BESTest), lower limb muscle strength (Five-Time Sit-to-Stand test), mobility (Timed-Up and Go test), dual-task ability (Timed-Up and Go test—Dual Task), fear of falling (Icon-FES) and executive function (Color Trails Test) were evaluated at baseline and 8 weeks.

**Results:** Thirty-one participants (74%) finished the 8-week assessment. The experimental group significantly improved their scores in six out of eight exercises (all $p < .031$). The mean scores of the self-perceived enjoyment, feasibility and improvement domains of the acceptability questionnaire were $3.46 \pm .53$, $3.08 \pm .59$, and $3.47 \pm .57$ respectively. A significant improvement in the anticipatory subscore of the Mini-BESTest was found in the experimental group compared to the control group ($p = .02$; Partial eta squared $= .14$).

**Conclusions:** The Nintendo Ring Fit Adventure™-based exercise program was feasible, acceptable, and potentially effective in community-dwelling older adults with a history of falls.

KEYWORDS
accidental falls, exergaming, muscle strength, pilot projects, postural balance

## 1 | INTRODUCTION

One-third of community-dwelling older adults fall each year.[1] Falls are associated with hip fractures, functional dependence, repeated hospitalisation and premature death.[2] Impaired balance and reduced muscle strength are common risk factors for falls in the older population.[3,4] Although exercise interventions have been shown to be effective in improving balance and muscle strength and reducing fall risk in older adults,[5,6] not many older adults are willing to take part in conventional exercise interventions.[7,8] Poor motivation, boredom, lack of knowledge, safety concern and low self-efficacy are the leading factors that impede older adults from participating in exercise interventions to prevent falls.[7,9,10]

Exergaming, a type of physical activity that blends exercise and video games using a variety of advanced technology such as motion sensors, dancing mats and virtual reality, is an increasingly popular approach to motivate older adults to adhere to exercise training and rehabilitation.[11–13] Exergames provide consistent verbal, visual and auditory feedback to participants to create a dynamic interaction and promote their participation when completing those complex tasks.[14] Exergames also create a safe but challenging virtual environment for participants to practice physical and cognitive tasks that simulate movements in daily living that may not be feasibly performed in reality.[15] Exergaming interventions using different platforms, such as Nintendo Wii Fit and Microsoft Kinect, have been shown to be beneficial in increasing balance, lower limb strength, and gait and reducing falls in healthy older adults.[16–20]

The Nintendo Ring Fit Adventure™ (NRFA; Nintendo, Kyoto, Japan) is an action role-playing exergame designed to promote fitness and physical activity. The NRFA consists of a ring-shaped controller and a leg sensor to detect body movements. Players need to move their body parts to perform various aerobic, resistance and yoga exercises.[21] The NRFA also enables players to customise their exercise regimes to meet individual needs. A few pilot studies reported that the NRFA is feasible and safe for older adults with musculoskeletal problems and is more fun compared to conventional exercise interventions.[21,22] The characteristics of the NRFA, including the wide range of exergames, high flexibility in exercise protocol design and engaging gaming experience, enhance its potential to be applied to different clinical populations, including older adults with an increased fall risk, as a means to deliver exercise intervention and improve health. However, it remains unclear whether an exercise program using the NRFA to improve balance and muscle strength is feasible and acceptable in older adults with high fall risk. Moreover, the effects of an NRFA-based exercise program on various clinical outcomes associated with falls in older adults, and the relationship between the participants' subjective perception and objective benefits of the exercise program have not been investigated.

The primary objectives of this pilot study were to investigate the feasibility and acceptability of the NRFA-augmented exercise program to improve muscle strength and balance for community-dwelling older adults who have a history of falls. In particular, the primary aims of this study were as follows:

1. to evaluate the feasibility of the NRFA exercise program based on the performance of participants in the exergames and
2. to investigate the acceptability of the exercise program based on the feedback collected using an acceptability questionnaire specifically designed for this trial

The secondary aims of this study were as follows:

1. to explore the potential effects of the NRFA exercise program on balance, lower limb muscle strength, general mobility, dual-task ability, executive function, and fear of falling in community-dwelling older people who fell and
2. to explore the potential association between the changes in clinical outcomes and participants' acceptability of the exercise program

**Policy Impact**

Exergaming using the NRFA is fun and suitable and can motivate older adults with an increased risk of falls to participate in exercise training. The government, health-care organisations and aged-care practitioners may consider including this NRFA-based exercise program as one of the fall prevention strategies.

**Practice Impact**

Health-care professionals may use the NRFA-based exercise program to improve balance in older adults with a history of falls. Adjustments to the exercise protocol (e.g., duration of the program, exergames to be included) may be required to maximise the potential benefits and acceptability of the exercise program.

## 2 | METHODS

### 2.1 | Study design

This pilot study was a randomised, assessor-blinded, parallel-group, controlled trial. The protocol was registered on ClinicalTrials.gov (identifier: NCT05949359). This study was approved by the Institutional Review Board of the Hong Kong Polytechnic University (identifier: HSEARS20210914002) and participating organisations following the Declaration of Helsinki prior to data collection.[23] This report follows the Consolidated Standards of Reporting Trials (CONSORT).[24]

### 2.2 | Participants

Participants were recruited from a community centre for older adults in Hong Kong between August 2022 and January 2023. Social workers affiliated with the participating organisation identified individuals who may fulfil the study inclusion criteria and invited them for eligibility screening. Eligible candidates received an information sheet detailing researchers' contact information and provided written consent.

Individuals were included if they (1) were aged 60 years or above, (2) had experienced at least one fall in the past year, (3) could walk independently without a walking aid for at least 10 m and (4) did not have any experience using the NRFA. Individuals who (1) had a severe musculoskeletal, cardiopulmonary, neurological, or psychiatric condition; (2) had significant visual or hearing impairment; (3) scored 18 or below on the Hong Kong version of the Montreal Cognitive Assessment (HK-MoCA)[25]; or (4) had joined any supervised exercise programme in the past 6 months were excluded.

### 2.3 | Randomisation

The participants were randomised to either the experimental or control group at a ratio of 1:1. The participants were randomly assigned to one of the groups by drawing a slip of paper indicating their group allocation from an obscured plastic box. The research team did not have any influence over group assignments.

### 2.4 | Sample size calculation

We estimated that the number of participants needed for this pilot trial would be around 15% of the number required for a future study. We hypothesised that the exercise program would have a moderate effect on the participants' lower limb muscle strength and balance. The sample size calculations revealed that 210 participants are required in the conclusive trial. Estimating that 20% of the participants would withdraw from the study, we therefore recruited 42 participants in this pilot study.[26]

We hypothesised that (1) the scores of at least 50% of the exergames would be significantly improved; and (2) the mean scores of all acceptability domains would be 3.00 or higher. These targets were set as an indicator for a full trial to be conducted in future.

### 2.5 | Intervention

The exercise program was conducted at the local community centre from which the participants were recruited. Two exercise instructors were involved to guide and monitor the participants in the experimental group to perform the exergames. The participants were instructed to grasp a ring-shaped controller with both hands in a standing position. Another controller was attached to the participants' thigh using an elastic Velcro strap to detect their movements. The NRFA software provided voice-over instructions and feedback, on-screen text, and animated video demonstrations to the participants throughout every exercise session.

Appendix S1 shows the details of the exercise program. The exercise program comprised two 60-min sessions per week for a total of eight weeks. The participants were asked to perform four types of core exergames: (1) yoga, (2) lower limb strengthening, (3) balance, and (4) rhythmic exergames. The exergames were selected to improve the participants' balance and lower extremity muscle strength. The participants were also instructed to perform a 5-min warm-up exercise (e.g., marching on the spot, abdominal exercises) and a 5-min cool-down exercise (e.g., simple stretching of upper and lower limbs) before and after the core exergames respectively. Stage 1 of the exercise program had 10 exergames, while Stages 2 and 3 consisted of 14 exergames. The number of repetitions of each exergame was steadily increased in Stages 2 and 3. The exercise intensity and challenge to balance were further increased in Stage 3 by asking the participants to step on a soft balancing board when performing certain exergames.

The principal investigator (WC), who is a registered physiotherapist with over 10 years of experience working with older adults, conducted a two-day training workshop to teach the two exercise instructors to assure safety, provide feedback and assistance, and adjust exercise intensity for each participant. The participants were suggested to wear comfortable clothes and shoes to perform the exercises. The participants were also advised to alert the instructors if they felt any discomfort (e.g., acute pain, dizziness or nausea) during exercise, and they had full autonomy to request for more rest or postpone any exercise session if needed.

The participants in the control group continued to receive their usual care across the eight-week study period. The exercise instructors also provided exercise recommendations to the participants to improve their muscle strength and balance after the initial assessment.

## 2.6 | Assessments

An assessor evaluated all the participants at baseline and eight weeks (postintervention). The assessor was unaware of the group assignment and the assessment results in any prior session.

## 2.7 | Outcome measures

Demographic data including age, gender, years of education, marital status, body mass index, history of falls, fall-related injuries and hospitalisation in the past year, medical history and medications, were collected at baseline.

### 2.7.1 | Primary outcomes—feasibility and acceptability

Feasibility was assessed based on the scores of the experimental group in the exergames throughout the eight-week study period. Eight exergames (e.g., chair pose, warrior 2 pose, wide squat, sidestep, knee lift combo, overhead bend, pendulum bend and rhythm game) that were performed in all exercise sessions were selected. In addition, the adherence of the experimental group to the exercise program, indicated by the percentage of exercise sessions attended by the participants, was also collected.

Acceptability was evaluated using a questionnaire specifically designed for this study when the experimental group finished the exercise program at 8-weeks. The questionnaire was divided into three domains: (1) enjoyment and suitability (six items), (2) feasibility (four items) and (3) self-perceived improvements (six items). The participants in the experimental group were instructed to rate each item on a scale from 1 (strongly disagree) to 4 (strongly agree) at the end of the exercise program. A higher score indicates better acceptability. Appendix S2 presents the details of the questionnaire.

### 2.7.2 | Secondary outcomes—clinical outcome measures

The Mini-Balance Evaluation Systems Test (Mini-BESTest) was used to measure dynamic balance.[27] The Five-Time-Sit-to-Stand Test (FTSS) was used as a proxy measure of lower extremity muscle strength.[28,29] The Timed-Up-and-Go (TUG) single and dual tasks were used to measure the general mobility and dual-task ability respectively.[30,31] The Iconographical Falls Efficacy Scale (Icon-FES) was used to evaluate fear of falling.[32] The Color Trails Test first trial (CTT-1), second trial (CTT-2), and the difference between the two trials (CTT-difference) were used to measure attention, executive function and set-shifting flexibility.[33] Both the experimental group and control group completed these measures at baseline and eight-weeks.

## 2.8 | Statistical analysis

The participants' characteristics were presented using descriptive statistics. The paired *t*-test was used to compare the mean scores of exergames achieved in the first and last exercise session by the experimental group. Adherence is expressed as percentages with 95% confidence intervals (CIs). Means (standard deviation) were reported for the acceptability scores. The paired *t*-test was performed to compare clinical outcomes measured at baseline and eight-weeks for the experimental group and control group separately. Cohen's *d* was used to calculate the effect sizes. The effect sizes were classified as small ($d = .2$–$.5$), medium ($d = .5$–$.8$), and large ($d > .8$).[34] One-way analysis of covariance (ANCOVA) was employed to compare mean changes in clinical outcomes at eight-weeks between the experimental group and control group adjusting for body mass index and the baseline scores of the corresponding clinical outcomes. Partial eta squared ($\eta^2$) was used to calculate the effect sizes of the ANCOVA. The effect sizes were classified as small ($\eta^2 = .01$), medium ($\eta^2 = .06$), or large effects ($\eta^2 = .14$).[34] The within- and between-group comparisons of clinical outcomes were conducted based on the intention-to-treat principle. The associations between acceptability domain scores and mean changes in clinical outcomes in the experimental group were evaluated using the Spearman correlation coefficient ($\rho$). SPSS version 23.0 (Chicago, IL, USA) was used to analyse all data. The level of significance was set at $p < .05$.

# 3 | RESULTS

## 3.1 | Participants' characteristics

Forty-two participants were recruited at baseline and 31 participants finished the assessment at 8 weeks (Appendix S3). Table 1 shows the participants' characteristics. The mean ages of the participants in the experimental group and control group were 68.2 ± 6.0 and 71.4 ± 5.1, respectively. The mean numbers of falls in the experimental group and control group were 1.5 ± .8 and 1.3 ± .5, respectively. Thirty-eight per cent of the participants in both the experimental group and control group had two or more falls in the past year.

## 3.2 | Feasibility

Table 2 presents the scores achieved in the exergames by the experimental group. Significant improvements were found in the scores of six out of eight exergames (all $p < .03$). The mean adherence to the exercise program was 88% (95% CI = 83%, 93%). No adverse event was reported during any exercise session.

## 3.3 | Acceptability

Table 3 shows the participants' acceptability of the NRFA exercise program. The mean scores of 'enjoyment and suitability', 'feasibility' and 'self-perceived improvements' domains were 3.46 ± .53, 3.08 ± .59, and 3.47 ± .57, respectively. The mean scores of all items in the acceptability questionnaire were at least 3.00, except items 9 and 10 which scored 2.93 ± .59 and 2.73 ± .59, respectively.

**TABLE 1** Participants' characteristics.

| Characteristics | EG ($n = 21$) | CG ($n = 21$) | *p* Value[a] |
|---|---|---|---|
| Age: years, mean (SD) | 68.2 (6.0) | 71.4 (5.1) | .08 |
| Female sex: *n* (%) | 15 (71) | 17 (81) | .47 |
| Body mass index: kg/m$^2$, mean (SD) | 22.53 (2.93) | 26.19 (3.18) | <.001 |
| Number of falls: *n*, mean (SD) | 1.5 (.8) | 1.3 (.5) | .47 |
| Having a history of recurrent falls (≥2 falls): *n* (%) | 8 (38) | 8 (38) | >.99 |
| Having a history of at least one injured fall: *n* (%) | 3 (14) | 4 (19) | .68 |
| Hypertension: *n* (%) | 12 (57) | 11 (52) | .76 |
| Type 2 diabetes: *n* (%) | 6 (29) | 8 (38) | .51 |
| Hyperlipidaemia: *n* (%) | 3 (14) | 6 (69) | .26 |

Abbreviations: CG, Control group; EG, Nintendo Ring Fit Adventure-based exercise group.

[a]The $\chi^2$ and independent *t*-test were used to compare characteristics between the EG and CG.

## 3.4 | Clinical outcomes

There were significant improvements in the anticipatory sub score of the Mini-BESTest ($p = .04$; Cohen's $d = .47$), the TUG dual task ($p = .048$; Cohen's $d = .46$), and the Icon-FES score ($p = .03$; Cohen's $d = .51$) at 8-weeks compared to the baseline in the experimental group (Table 4). In the control group, the FTSS score was significantly improved at eight-weeks ($p = .03$; Cohen's $d = .51$). There was a significant improvement in the anticipatory sub score of the Mini-BESTest in the experimental group compared to the control group ($p = .02$; $\eta^2 = .14$).

## 3.5 | Association between acceptability and clinical outcomes

Table 5 presents the associations between acceptability and clinical outcomes. Significant associations were found between 'enjoyment and suitability' and the Mini-BESTest anticipatory ($\rho = .68$; $p = .005$) and sensory orientation sub scores ($\rho = .54$; $p = .04$), FTSS ($\rho = .55$; $p = .03$), and CTT-1 ($\rho = -.55$; $p = .03$).

# 4 | DISCUSSION

The results of this pilot trial demonstrated that the NRFA exercise program was generally feasible and well-accepted by community-dwelling older adults who experienced a fall in the previous year. The performance of the participants in the exergames and the scores given by the participants in the acceptability questionnaire reached the feasibility and acceptability criteria for a definitive trial. A significant improvement in the anticipatory postural control with a large effect was found in the experimental group compared to that in the control group. Moreover, the self-perceived enjoyment and suitability of the exercise program were significantly associated with the improvements in dynamic balance, muscle strength, and attention in the experimental group. The exploratory findings indicate that community-dwelling older fallers who think this exercise program is interesting and able to fit their capability and needs may be more likely to show greater improvements in certain physical and cognitive outcomes.

**TABLE 2** Nintendo Ring Fit Adventure exergame scores ($n$=15).

| | Score in the first session[a] | Score in the last session[a] | Score difference between the first and last session | |
|---|---|---|---|---|
| **Exergames** | **Mean (SD)** | **Mean (SD)** | **Mean difference (95% CI)** | ***p* Value[b]** |
| Chair pose | 86.04 (10.46) | 92.30 (7.13) | 6.26 (−.37, 12.88) | .03 |
| Warrior 2 pose | 86.50 (7.29) | 97.33 (3.15) | 7.84 (3.70, 11.98) | <.001 |
| Wide squat | 45.83 (20.30) | 59.40 (24.63) | 13.57 (2.54, 24.59) | .01 |
| Sidestep | 67.52 (19.31) | 79.67 (16.80) | 12.45 (.57, 24.32) | .02 |
| Knee lift combo | 72.68 (15.78) | 76.60 (21.06) | 3.92 (−8.13, 15.98) | .25 |
| Overhead bend | 92.12 (11.39) | 96.81 (5.45) | 4.68 (−2.58, 11.95) | .09 |
| Pendulum bend | 85.90 (14.05) | 95.07 (4.49) | 9.16 (1.01, 17.32) | .02 |
| Rhythm game | 4222.29 (934.30) | 8019.83 (1537.89) | 3797.54 (2848.03, 4747.05) | <.001 |

[a]The score of the exergames (except 'rhythm game') ranges from 0 to 100. The score of 'rhythm game' does not have a lower or upper limit.
[b]Paired $t$ test was used to compare scores between the first and the last sessions of each exergame.

Compared to the exergame scores the participants in the experimental group achieved in the first exercise session, six exergame scores were significantly improved in the last session. The improvements in the exergame scores in this trial were similar to the findings reported in previous studies on older adults using other exergaming platforms.[17,35–38] The diverse and frequent visual (e.g., the exergame scores) and auditory (e.g., voice-over encouragement) feedback provided by the NRFA may be the facilitators that enhance the learning process and in turn the performance of older adults in the exergames.[17] Nevertheless, no significant difference in the scores between the first and last exercise session was found in two exergames; 'knee lift combo' and 'overhead bend'. 'Knee lift combo' requires players to raise their knees alternately at a fast speed. We found that some participants had difficulty catching up with the pace of movement. 'Overhead bend' requires players to flex their trunks laterally to two sides. Most of the participants found it too easy and achieved a very high score in the first session (mean score = 92 out of 100), so the room for improvement was very narrow. Future studies should pay more attention to selecting appropriate exergames and adjusting their difficulties to accommodate participants with different physical capabilities. Moreover, the experimental group achieved a high attendance rate, which was similar to that reported in previous exergaming studies on older adults.[11,17,35] The high feasibility and adherence indicate that older people who fell can complete our exercise program and are willing to play exergames as a means to improve their health.

The scores of the acceptability questionnaire exceeded the predetermined target, indicating that the participants generally accepted our exercise program. Such high ratings for enjoyment and self-perceived benefits can explain the high adherence observed in our exercise program. Community-dwelling older adults are less likely to participate in conventional exercise interventions than in other effective strategies to prevent falls.[8,39] Exergaming has emerged as an effective strategy to enhance participation and adherence to fall-prevention exercise interventions, because of its engaging nature, immediate feedback mechanism and ease of personalisation.[11,40] Nevertheless, two items querying the participants on their confidence in completing the exercise program without supervision (mean score = 2.93 ± .59) and their perception in performing the exercise alone (mean score = 2.73 ± .59) received relatively low scores. These findings suggest that older people who fell need more support in gaining knowledge, skills and confidence when performing the exercise in minimally supervised environments (e.g., at home).[41] Additional studies should investigate whether the NRFA-based exercise with sporadic face-to-face or remote monitoring is feasible and effective in older adults with an increased risk of falls.

The experimental group demonstrated significant improvements in anticipatory control, dual-task performance, and fear of falling with small to medium effects at eight weeks compared with baseline. Moreover, a significant improvement in the anticipatory postural control with a large effect was found in the experimental group compared to that in the control group. Previous studies have shown that exergaming using other platforms is effective in improving anticipatory control and dynamic balance in older adults.[20,42,43] Our exploratory analyses further demonstrated that the participants with more fun and satisfaction in the exercise program may have greater improvements in dynamic balance, muscle strength and attention. Although previous studies reported similar results of the acceptability of exergaming interventions,[17,22,35] this is the first study to examine the potential association between acceptability and improvements in clinical outcomes. Maximising the 'fun' factor

**TABLE 3** Acceptability of the Nintendo RingFit exercise program ($n = 15$).

| Items | | Mean score (SD) |
|---|---|---|
| Domain 1—Enjoyment & Suitability | | |
| 1. | The duration of the Ring Fit-based exercise program was appropriate. | 3.53 (.52) |
| 2. | The Ring Fit-based exercise program was challenging for me. | 3.13 (.52) |
| 3. | The type of exercise and games in the Ring Fit-based exercise program is suitable for me. | 3.47 (.52) |
| 4. | The Ring Fit-based exercise program is fun and interesting. | 3.67 (.49) |
| 5. | After finishing this program, I'm interested in continuing the Ring Fit-based exercise program. | 3.40 (.51) |
| 6. | Overall, I enjoyed the Ring Fit-based exercise program. | 3.53 (.52) |
| Mean domain score | | 3.46 (.53) |
| Domain 2—Feasibility | | |
| 7. | I could follow the instructions and procedures of the Ring Fit-based exercise program. | 3.40 (.51) |
| 8. | I could complete all the Ring Fit-based exercises as instructed. | 3.27 (.46) |
| 9. | I am capable of finishing the Ring Fit-based exercise program by myself without guidance from others. | 2.93 (.59) |
| 10. | I would feel safe doing Ring Fit-based exercise alone without supervision. | 2.73 (.59) |
| Mean domain score | | 3.08 (.59) |
| Domain 3—Self-perceived improvements | | |
| 11. | The Ring Fit-based exercise program has helped me to improve my muscle strength. | 3.53 (.52) |
| 12. | The Ring Fit-based exercise program has helped me to improve my balance. | 3.20 (.68) |
| 13. | The Ring Fit-based exercise program has helped me to improve my cognitive function. | 3.47 (.52) |
| 14. | The Ring Fit-based exercise program has helped me to reduce falls. | 3.53 (.52) |
| 15. | The Ring Fit-based exercise program has helped me to reduce my fear of falling. | 3.40 (.63) |
| 16. | Using Ring Fit can help me cultivate a regular exercise habit. | 3.67 (.49) |
| Mean domain score | | 3.47 (.57) |

*Note*: Each item is rated using a four-point Likert scale (1—strongly disagree; 2—disagree; 3—agree; 4—strongly agree). A higher score indicates better acceptability.

and designing a suitable program that tailors to the capacity and needs of older people who fell may be crucial to improve their physical and cognitive function and in turn, reduce their fall risk.

In this pilot study, we have demonstrated that the NRFA exercise program is highly feasible and acceptable to older adults with a history of falls. In fact, the NRFA is very popular in the community and is one of the best-selling software programs on the Nintendo Switch game console. The cost of a set of console and software is relatively low compared to other advanced technology in geriatric rehabilitation (e.g., immersive technology). We believe that our NRFA exercise program can be widely disseminated in different community settings to address the exercise needs of older adults who have an increased fall risk. However, further evaluations of the feasibility, safety, acceptability, and effects of the NRFA exercise program in older people who fell in different community settings (e.g., day care centres, home environment) will be required.

## 4.1 | Study limitations

This pilot study aimed to evaluate the feasibility and acceptability of the NRFA exercise program and was not powered to evaluate the clinical outcomes. As we recruited participants with a history of falls in the past year, our findings may not be applicable to older adults without a fall. The exercises prescribed to our participants

**TABLE 4** Comparison of clinical outcomes within and between groups.

| Clinical outcomes | Groups | Mean (SD) Baseline | Mean (SD) At 8 weeks | Mean change (95% CI) | *p* Value[a] | Effect size[b] |
|---|---|---|---|---|---|---|
| Mini-BESTest[c] | | | | | | |
| Anticipatory (0–6): score | EG (*n* = 21) | 4.81 (.98) | 5.19 (.51) | .38 (.01, .75) | .04 | .47 |
| | CG (*n* = 21) | 4.67 (.73) | 4.62 (.80) | −.05 (−.35, .26) | .75 | −.07 |
| | Adjusted group difference (95% CI) | | | .51 (.09, .93) | .02 | .14 |
| Reactive Postural Control (0–6): score | EG (*n* = 21) | 5.10 (1.00) | 4.81 (1.17) | −.29 (−.90, .33) | .34 | −.21 |
| | CG (*n* = 21) | 4.05 (1.63) | 4.00 (1.55) | −.05 (−.79, .69) | .90 | −.03 |
| | Adjusted group difference (95% CI) | | | .29 (−.68, 1.25) | .55 | .01 |
| Sensory orientation (0–6): score | EG (*n* = 21) | 5.24 (.94) | 5.62 (.67) | .38 (−.08, .85) | .10 | .37 |
| | CG (*n* = 21) | 5.38 (.86) | 5.71 (.56) | .33 (−.06, .72) | .09 | .39 |
| | Adjusted group difference (95% CI) | | | .04 (−.41, .48) | .88 | .00 |
| Dynamic gait (0–10): score | EG (*n* = 21) | 8.57 (.51) | 8.62 (1.07) | .05 (−.37, .47) | .82 | .05 |
| | CG (*n* = 21) | 8.00 (1.38) | 7.62 (1.53) | −.38 (−.85, .08) | .10 | −.37 |
| | Adjusted group difference (95% CI) | | | .58 (−.16, 1.32) | .12 | .06 |
| Total (0–28): score | EG (*n* = 21) | 23.76 (2.14) | 24.29 (2.08) | .52 (−.61, 1.65) | .35 | .21 |
| | CG (*n* = 21) | 22.14 (3.10) | 22.00 (3.19) | −.14 (−1.20, .92) | .78 | −.06 |
| | Adjusted group difference (95% CI) | | | 1.51 (−.13, 3.14) | .07 | .08 |
| Single-task TUG: seconds | EG (*n* = 21) | 11.03 (2.56) | 10.52 (2.51) | −.50 (−1.18, .17) | .13 | .34 |
| | CG (*n* = 21) | 12.50 (3.24) | 11.68 (2.59) | −.82 (−1.75, .11) | .08 | .40 |
| | Adjusted group difference (95% CI) | | | −.70 (−1.80, .40) | .20 | .04 |
| Dual-task TUG: seconds | EG (*n* = 21) | 19.75 (9.74) | 17.97 (9.29) | −1.78 (−3.55, .02) | .048 | .46 |
| | CG (*n* = 21) | 20.32 (5.07) | 19.78 (5.70) | −.54 (−2.25, 1.17) | .52 | .14 |
| | Adjusted group difference (95% CI) | | | −1.65 (−4.42, 1.11) | .23 | .04 |
| FTSS: seconds | EG (*n* = 21) | 13.14 (3.20) | 11.51 (3.09) | −1.62 (−3.26, .01) | .05 | .45 |
| | CG (*n* = 21) | 13.69 (5.44) | 11.41 (2.92) | −2.28 (−4.31, .25) | .03 | .51 |
| | Adjusted group difference (95% CI) | | | −.02 (−2.02, 1.98) | .98 | .00 |
| Icon-FES (0–40)[c]: score | EG (*n* = 21) | 20.24 (5.38) | 18.48 (5.83) | −1.76 (−3.33, −.19) | .03 | .51 |
| | CG (*n* = 21) | 22.71 (6.87) | 20.95 (7.08) | −1.76 (−4.40, .88) | .18 | .30 |
| | Adjusted group difference (95% CI) | | | −1.50 (−4.86, 1.85) | .37 | .02 |
| CTT-1: seconds | EG (*n* = 21) | 69.44 (27.09) | 65.19 (27.87) | −4.25 (−15.45, 6.96) | .44 | .17 |
| | CG (*n* = 21) | 68.85 (31.14) | 65.22 (24.99) | −3.63 (−15.29, 8.02) | .52 | .14 |
| | Adjusted group difference (95% CI) | | | −2.76 (−18.74, 13.22) | .73 | .00 |
| CTT-2: seconds | EG (*n* = 21) | 123.20 (43.15) | 128.53 (55.68) | 5.33 (−15.38, 26.03) | .60 | −.12 |
| | CG (*n* = 21) | 138.23 (45.10) | 125.44 (40.79) | −12.79 (−28.50, 2.92) | .11 | .37 |
| | Adjusted group difference (95% CI) | | | 11.83 (−18.24, 41.89) | .43 | .02 |
| CTT-difference: seconds | EG (*n* = 21) | 53.76 (35.16) | 63.35 (42.99) | 5.33 (−9.15, 28.33) | .30 | −.23 |
| | CG (*n* = 21) | 69.38 (29.60) | 60.23 (31.78) | −9.16 (−23.13, 4.82) | .19 | .30 |
| | Adjusted group difference (95% CI) | | | 10.04 (−16.40, 36.47) | .45 | .02 |

Abbreviations: 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.

[a]Paired *t*-test was used to compare the outcomes between the baseline and 8 weeks within the same group. One-way ANCOVA was used to compare mean changes between the EG and CG groups after controlling for body mass index and the scores of the corresponding clinical outcomes at baseline.

[b]Cohen's *d* was used to calculate the effect size of the paired *t* test (within-group difference) and partial eta squared $\eta^2$ was used to calculate the effect size of the one-way ANCOVA (between-group difference).

[c]The brackets indicate the range of scores in the Mini-BESTest and Icon-FES. A higher score in the Mini-BESTest and a lower score in the Icon-FES indicate better performance.

**TABLE 5** Association between acceptability domain scores and mean changes of clinical outcomes ($n = 15$).

| Clinical outcomes | Acceptability | | | | | |
|---|---|---|---|---|---|---|
| | Enjoyment and suitability | | Feasibility | | Self-perceived improvements | |
| | Spearman correlation ($\rho$) | *p* Value[a] | Spearman correlation ($\rho$) | *p* Value[a] | Spearman correlation ($\rho$) | *p* Value[a] |
| Mini-BESTest | | | | | | |
| Anticipatory | .68 | .005 | .44 | .10 | .48 | .067 |
| Reactive postural control | −.25 | .38 | −.19 | .50 | −.28 | .31 |
| Sensory orientation | .54 | .037 | .33 | .23 | .42 | .12 |
| Dynamic gait | −.20 | .47 | −.21 | .45 | −.09 | .76 |
| Total | .15 | .60 | .10 | .73 | .06 | .83 |
| Single-task TUG | .28 | .32 | −.03 | .92 | .28 | .32 |
| Dual-task TUG | .16 | .57 | −.12 | .66 | .10 | .73 |
| FTSS | −.55 | .034 | −.29 | .30 | −.29 | .29 |
| Icon-FES | .16 | .58 | −.11 | .71 | .04 | .90 |
| CTT-1 | −.55 | .032 | −.26 | .35 | −.23 | .42 |
| CTT-2 | .18 | .53 | .18 | .53 | .35 | .20 |
| CTT-difference | .29 | .30 | .18 | .51 | .21 | .44 |

Abbreviations: CTT, Color Trails Test; 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.

[a]Spearman correlation coefficient $\rho$ was used to evaluate the associations between mean acceptability domain scores and mean changes of clinical outcomes in the EG.

were generally standardised with minimal adjustments between participants. Future studies should consider to tailor the exercise program to the physical capability of each participant to maximise the benefits of the program. Moreover, the cost of our exercise program was not calculated in this study, and the cost-effectiveness of our exercise program remains unclear.

## 5 | CONCLUSIONS

The NRFA exercise program is feasible and acceptable for community-dwelling older adults with a history of falls. The program may be effective in improving anticipatory control in older fallers, and the effect may be further increased if they perceive that the exercise program is interesting and suitable. These findings suggest that future studies with a bigger sample of older adults at high risk of falling to evaluate the effects of the NRFA exercise program are warranted.

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### CONFLICT OF INTEREST STATEMENT

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### 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.

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### REFERENCES

1. Ganz DA, Latham NK. Prevention of falls in community-dwelling older adults. *N Engl J Med*. 2020;382(8):734-743. doi:10.1056/NEJMcp1903252
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(Suppl 2):i3-i11. doi:10.1136/injuryprev-2019-043286
3. Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: a review of the literature. *Maturitas*. 2013;75(1):51-61. doi:10.1016/j.maturitas.2013.02.009
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(5):658-668. doi:10.1097/EDE.0b013e3181e89905
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(24):1750-1758. doi:10.1136/bjsports-2016-096547
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. doi:10.1002/14651858.CD007146.pub3
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(4):262-275. doi:10.1016/J.YPMED.2012.07.007
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(1):16-23. doi:10.1093/ageing/afr103
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. *Age Soc*. 2008;28(4):449-472. doi:10.1017/S0144686X07006861
10. de Groot GCL, Fagerström L. Older adults' motivating factors and barriers to exercise to prevent falls. *Scand J Occup Ther*. 2011;18(2):153-160. doi:10.3109/11038128.2010.487113
11. 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(1):49-61. doi:10.1519/JPT.0000000000000095
12. 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):1-16. doi:10.1016/j.ijmedinf.2015.10.008
13. Gerling K, Mandryk R. Custom-designed motion-based games for older adults: a review of literature in human-computer interaction. *Gerontechnology*. 2014;12(2):68-80. doi:10.4017/gt.2013.12.2.001.00
14. Skjæret-Maroni N, Vonstad EK, Ihlen EAF, Tan XC, Helbostad JL, Vereijken B. Exergaming in older adults: movement characteristics while playing stepping games. *Front Psychol*. 2016;7:964. doi:10.3389/fpsyg.2016.00964
15. Staiano A, Flynn R. Therapeutic uses of active videogames: a systematic review. *Games Health J*. 2014;3(6):351-365. doi:10.1089/g4h.2013.0100
16. 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(3):352-360. doi:10.1080/02701367.2020.1733456

17. Gomes GCV, Simões MS, 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. doi:10.1016/j.maturitas.2018.10.002
18. 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(12):2096-2102. doi:10.1016/j.apmr.2015.08.427
19. Yang CM, Chen Hsieh J, Chen YC, Yang SY, Lin HCK. Effects of Kinect exergames on balance training among community older adults. *Medicine (Baltimore)*. 2020;99(28):e21228. doi:10.1097/MD.0000000000021228
20. 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. doi:10.2147/CIA.S69673
21. 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(3):158-164. doi:10.1089/g4h.2020.0180
22. 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. doi:10.1080/17483107.2022.2115562
23. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bull World Health Organ*. 2001;79(4):373-374.
24. Eldridge SM, Chan CL, Campbell MJ, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *BMJ*. 2016;355:i5239. doi:10.1136/bmj.i5239
25. 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(6):504-510. doi:10.12809/hkmj144219
26. 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(3):1057-1073. doi:10.1177/0962280215588241
27. 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(4):323-331. doi:10.2340/16501977-0537
28. 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(8):M539-M543. doi:10.1093/gerona/57.8.M539
29. 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(10):1034-1045. doi:10.1093/ptj/85.10.1034
30. Podsiadlo D, Richardson S. The timed "up & go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142-148. doi:10.1111/j.1532-5415.1991.tb01616.x
31. 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. doi:10.1177/2333721416637798
32. Delbaere K, Smith ST, Lord SR. Development and initial validation of the iconographical falls efficacy scale. *J Gerontol A Biol Sci Med Sci*. 2011;66A(6):674-680. doi:10.1093/gerona/glr019
33. D'Elia L, Satz P, Uchiyama C, White T. *Color Trails Test: Professional Manual*. Psychological Assessment Resources; 1996.
34. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol*. 2013;4:863. doi:10.3389/fpsyg.2013.00863
35. Bacha JMR, Gomes GCV, de Freitas TB, et al. Effects of Kinect adventures games versus conventional physical therapy on postural control in elderly people: a randomized controlled trial. *Games Health J*. 2018;7(1):24-36. doi:10.1089/g4h.2017.0065
36. Pompeu JE, Mendes FA, Silva KG, et al. Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: a randomised clinical trial. *Physiotherapy*. 2012;98(3):196-204. doi:10.1016/j.physio.2012.06.004
37. Pompeu JE, Arduini LA, Botelho AR, et al. Feasibility, safety and outcomes of playing Kinect adventures!™ for people with Parkinson's disease: a pilot study. *Physiotherapy*. 2014;100(2):162-168. doi:10.1016/j.physio.2013.10.003
38. Galna B, Jackson D, Schofield G, et al. Retraining function in people with Parkinson's disease using the Microsoft kinect: game design and pilot testing. *J Neuroeng Rehabil*. 2014;11(1):60. doi:10.1186/1743-0003-11-60
39. 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(2):304-326. doi:10.1123/japa.2016-0326
40. Jorgensen MG, Laessoe U, Hendriksen C, Nielsen OBF, Aagaard P. Efficacy of Nintendo Wii training on mechanical leg muscle function and postural balance in community-dwelling older adults: a randomized controlled trial. *J Gerontol A Biol Sci Med Sci*. 2013;68(7):845-852. doi:10.1093/gerona/gls222
41. Ning H, Jiang D, Du Y, et al. Older adults' experiences of implementing exergaming programs: a systematic review and qualitative meta-synthesis. *Age Ageing*. 2022;51(12):afac251. doi:10.1093/ageing/afac251
42. 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(9):1293-1309. doi:10.1007/s40279-016-0485-1
43. 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(1):164. doi:10.1186/s12984-021-00917-0

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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