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Review

VR exergame interventions among older adults living in long-term care facilities: A systematic review with Meta-analysis

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A B S T R A C T

Background: To improve the motivation toward exercise in older adults, exergames have shifted from entertainment to rehabilitation.
Objectives: To review the training focus of exergames and analyze the effectiveness of exergame training on physical, psychological, or cognitive outcomes among older adults in long-term care facilities (LTCFs).
Methods: This review followed the PRISMA guidelines. By searching 7 electronic databases up to April 30, 2022, studies were included if they 1) involved adults ≥65 years old residing in LTCFs, 2) were randomized controlled trials (RCTs) with virtual reality-based exergames as the intervention, 3) compared the effects of exergames to usual care or conventional exercises, and 4) reported physical, psychological, or cognitive outcomes. The Cochrane Risk-of-Bias tool for randomized trials version 2 (RoB 2) and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) were used to evaluate the methodological quality of studies and levels of evidence for outcomes. The meta-analysis was conducted with Review Manager 5.4. Results are presented as standardized mean differences (SMDs) and 95% confidence intervals (CIs).
Results: A total of 12 RCTs were included in the systematic review and meta-analysis. For overall methodological quality, 10 studies showed some concerns and 2 studies showed high risk. Levels of evidence for outcomes were assessed as low (n = 8) and very low (n = 4). The studies involved a total of 482 older adults. Most studies implemented balance exercise as the exergame intervention. Older adults who completed exergame interventions showed improvements in cognitive outcomes (SMD 0.90, 95%CI 0.61–1.19, p<0.001) and in balance self-efficacy (SMD 1.04, 95%CI 0.47–1.61, p<0.001) as compared with those in usual care. They also showed improvements in balance (SMD 0.49, 95%CI 0.20–0.78, p<0.001) as compared with those in conventional exercise programs. Overall, exergames had a positive effect on balance (SMD 0.62, 95%CI 0.29–0.95, p<0.001).
Conclusion: This review revealed that exergames can improve the balance ability of older adults in LTCFs.

Introduction

Aging can lead to the development of multiple dysfunctions and the consequent loss of independence [1]. With aging, gait performance, motor control, and cognitive function decreases [2]. Therefore, the demand for living in some form of long-term care facility (LTCF) to receive assistance with activities of daily life and primary medical care among older adults is expected to increase [3]. Previous studies indicated that regular exercise can improve physical performance and quality of life, reduce risks of falls and depressive symptoms, and lower the probability of cognitive decline in older adults [4,5]. However, older adults living in LTCFs have difficulties engaging in an adequate amount of exercise because they are usually in poor health and have multiple health-related comorbidities, including frailty and severe cognitive impairments [3]. Physical inactivity significantly increases the likelihood of further declines in cognitive and functional abilities [6].

Given the globally aging population and increasing demand on LTCFs, there is a need for effective and sustainable interventions that can provide opportunities for physical, psychological, and cognitive stimulation as well as motivation to older adults in LTCFs. To improve these outcomes in older adults, exergame training methods have become a trend in recent years [7,8]. Previous studies suggested that exergames or virtual reality-based exercises, whereby players are able to interact with the game scenario and have the advantages of

Abbreviations: LTCFs, long-term care facilities; PRISMA, The Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement; SMD, standardized mean difference

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exciting game content and instant feedback [9], provide experiences of actual exercise and stimulate sensorial, cognitive, psychological, and motor functions [10,11]. Exergames, as an enjoyable activity, are able to motivate older adults in LTCFs and offer opportunities to practice both motor and cognitive skills [12,13]. Exergames may exert their positive effects by providing simultaneous physical, psychological, and cognitive stimulation, which may in turn mitigate functional decline.

Results of empirical studies and meta-analyses indicated that exergames have positive effects on muscle strength, balance and mobility [14], cognitive function [15], and self-efficacy in balance [16] among community-dwelling older adults. As compared with community-dwelling and hospitalized individuals, older adults in LTCFs have the worst physical conditions, such as less muscle mass or physical activities [17]. Despite clinical trials investigating the effects of exergames among older adults in LTCFs, the results were mixed [9,18,19]. Moreover, no systematic reviews or meta-analyses have been conducted to investigate the effects of exergames among older adults in LTCFs.

This study aimed to review the training focus of exergames and analyse the effectiveness of exergame training on physical, psychological, or cognitive outcomes as compared with usual care and conventional exercises among older adults in LTCFs.

Methods

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20]. It was registered at PROSPERO (CRD42021241923).

Data search and study selection

The search strategy aimed to identify peer-reviewed journal articles published in English. Electronic searches were performed in the databases Cochrane Library (CENTRAL), Cumulative Index to Nursing and Allied Health Literature (CINAHL) Plus with Full Text, Embase, MEDLINE Complete, ProQuest Health Research Premium Collection, PubMed, and Web of Science from the date of the inception up to and including April 30, 2022. The following keywords and controlled vocabulary terms were used: Medical Subject Headings (MeSH) related to long-term care facility (assisted living facility OR institutionalization OR institutional care OR long-term care facility OR nursing home OR care home OR residential care facility OR aged care facility), older adults (aged OR elder* OR geriatr* OR old OR older adult OR older people OR older person OR senior), and exergame (exergame OR exergaming OR video game OR virtual reality OR augmented reality OR Kinect OR Wii OR play station). Reference lists of identified studies were examined for additional eligible studies. A search strategy sample is provided in Appendix A.

The Participants, Interventions, Comparisons, and Outcomes (PICO) criteria were used to select studies: 1) adults ≥ 65 years old who resided in LTCFs or nursing homes with no restrictions to cognitive conditions but able to perform exergames; 2) the study was a randomized controlled trial and used VR-based exergames, including commercial game systems or self-developed game systems, as the intervention for participants in the intervention groups; 3) the control groups received usual care or conventional exercises; and 4) studies reported any physical, psychological, or cognitive outcomes. The exclusion criteria were 1) abstracts, case reports, conference papers, commentary articles, grey literature, protocols, review articles, systematic reviews, and meta-analyses; 2) studies that used exergames combined with other treatments as the intervention; 3) studies that implemented a single session as the intervention period; and 4) studies that were conducted with hospitalized or community-dwelling older adults.

Quality appraisal, data extraction, and data synthesis

Two reviewers independently reviewed the titles and abstracts of articles obtained from the database search. Full texts were reviewed by the 2 reviewers (PJC, HFH) independently. Consensus was achieved by discussion or with a third reviewer (KMC). One reviewer (PJC) extracted data using standardized data extraction tools suggested by Cochrane [21]. The extracted data included the first author's name, year of publication, country, research design, number and characteristics of research participants, outcomes, content of the intervention, and main findings. All reviewers checked the accuracy of extracted data.

Two reviewers (PJC, HFH) used the Cochrane Risk-of-Bias tool for randomized trials version 2 (RoB 2) [22] to evaluate the methodological quality of the studies and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) [23] to grade the levels of evidence for outcomes. In the RoB 2, the randomized controlled trials were rated as having low, some concerns, or high risk of bias based on criteria of the randomization process, deviations from protocol, missing outcome data, measurement of the outcome, and selective reporting. Each outcome was graded as very low, low, moderate, and high level using the GRADE system. Additional information from the study authors was sought if necessary. EndNote 19 (Clarivate Analytics, London, UK) was used to group results and exclude duplicate articles.

Statistical analysis

The meta-analysis was conducted with Review Manager version 5.4 (Cochrane Collaboration, Oxford, UK). The Cochran Q test and I^2 statistic were used to assess the degree of heterogeneity [24]. With $p < 0.05$ for the Q test and $I^2 > 50\%$, considered high heterogeneity, we used a random-effects model [24]; otherwise, we used a fixed-effects model. For a single study, when multiple measurements were taken for a given outcome, the inverse-variance method was used [25]. All outcomes were continuous, and the results are presented as standardized mean differences (SMDs) and 95% confidence intervals (CIs). $P < 0.05$ was considered statistically significant. The summary value for each study is shown in forest plots. Sensitivity and subgroup analyses were conducted to explore the sources of heterogeneity. Sensitivity analysis was conducted to observe changes by removing a single study. Because the control groups have different intervention methods, subgroup analyses were conducted to detect the difference. The publication bias was examined by Egger's regression test [26] using the Comprehensive Meta-Analysis version 2 (Biostat Inc., Englewood, NJ, USA).

Results

Identification of studies

A total of 3,212 published articles were identified in the databases. After the removal of duplicates, 2,513 articles were identified as potentially relevant for title and abstract examinations. A total of 118 full texts were screened for eligibility. Finally, 12 publications were selected and included in the systematic review and all were included in the meta-analysis (Appendix B).

Methodological quality of the studies

Table 1 shows the methodological quality of the included studies. For randomization process, most of the studies showed some concerns (n = 8), 3 studies showed low risk [27–29], and one study showed high risk [30]. Regarding deviations from intended interventions, 4 studies showed low risk [28,31-33] and 8 studies showed some concerns. For the item missing outcome data, most of the

Table 1
Methodological quality of the included studies by using the Cochrane Risk-of-Bias tool for randomized trials version 2 [22].

Author (year)	Randomization process	Deviations from the intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Daniel (2012) [38]	Some concerns	Some concerns	Low risk	Low risk	Low risk	Some concerns
Delbroek et al. (2017) [31]	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns
Fakhro et al. (2020) [34]	Some concerns	Some concerns	Some concerns	High risk	Low risk	High risk
Fu et al. (2015) [28]	Low risk	Low risk	Low risk	Low risk	Low risk	Some concerns
Gunst et al. (2022) [29]	Low risk	Some concerns	Some concerns	Low risk	Low risk	Some concerns
Htut et al. (2018) [30]	High risk	Some concerns	Low risk	Low risk	Low risk	High risk
Liao et al. (2019) [37]	Some concerns	Some concerns	Low risk	Low risk	Low risk	Some concerns
McCord et al. (2020) [36]	Some concerns	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Mugueta-Aguinaga & Garcia-Zapirain (2017) [32]	Some concerns	Low risk	Low risk	Some concerns	Low risk	Some concerns
Padala et al. (2012) [35]	Some concerns	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Taylor et al. (2018) [27]	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
Yeşilyaprak et al. (2016) [33]	Some concerns	Low risk	Low risk	Low risk	Low risk	Some concerns

studies (n = 10) showed low risk and 2 studies showed some concerns [29,34]. Regarding measurement of the outcome, most of the studies (n = 8) showed low risk, 3 studies showed some concerns [32,35,36], and one study showed high risk [34]. Finally, all studies (n = 12) showed low risk for selection of the reported result. For overall methodological quality, 2 studies [30,34] showed high risk and the remaining studies showed some concerns (n = 10). Appendix C shows the levels of evidence for outcomes. Because of an insufficient number of studies, levels of outcomes for quality of life and activities of daily living could not be assessed. Levels of evidence for other outcomes were assessed as low (n = 8) and very low (n = 4). The low level of evidence was mainly due to the high heterogeneity and insufficient number of participants.

Sensitivity analysis and publication bias

Sensitivity analysis was conducted to observe changes by removing a single study. Subgroup analysis was by the control group with different intervention methods (usual care or conventional exercise). However, a high heterogeneity was shown for the outcomes of balance self-efficacy (I^2 = 68%, p = 0.005), balance (I^2 = 68%, p < 0.001), mobility (I^2 = 75%, p < 0.001), strength (I^2 = 75%, p < 0.001), and activities of daily living (I^2 = 54%, p = 0.14). No heterogeneity was shown for the outcomes of cognition (I^2 = 16%, p = 0.3), flexibility (I^2 = 0%, p = 0.75) and quality of life (I^2 = 0%, p = 0.79). Furthermore, results of Egger's test showed no significant publication bias (all p > 0.05).

Characteristics of studies and participants

The 12 studies were published between 2012 and 2022 (Table 2). They were carried out in Australia [28], Belgium [29,31], Lebanon [34], Myanmar [30], New Zealand [27,36], Spain [32], Taiwan [37], Turkey [33], and the United States [35,38]. The reviewed studies reported the results for a total of 482 older adults. The sample size varied from 17 [31] to 84 [30]. The mean (SD) age ranged from 70.1 (4.0) [33] to 89.5 (3.6) [36] years old. Most of the participants were wellfunctioning (n = 7); 3 studies involved pre-frail or frail older adults [28,37,38], and 2 studies included older adults with cognitive impairments [31,35]. There were more females than males in most of the studies (n = 10). The proportion of females ranged from 60% [32] to 79% [36]. Only one study had more males than females [30]. One study did not mention the sex of the participants [34]. Considering the safety of performing exergames, these participants had a certain degree of cognitive ability and the minimum requirement needed for these participants was to be able to walk with assistive devices [9,27,35]. Nine studies reported the reasons for withdrawals, which included low motivation, personal reasons, illness, hospitalization, and death. According to the researchers' statements, no participants were harmed by the study interventions.

Exergame program features

The exergame intervention period ranged from 3 weeks [32,36] to 15 weeks [38] with a mode of 4-8 weeks (n = 7). The frequency of conducting exergames was 2-3 times per week (n = 11), and each training session lasted from 18 min [31] to 60 min [28,29,37]. Some studies added warm-up and cooling sessions [33-35,38] or inserted a break time [28] to protect participants. The mostemployed exergame interface was the Wii [28,34,35,38] and the Kinect-based systems [27,29,32,37], followed by the Play Station [36]. The remaining studies used self-made systems [30,31,33]. Seven studies applied more than one type of exercise as the intervention [27,29-32,35,37] and the training focus of exergames included balance exercise (n = 9, 75% of the included studies), strength training (n = 6, 50% of the included studies), aerobic exercise (n = 4, 33% of the included studies), cognitive-motor dual tasking training (n = 2, 17% of the included studies), and mind-body exercises such as yoga or Tai-Chi (n = 2, 17% of the included studies). Most of the control groups (n = 8) received usual care that they continue with their daily activities but without doing any exercises and received health education or cognitive training games, and others performed conventional exercises (n = 6) such as walking, resistance exercise, aerobic exercise, balance exercise, or a combination of these exercises [28,30,33,35,37,38].

Outcome variables and measurements

Study outcomes focused on balance, mobility, strength, flexibility, cognition, balance self-efficacy, quality of life, and activities of daily living. The most-used measurements for these variables were the Berg Balance Scale for balance [30,33,35], Timed Up and Go test for mobility [30,31,34,35,37], 30-sec chair to stand test for strength [37,38], back scratch test for flexibility [37,38], Montreal Cognitive Assessment test for cognition [30,31,34], Falls Efficacy Scale International for balance self-efficacy [30,33,37], Quality of Life-Alzheimer's Disease scale [35] and Older People's Quality of Life questionnaire [36] for quality of life, and activities of daily living and instrumental activities of daily living scales for activities of daily living [35].

Effects of exergames

Twelve studies were included in the meta-analysis. Figures 1 to 3 and Appendices D to H show the results of 8 outcomes in the meta-analyses. As compared with control groups receiving usual care, the intervention groups showed significant improvement in cognition

Table 2
Characteristics of the included studies.

Author (year), Country	Design, Population	Participants (age, years)	Female (%)	Outcomes (Measurements)	Intervention	Results
Daniel (2012) [38], USA	RCT, Pre-frail older adults (Fried's frailty criteria: 1-2 of 5 physical characteristics) [52]	CG1: 5 (72.6) CG2: 8 (78.13) EG: 8 (80)	60.87	Mobility (CHAMPS) Balance Self-efficacy (ABC) SFT LLFDI	Duration: 45 min, 3 times/week, 15 weeks. CG1: Usual care CG2: Seated exercise EG: Wii Fit exergames, including bowling, tennis, and boxing games (The games involved aerobic training).	CG2 showed significant improvement between CG2 & CG1 in SFT. EG showed significant improvement between EG & CG1 in SFT. Only EG improved within-group in caloric expenditure of CHAMPS.
Delbroek et al. (2017) [31], Belgium	RCT, Older adults with mild cognitive impairment (MoCA < 26)	CG: 9 (87.5) EG: 8 (86.9)	65	Cognition (MoCA) Balance (Tinetti-POMA) Mobility (iTUG)	Duration: 18-30 min, 2 times/week, 6 weeks. CG: Usual care EG: BioRescue system, including "Memory Exercise", "Avoidance Whilst Walking", "Hot Air Balloon", "Blackboard", "Spaceshuttle", "Simple Maze", "Tortoise", "Rally", and "Downhill Ski" games (The games involved cognitive-motor dual tasking and balance training).	EG showed significant improvement between-group in total TUG duration and the turn-to-sit duration during single-task walking.
Fakhro et al. (2020) [34], Lebanon	RCT, Older adults	CG: 30 (≥ 65) EG: 30 (≥ 65)	None	Mobility (TUG) NWBB	Duration: 30 min, 3 times/week, 8 weeks. CG: Usual care EG: Wii exergames, including "Soccer Heading" for first 4 weeks and "Table Tilt" game for the remaining 4 weeks (the games involved balance training).	EG showed significant improvement within-group in TUG and center of pressure. EG showed significant improvement between-group in TUG.
Fu et al. (2015) [28], Australia	RCT, Frail older adults (Functional Ambulation Category grade 2 or 3)	CG: 27 (82.3) EG: 28 (82.4)	65	Balance (PPA) Numbers of falls	Duration: 60 min, 3 times/week, 6 weeks. CG: Conventional exercise (Conventional balance training) EG: Wii Fit exergames, including "Soccer Heading", "Table Tilt", and "Balance Bubble" games (The games involved balance training).	Post-test (6 weeks later): EG and CG both showed significant improvement in quadriceps strength, reaction time, PPA z scores, number of falls at follow-up and 12 month later. EG showed significant improvement within-group in postural sway.
Gunst et al., (2022) [29], Belgium	RCT, Older adults	CG: 17 (≥ 71) EG: 15 (≥ 71)	68.75	Cognition (IQCODE-N & NHG guidelines dementia) Domus Medica guideline sleep disorders OPQOL-35 RAND 36 Bel Rai	Duration: 60 min, 2 times/week, 13 weeks. CG: Usual care EG: Xbox 360 Kinect Sport, including boxing, bowling, and football (The games involved strength and aerobic exercises).	The median score of mental wellbeing, sleep quality, pain complaints, and cognitive functioning increased in EG.
Htut et al. (2018) [30], Myanmar	RCT, Older adults	CG: 21 (76.0) EG1: 21 (75.9) EG2: 21 (75.8) EG3: 21 (75.6)	44.05	Balance (BBS) Mobility (TUG) Strength (5TSTS) Strength (HGS) Cognition (MoCA) Cognition (TUG-cog) Balance Self-efficacy (FES-I) Borg CR-10	Duration: 30 min, 3 times/week, 8 weeks. CG: Usual care EG1: Physical exercise, including strength and balance exercises. EG2: Virtual reality games, including "Light Raise", "Virtual Smash", "Stack' em Up", "One Ball Roll", "Pin Push", "Super Saver", "Target Kick, "Play Paddle Panic", "Body Bally", and "Bamp Bash" games (The games involved strength and balance training). EG3: Cognitive training games, including "Chinese checker", "Jenga", "Match pair games".	EG1 showed significant improvement between EG1 & EG2 in TUG and 5TSTS. EG1 showed significant improvement between EG1 & EG3 in TUG and 5TSTS. EG2 showed significant improvement between EG2 & EG1 in MoCA & FES-I. EG2 showed significant improvement between EG2 & EG3 in 5TSTS & FES-I. EG3 showed significant improvement between EG3 & EG1 in MoCA. EG3 showed significant improvement between EG3 & EG2 in MoCA & TUG-cog. EG1 & EG2 showed significant improvement within-group in Borg CR-10. EG3 showed significant improvement within-group in Borg CR-10 in the first 4 sessions. EG3 showed significant improvement between EG3 & CG in Satisfaction. EG2 showed significant between EG2 & EG1 improvement in pleasure. EG3 showed significant between EG3 & EG1 improvement in pleasure. EG1 showed significant improvement between EG1 & CG in benefit. EG2 showed significant improvement between EG2 & CG in benefit. EG3 showed significant improvement between EG3 & CG in benefit.

(*continued on next page*)

Table 2 (*Continued*)

Author (year), Country	Design, Population	Participants (age, years)	Female (%)	Outcomes (Measurements)	Intervention	Results
Liao et al. (2019) [37], Taiwan	RCT, Pre-frail & frail older adults (Fried's frailty criteria: at least 1 item of 5 physical characteristics) [52]	CG: 25 (84.1) EG: 27 (79.6)	69.23	Balance (SPPB) Balance (FRT) Balance (SLST) Mobility (TUG) Mobility (Walking velocity) Strength (30CST) Strength (Stepping) Strength (Grip strength) Flexibility (Back scratch) Flexibility (CSR) Balance Self-efficacy (FES-I) Frailty Score	Duration: 60 min, 3 times/week, 12 weeks. CG: Conventional exercise (Combined exercise program: resistance exercises, aerobic exercises, and balance exercises). EG: Kinect-based game, including Tai-chi, strength, aerobic, and balance games.	EG & CG both showed significant improvement in frailty status. CG showed significant improvement within-group in 30CST, Grip strength, and FES-I. EG showed significant improvement within-group in 30CST, FRT, SLST, TUG, grip strength, walking velocity, and FES-I. EG showed significant difference between-group in FRT and SLST.
McCord et al. (2020) [36], New Zealand	RCT, Older adults	CG: 12 (89.00) EG: 12 (89.50)	79.17	Cognition (TMT) Quality of Life (OPQOL-Brief) WMS-III	Duration: 30 min/session, total 6 sessions in 3 weeks. CG: Usual care EG: Sony PlayStation exergames, including "Star Wars battlefront" (The game involved cognitive-motor dual tasking training).	EG showed significant improvement between-group in TMT, in post-test and 1 month later. EG improve within-group in working memory. The Letter-Number Sequencing return to baseline after one month later in EG.
Mugueta-Aguinaga & Garcia-Zapirain (2017) [32], Spain	RCT, Older adults	CG: 19 (> 65) EG: 20 (> 65)	60	Balance (SPPB)	Duration: 20 min, 3 times/week, 3 weeks. CG: Usual care EG: Kinect-based exergames, including limbs movement, balance, and coordination games (The games involved strength and balance training).	EG showed significant improvement between-group in SPPB.
Padala et al. (2012) [35], USA	RCT, Older adults with mild Alzheimer's dementia (History of mild Alzheimer's disease with MMSE ≥ 18)	CG: 11 (79.3) EG: 11 (81.6)	72.73	Balance (BBS) Balance (TT) Mobility (TUG) Cognition (MMSE) Quality of Life (QOL-AD) Activity of Daily Living (ADL) Activity of Daily Living (IADL)	Duration: 30 min, 5 times/week, 8 weeks. CG: Walking EG: Wii Fit exergames, including "Single Leg Extensions", "Lunges", "Torso Twists", "Yoga" ("half-moon", "warrior", "chair", and "sun salutation"), "Soccer Heading", "Ski Slalom", "Ski Jump, "Table Tilt", "Balance Bubble", and "Penguin Slide" games (The games involved yoga**,** strength, aerobic, and balance training).	EG showed significant improvement within-group on BBS and TT. CG showed significant improvement within-group on TT.
Taylor et al. (2018) [27], New Zealand	RCT, Older adults	CG: 32 (85.80) EG: 26 (86.75)	74.14	Mobility (DEMMI)	Duration: 35 min, 2 times/week, 8 weeks. CG: Usual care EG: Xbox Kinect exergames, including "Your Shape Fitness Evolved", simple lower and upper limb games (The games involved strength and balance training).	EG showed improve within-group in DEMMI scores. No interaction between cognition scores and DEMMI scores.
Yeşilyaprak et al. (2016) [33], Turkey	RCT, Older adults	CG: 11 (73.1) EG: 7 (70.1)	66.67	Balance (BBS) Balance (OLS) Balance (TS) Mobility (TUG) Balance Self-efficacy (FES-I)	Duration: 35-45 min, 3 times/week, 6 weeks. CG: Conventional exercise (Balance exercises) EG: BTS NIRVANA VR Interactive System, including maintaining balance with visual and audio feedback games (The games involved balance training).	EG & CG both showed significant improvement within-group in BBS, OLS-EC-L, TS-EC, TUG. No significant improvement between-group at all.

10MWT, 10-m walking test; 30CST, 30-sec chair to stand test; 5TSTS, muscle strength by 5 times sit to stand; 6MWT, Six-min walk test; ABC, Activities-Specific Confidence Scale; ADL, Activities of daily living; BBS, Berg Balance Scale; Bel Rai, Belgian implementation of the interRAI assessment tools; Borg CR-10, Borg Category Ratio scale; CG, Control Group; CHAMPS, Community Healthy Activities Model Program for Seniors; CSR, Chair sit and reach test; DEMMI, The de Morton Mobility Index; EG, Experimental Group; FES-I, The Falls Efficacy Scale International; FRT, Functional Reach Test; FSST, Four square step test; HGS, Hand grip strength; IADL, Instrumental activities of daily living; IQCODE-N, Dutch short form Informant Questionnaire on Cognitive Decline in the Elderly; iTUG, instrumented Timed Up and Go test; LAPAQ, LASA Physical Activity Questionnaire; LLFDI, Late Life Function and Disability Index; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; NWBB, Nintendo Wii balance board; OLS, A one-leg stance test; OLS-EC-L, One leg stance-eyes closed-left; OPQOL-35, Older People's Quality of Life Questionnaire; OPQOL-Brief, Older People's Quality of Life-Brief version; PPA, Physiological Profile Assessment; QoL, quality of life; QOL-AD, Quality of Life-Alzheimer's disease; RAND 36, RAND 36-Item Short Form Survey; RCT, randomized controlled trial; SFT, Senior Fitness Test; SLST, The single leg stance test; SPPB, Short Physical Performance Battery; Tinetti-POMA, Tinetti Performance Oriented Mobility Assessment scale; TMT, Trail Making Test A/B; TS, Tandem stance test; TS-EC, Tandem stance-eyes closed; TT, Tinetti Test; TUG, Timed Up and Go; TUG-cog, Timed Up and Go test Cognition; WMS-III, Wechsler Memory Scale-III.

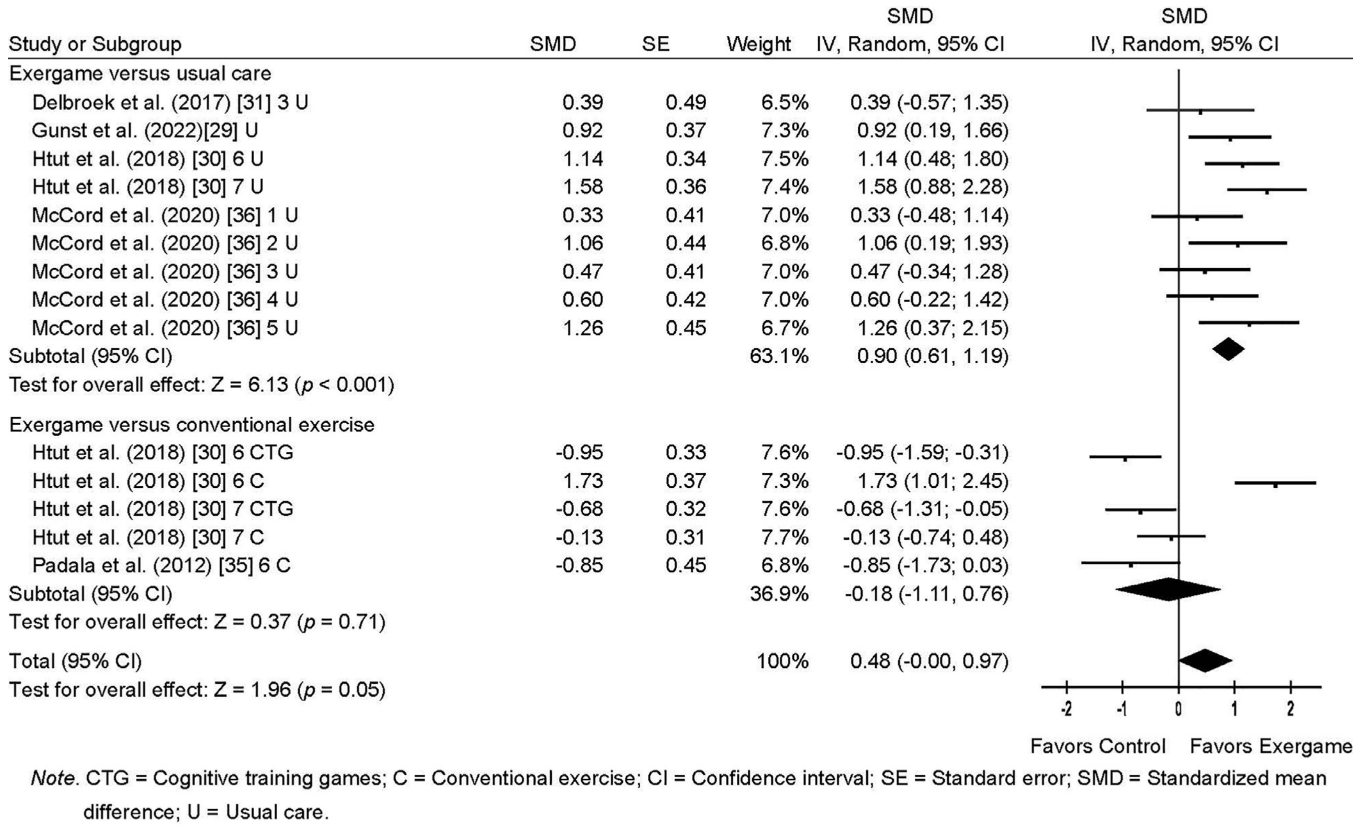


Figure 1. Meta-analysis of the effects of virtual reality exergames on cognition.

(SMD 0.90, 95% CI 0.61–1.19, $p < 0.001$) (Fig. 1) and balance self-efficacy (SMD 1.04, 95% CI 0.47–1.61, $p < 0.001$) (Fig. 2). The remaining outcomes showed no significant differences. As compared with the control groups receiving conventional exercises, the intervention groups showed significant improvement in balance (SMD 0.49, 95% CI 0.20–0.78, $p < 0.001$) (Fig. 3) and the remaining outcomes showed no significant differences. The overall effect of using exergames showed a significant difference in the outcome of balance (SMD 0.62, 95% CI 0.29–0.95], $p < 0.001$) (Fig, 3).

Discussion

The objective of this study was to explore the training focus of exergames and to analyse the effectiveness of virtual reality-based

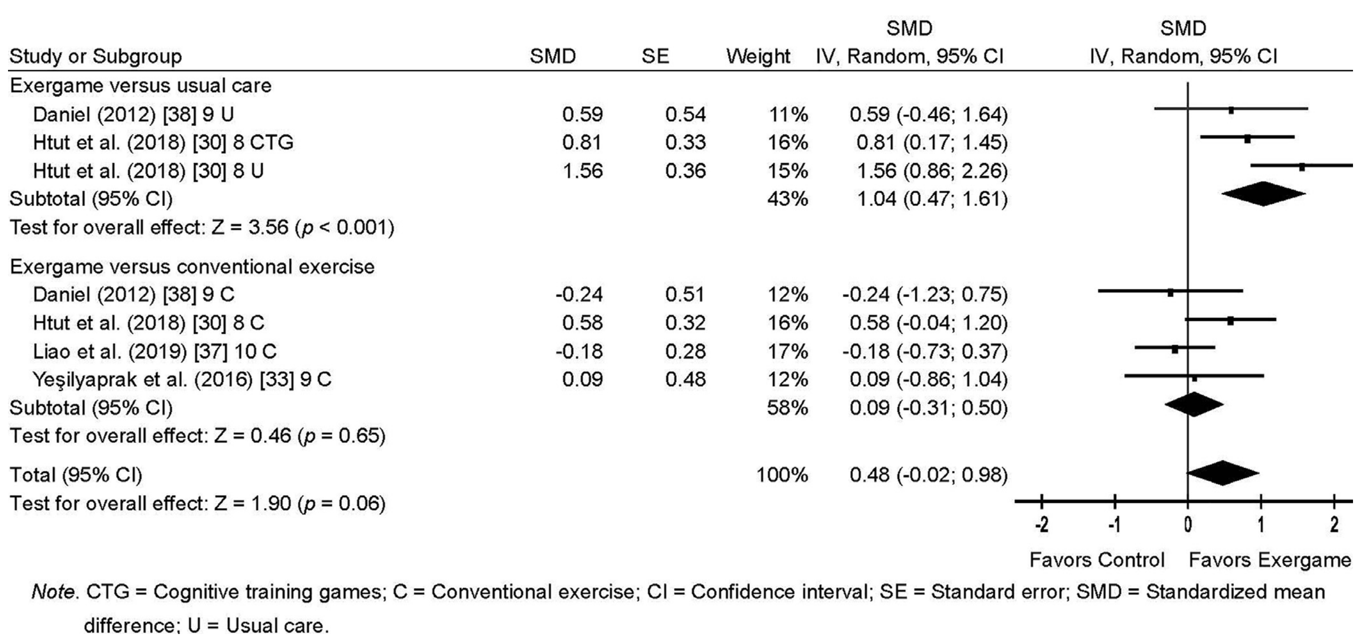
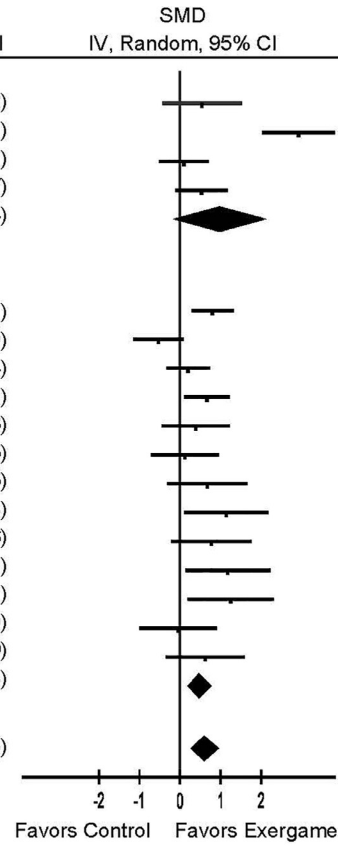


Figure 2. Meta-analysis of the effects of virtual reality exergames on balance self-efficacy.

Study or Subgroup	SMD	SE	Weight	SMD IV, Random, 95% CI
Exergame versus usual care				
Delbroek et al. (2017) [31] 2 U	0.54	0.50	5%	0.54 (-0.44; 1.52)
Htut et al. (2018) [30] 1 CTG	2.92	0.46	6%	2.92 (2.02; 3.82)
Htut et al. (2018) [30] 1 U	0.10	0.31	7%	0.10 (-0.51; 0.71)
Mugueta-Aguinaga & Garcia-Zapirain (2017) [32] 1 U	0.53	0.33	7%	0.53 (-0.11; 1.17)
Subtotal (95% CI)			24%	1.00 (-0.15; 2.14)
Test for overall effect: Z = 1.71 (*p* = 0.09)				
Exergame versus conventional exercise				
Fu et al. (2015) [28] 1 C	0.80	0.27	8%	0.80 (0.28; 1.32)
Htut et al. (2018) [30] 1 C	-0.53	0.32	7%	-0.53 (-1.15; 0.09)
Liao et al. (2019) [37] 4 C	0.20	0.28	7%	0.20 (-0.34; 0.74)
Liao et al. (2019) [37] 5 C	0.66	0.29	7%	0.66 (0.10; 1.22)
Padala et al. (2012) [35] 1 C	0.39	0.43	6%	0.39 (-0.45; 1.23)
Padala et al. (2012) [35] 2 C	0.12	0.42	6%	0.12 (-0.71; 0.95)
Yeşilyaprak et al. (2016) [33] 1 C	0.67	0.50	5%	0.67 (-0.31; 1.65)
Yeşilyaprak et al. (2016) [33] 3 C	1.14	0.53	5%	1.14 (0.10; 2.18)
Yeşilyaprak et al. (2016) [33] 4 C	0.77	0.51	5%	0.77 (-0.22; 1.76)
Yeşilyaprak et al. (2016) [33] 5 C	1.18	0.53	5%	1.18 (0.14; 2.22)
Yeşilyaprak et al. (2016) [33] 6 C	1.25	0.54	5%	1.25 (0.19; 2.31)
Yeşilyaprak et al. (2016) [33] 7 C	-0.05	0.48	5%	-0.05 (-1.00; 0.90)
Yeşilyaprak et al. (2016) [33] 8 C	0.62	0.49	5%	0.62 (-0.35; 1.59)
Subtotal (95% CI)			76%	0.49 (0.20; 0.78)
Test for overall effect: Z = 3.32 (*p* < 0.001)				
Total (95% CI)			100%	0.62 (0.29; 0.95)
Test for overall effect: Z = 3.63 (*p* < 0.001)				



Note. CTG = Cognitive training games; C = Conventional exercise; CI = Confidence interval; SE = Standard error; SMD = Standardized mean difference; U = Usual care.

Figure 3. Meta-analysis of the effects of virtual reality exergames on balance.

exergame training on physical, psychological, or cognitive outcomes as compared with usual care and conventional exercises among older adults in LTCFs. A total of 12 studies examined the effects of exergames on outcomes of balance, mobility, strength, flexibility, cognition, balance self-efficacy, quality of life, and activities of daily living. Results of the 12 studies included in the meta-analysis indicated that the intervention groups showed significantly improved cognition and balance self-efficacy as compared with the control groups receiving usual care. As compared with the control groups receiving conventional exercises, the intervention groups showed significantly improved balance.

Self-efficacy in balance is not associated with balance ability in older adults who are at increased risk of falling [39]. In this meta-analysis, although older adults receiving exergame interventions showed improvements in balance as compared with those receiving usual care (regular daily activities without doing any exercises), significant improvements were shown only in balance self-efficacy rather than balance ability. Individuals successfully completing the training activities may have contributed to the increase in balance self-efficacy [40]. In addition, exergames contain elements of cognitive tasks, which may improve balance self-efficacy [2]. Although the exercise content focused on balance training in both the exergame intervention group and the conventional exercise group, the immediate interaction and cognitive-motor dual task training components in the exergames may have resulted in better balance performance in participants [9,10]. For cognition, exergames only showed a significant difference when compared to usual care groups but not conventional exercise groups, which suggests that although exergames are helpful for cognition, they have limitations. For balance, exergames produced better results when compared to conventional exercise groups, which suggests that in balance, exercise combined with cognitive tasks is more beneficial than exercise alone.

In this systematic review and meta-analysis, 3 studies used the Falls Efficacy Scale [30,33,37] to measure balance self-efficacy, and one study used the Activities-Specific Confidence Scale [38]. A total of 114 participants, 49 in the usual care subgroup and 65 in the conventional exercise subgroup, were assessed. Because of the small number of studies, small sample sizes, and the high heterogeneity associated with the random-effects model among the included studies, the range of the 95% CI was increased, thus resulting in decreased precision of effect estimates in this meta-analysis [21].

Although these included studies had requirements for fitness level such as being able to walk independently for 3 m [29] or for 10 m with assistance [33], the Timed Up and Go and Berg Balance Scale scores of some participants at the beginning indicated low performance [30,31,34,35,37], and some studies involved participants who were pre-frail or frail older adults [28,37,38]. These older adults were at high risk of falling [41] and would likely require more attention when performing exergames. Furthermore, some studies included in this systematic review and meta-analysis investigated the effects of exergames among older adults with cognitive impairments [31,35]. Their findings indicated that exergames can improve the functional fitness of older adults with mild cognitive impairments [31,35]. Although older adults with cognitive impairment may need more time to adapt to exergames, challenging tasks in a virtual environment may be more beneficial than cognitive stimulation [42]. Accordingly, mild cognitive impairment does not affect the ability to perform and benefit from exergames.

In this review, the most frequently used exergame hardware was the Wii and the Kinect, both having their own features. As compared with the Wii, the Kinect requires a larger space for execution, and it may not be suitable if the indoor space is limited [43–45]. As compared with the Kinect, the Wii has more multiplayer games [27,35]. Regardless of the exergame consoles, the training focus is mainly on balance or strength exercise in this review. The results suggested that when the training focus of exergames is related to balance, the balance ability of older adults is improved. Therefore, the training focus of exergames may be more important than the exergame interface.

The WHO recommends that older adults with limited mobility engage in functional balance and strength training at moderate or higher intensity at least 3 times a week [46]. In this review, the training frequency in most of the studies was 3 times a week, and the results showed significant improvements in balance. Some studies implemented exergames less frequently than 3 times a week, but balance was still significantly improved [27,31]. Accordingly, exercising 2-3 times a week using exergames could have positive benefits for older adults in LTCFs.

For older adults in LTCFs, injuries should be avoided when performing exergames. Participants in some studies reported that performing exergames was laborious, and adjusting the difficulty is an option [27,28]. According to the results of the studies in this review, none of the participants were harmed by the intervention. Playing exergames requires players to stand still to maintain their balance in many situations. The reasons for the absence of harm after the interventions could be that most of the studies implemented the intervention for 30 min per session, and some interventions were designed with warm-ups and break times. Exercise injuries in older adults are often linked to repetitive stress and overuse [47], and proper rest could help relieve symptoms of fatigue and prevent injury [48]. Some of the included studies indicated that in the absence of a monitoring mechanism, participants chose to sit instead of stand to play the exergames [33,35]. Although these behaviors may reduce the benefits of performing exergames, they may be a form of self-protection for the participants.

Overall, the intervention groups significantly improved their balance. While performing exergames, both physical and psychological functions were trained [30,37]. Playing exergames involves a dual-task training [49,50] in that the players are required to move in different directions when reacting to the game content in order to score points [28,33,37]. Using the audio and visual instant feedbacks of the game, the players learn to improve their balance skills [28].

Limitations

This systematic review and meta-analysis did not include studies published in languages other than English, so information bias may occur. In our meta-analyses, there was large heterogeneity in several outcomes, and the use of sensitivity and subgroup analyses was still unable to reveal the sources of heterogeneity, which affected the results. Because of the high proportion of female participants in most of the studies and the data were not shown separately by sex in the studies, the sex-specific responses are not possible to discern.

Conclusions

Most outcomes had a low level of evidence as assessed by the GRADE because of high heterogeneity and a small number of participants. Although most studies presented some concerns in methodological quality as assessed by the RoB 2, mainly stemming from the randomization process and deviations from expected interventions, the level of the methodological quality might be acceptable. Because older adults in LTCFs are more sensitive in the psychological state, conducting randomization is sometimes difficult [9]. In addition, older adults in LTCFs lived in groups, so blinding is difficult to perform [27,51]. Older adults in LTCFs are usually in poor health and have health-related conditions such as cognitive impairment or the need for assistive devices. This systematic review and meta-analysis found that exergames could improve the balance ability of older adults in LTCFs, even if they have mild cognitive impairments. Including dual-task training and instant feedback, exergames have positive effects on balance training for older adults.

Relevance to clinical practice

To avoid injury, a certain level of cognition and physical fitness is required when playing exergames. The cognitive condition may affect the time needed for an individual to adapt to the game, but older adults with cognitive impairment can still execute exergames. Being able to walk may be required to perform exergames. To achieve the positive effects of exergames in older adults in LTCFs, exergame programs should be delivered for 4-8 weeks and 2-3 times per week. If participants are at a weaker fitness level, increasing rest periods or adjusting the difficulty of exergames may help them avoid injury while performing exergames.

Contributors

All authors meet the criteria for authorship, have approved the final article, and all those entitled to authorship are listed as authors. **Po-Jung Chen:** manuscript draft preparation. **Hui-Fen Hsu and Frank Belcastro:** Data validation and manuscript reviewing and editing. **Kuei-Min Chen:** manuscript reviewing and editing.

Declaration of competing interest

None declared.

CRediT authorship contribution statement

Po-Jung Chen: Conceptualization, Data curation, Formal analysis, Methodology. **Kuei-Min Chen:** Conceptualization, Formal analysis, Methodology, Supervision.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rehab.2022.101702.

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