REVIEW

Effects of active video games on physical function in independent community-dwelling older adults: A systematic review and meta-analysis

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Abstract

Aim: To analyse the effects of active video games on physical function in independent community-dwelling older adults.

Design: Systematic review and meta-analysis of randomized controlled trials.

Data sources: The CINAHL, LILACS, Medline, Proquest and Scopus databases were consulted, with no restriction by year of publication.

Review methods: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. The meta-analysis was performed using RevMan software.

Results: The analysis included 22 randomized controlled trials with a total of 1208 participants (all ≥55 years old). In our meta-analyses, the effects produced by playing the active video games (mean differences) were statistically significant for the variables *Gait speed* and *Timed up-and-go*. The differences between the control and experimental groups were not significant in the following tests: *6-minute walk*, *30-second chair stand*, *balance* (measured with the Berg Balance Scale), *cadence*, *grip strength*, *knee extension strength*, *8-Foot Up-and-Go* or *velocity*.

Conclusions: Physical exercise from participation in active video games has beneficial effects on two clinical parameters (*Gait speed* and *Timed up-and-go*) in independent community-dwelling older adults. However, the effects on other parameters do not differ from those obtained with conventional exercise training. Therefore, the clinical significance of these benefits is limited.

Impact: Older adults usually perform little physical activity. In consequence, researchers have increasingly considered alternatives to traditional forms of exercise. One such is that provided by active video games, which can be a source of stimulation, encouraging adherence and motivation in exercise programmes. Our review shows that active video games can improve gait speed and mobility, but in other respects obtain no differences from conventional exercises. Further tailored randomized clinical trials

should be undertaken with diverse populations of older adults to evaluate different physical function variables to determine the most appropriate training approach and its optimal design and duration.

1 | INTRODUCTION

With global ageing, it is expected that 20% of the population will be over 50 years of age by 2050 (World Health Organization, 2017). However, this rising life expectancy is associated with a parallel increase in the incidence of age-related diseases, meaning greater overall morbidity and mortality (Cao et al., 2020). In addition, ageing causes physiological changes that may compromise functional performance (Nicholson et al., 2015). However, lifestyle is an important determinant of functional levels in old age, and studies have highlighted the important benefits offered by regular physical exercise (Gopinath et al., 2018).

1.1 | Background

Inactivity is said to be the fourth leading cause of death worldwide, and older people are at particular risk in this respect (Kohl et al., 2012). Therefore, behavioural strategies to promote healthy ageing should include the regular practice of physical exercise (Xiong et al., 2021). Physical activity can delay the functional decline effects of ageing, in areas such as physical performance, balance, mobility and muscle strength (Nakano et al., 2014), thus helping preserve independence and autonomy. The evaluation of physical function is a critical element in assessing the status of older persons and should be performed using standard, commonly-available tools in order to ensure objectivity (Patrizio et al., 2021). The definition of physical function usually refers to concepts (and the tools for measuring them) such as gait and balance (Berg Balance Scale, Tinetti Test, 8-Foot Up-and-Go or Unipedal Stance Test), mobility and the risk of falling (Timed Up-and-Go Test), endurance (6-minute walk test and 30-second chair stand) and muscle strength (Patrizio et al., 2021).

Among other positive effects, physical exercise benefits the cardiovascular and respiratory systems, metabolism, the immune system and body composition (Su & Yu, 2019). Furthermore, it is associated with a higher quality of life, greater strength, improved balance and coordination and reduced cognitive impairment (Montero-Alía et al., 2019; Song et al., 2018).

The World Health Organization (WHO), in its report on ageing and health (WHO, 2016), recommended the development of healthy ageing strategies to involve older people while they still have a high and relatively stable functional capacity. Such strategies, however, require a change in attitudes towards the prevention of age-related diseases and the adoption of innovative solutions that would allow older adults to remain independent for longer and thus actively participate in their own health care (Foster et al., 2013).

Technological advances may offer viable alternatives to traditional exercise programmes, for example, through game-based interventions. The use of games in the learning process, or gamification, provides players with continuous feedback and entertainment (DeSmet et al., 2014). Interventions devised for this purpose may be based on video games originally developed purely for entertainment or take a directly physical approach, as is the case with 'exergames', designed to improve physical and cognitive functions and/or facilitate rehabilitation (Pirovano et al., 2016). Physically active video games include virtual reality programmes (Corregidor-Sánchez et al., 2020) and those combining video interaction with physical exercise, by means of appropriate devices (such as the Nintendo Wii or Microsoft Xbox 360 Kinect consoles) (Vieira et al., 2016). Both types of intervention are based on virtual experiences, mixing physical exercise and video stimuli and providing attractive audio/visual feedback, in order to involve and motivate the participant (Nyman & Victor, 2012). Furthermore, these video games can respond to changes in the frequency, direction, speed and acceleration of movement, encouraging the player to complete the task set and to achieve the goals desired (Meekes & Stanmore, 2017).

Personalized interventions fostering healthier behaviour can promote active, healthy ageing and thus lead people to live independently longer (Li et al., 2018), and for some of those concerned a technology-based approach may be very attractive (Helbostad et al., 2017).

Studies have shown that interventions with exergames can improve cognitive and physical functions in older people (Zhao et al., 2020). Some authors have studied game modalities such as 'cyber-cycle' for patients with diabetes (Anderson-Hanley et al., 2012) or 'cyber-golfing' (Chow & Mann, 2015), and have reported improvements in clinical parameters such as cognition, executive function and balance. The use of active video games is also associated with a reduced risk of falls by older people (Chan et al., 2021; Zeng et al., 2017), with the alleviation of depressive symptoms (Drazich et al., 2020; Fang et al., 2020), with an enhanced quality of life (Cacciata et al., 2019) and with better motor function in patients with Parkinson's disease (Dockx et al., 2016). In addition, studies have assessed the effects of exergames on parameters of physical function in older adults-like balance, the Timed Up-and-Go test and the 30-second sit-to-stand test (Pacheco et al., 2020; Taylor et al., 2018). An older systematic review, based on fewer studies and lacking a

meta-analysis, reported inconclusive results about the effectiveness of virtual reality games for enhancing physical function in older adults (Molina et al., 2014). However, these studies omitted some parameters that are objectively measurable and sensitive to change in the assessment of physical function in older adults, such as handgrip strength, the 6-minute walk test, gait speed and walk distance (Patrizio et al., 2021). By addressing the largest possible number of functional parameters, using reliable, widely available measures, researchers could better analyse the improvements to be gained by exergame-based approaches to physical outcomes and functional status in independent community-dwelling older adults. With these considerations in mind, we conducted the following systematic review and meta-analysis.

2 | THE REVIEW

2.1 | Aims

The aim of this systematic review and meta-analysis is to analyse the effects of interventions based on interactive games (exergames or virtual reality) on physical function in independent community-dwelling older adults.

2.2 | Design

This systematic review and meta-analysis was performed in accordance with the guidelines of the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analyses) (Moher et al., 2015).

2.3 | Search methods

The following databases were consulted: CINAHL, LILACS, Medline, Proquest and Scopus, using the search equation: '(game OR gamification) AND (aged OR elderly OR adult OR senior) AND (exercise OR sport OR physical activity OR physical functional performance OR physical fitness OR health) AND (RCT OR randomised controlled trial)'. The search started in March 2021 and was completed in April 2021 using the PICO strategy. The search and selection process were performed independently by NSM and JLGU. The eligibility criteria applied to the studies included are shown in Table 1.
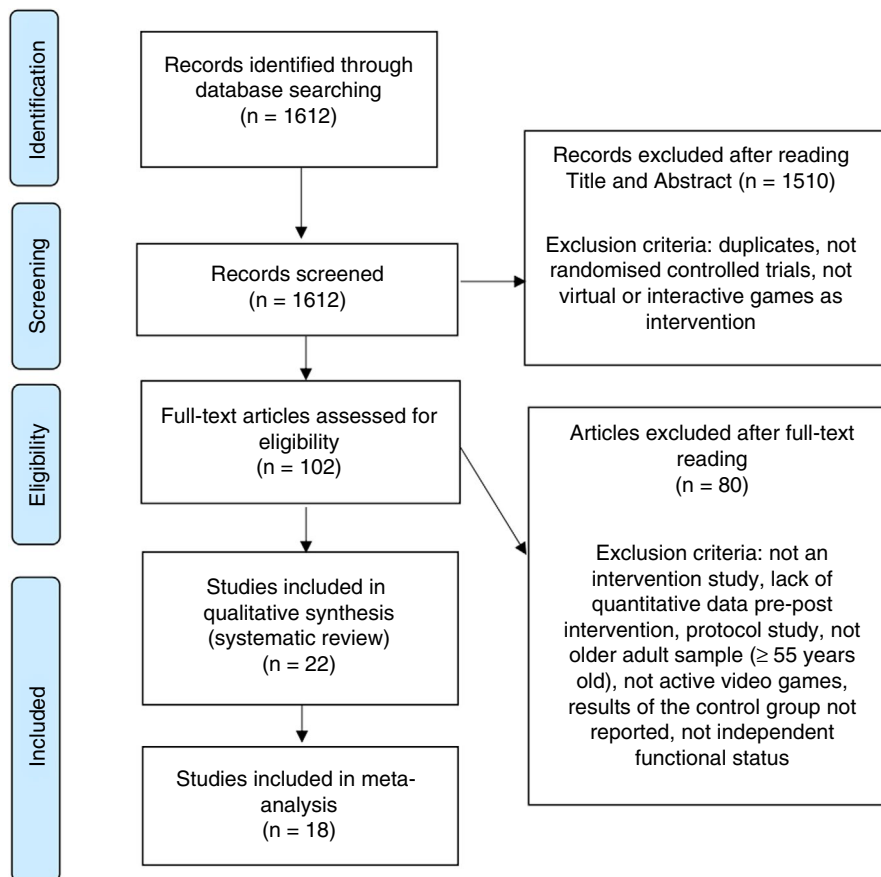
2.4 | Search outcomes

The following inclusion criteria were applied: (1) randomized controlled trial; (2) community-dwelling older adults; (3) independence in ambulatory functions with or without a walking support; (4) no severe motor functional impairment in terms of mobility, postural balance or musculoskeletal function that would prevent participation in the training programme; (5) capable of understanding and following the game; (6) use of video games or interactive experiences (rules-based games providing interaction and feedback and focused on the achievement of specific objectives); (7) analysis of the impact of the intervention on clinical outcomes related to physical condition; (8) measurement of the effect produced by the intervention in terms of altered muscle strength, balance, mobility, gait and speed, using a validated instrument; (9) publication of data describing the effect of the intervention. No restrictions were placed on the language or year of publication.

Any studies matching the following criteria were excluded: (1) pilot study or protocol; (2) no randomization or control group; (3) mixed samples (young participants and adults) lacking independent data by age groups; (4) severe cognitive impairment (a test score <22 measured with the Mini-Mental State or the Montreal Cognitive Assessment); (5) mobility or cognitive impairments that prevented participation; (6) studies focused on participant samples including specific clinical conditions (stroke or epilepsy, Parkinson's disease, Alzheimer's disease or other forms of dementia, neurological disease, neurodegenerative disease, terminal illness or unstable chronic illness); (7) impaired vision or auditory function that impeded participation and/or monitoring of the intervention programme; (8) interventions with no form of physical activity.

In the first stage of the selection process, two of the authors (NSM and RGL), working independently, reviewed the title and abstract of each article found. Then, the full text was read. A third author (JLRB) was consulted to resolve any disagreement (see Figure 1).

2.5 | Quality appraisal

The quality of the studies was evaluated according to the levels of evidence and grades of recommendation stipulated by the OCEBM (Centre for Evidence-Based Medicine) (Howick et al., 2011) (see Table 2). The risk of bias was analysed by two of the authors (NSM and RGL), working independently, using the Cochrane Collaboration Risk of Bias tool (Higgins & Green, 2011).

TABLE 1 PICO search strategy

Participants	Intervention	Comparison	Outcomes
Independent community-dwelling older adults (≥55 years old)	Interactive game or virtual game aimed at enhancing physical function, strength, balance, mobility, gait or velocity	Control group (traditional intervention or no intervention) and Intervention group in order to test the efficacy of the intervention	Evaluation of health measures, muscle strength, balance, mobility, gait or velocity, before and after intervention through measuring instruments

Identification

Records identified through database searching (n = 1612)

Screening

Records screened (n = 1612)

Records excluded after reading Title and Abstract (n = 1510)

Exclusion criteria: duplicates, not randomised controlled trials, not virtual or interactive games as intervention

Eligibility

Full-text articles assessed for eligibility (n = 102)

Articles excluded after full-text reading (n = 80)

Exclusion criteria: not an intervention study, lack of quantitative data pre-post intervention, protocol study, not older adult sample (≥ 55 years old), not active video games, results of the control group not reported, not independent functional status

Included

Studies included in qualitative synthesis (systematic review) (n = 22)

Studies included in meta-analysis (n = 18)

2.6 | Data abstraction

All data were extracted on a coding sheet by two of the authors (NSM and GCDF). If there was any disagreement, a third author (JLRB) checked the data. The following variables were obtained for each of the articles: (1) author, year, country; (2) design; (3) sample; (4) aim; (5) type of intervention; (6) adherence rate; (7) duration of intervention; (8) measuring instruments used and main results obtained.

The reliability of the researchers' data coding was assessed by calculating the intraclass correlation coefficient and Cohen's kappa coefficient.

2.7 | Data synthesis and analysis

For the descriptive analysis, the information reported in each study was classified into data tables and these results were categorized in a systematic review. The meta-analysis considered only those studies with sufficient outcomes, including appropriate statistical data (sample size, postintervention mean and standard deviation, for the control and intervention groups). Publication bias was assessed with a funnel plot. Heterogeneity was assessed by the I^2 index. If it exceed 50%, a random effects meta-analysis was performed, otherwise a fixed effects meta-analysis was applied. The following random effects meta-analyses were performed on the outcomes: (1) 6-minute

walk test; (2) Berg Balance Scale; (3) Grip strength; (4) Knee extension strength; (5) 8-Foot Up-and-Go. In addition, fixed effects meta-analyses were applied to the following outcomes: (6) 30-second chair stand; (7) Cadence; (8) Gait speed; (9) Timed Up-and-Go; (10) Velocity. RevMan Web software was used for the meta-analysis.

3 | RESULTS

3.1 | Search process and study characteristics

The initial search obtained 1612 papers. After reviewing the titles and abstracts, 1510 were excluded, because they were duplicates or did not meet the inclusion criteria. After reading the full-text articles, the final sample was then reduced to 22 papers, all of which provided sufficient analytical quality according to the quality assessment tools applied. The intraclass correlation coefficient was 0.96 (minimum = 0.95; maximum = 1) and Cohen's kappa coefficient of the categorical variables was 0.96 (minimum = 0.92; maximum = 1). The search and selection process are illustrated in Figure 1.

In the papers considered, the total sample size was n = 1208 participants, all of whom were aged 55 years or more. The majority were women. Of these 22 studies, 18 had information on one or more of the outcomes assessed in our meta-analysis. The publication dates ranged from 2012 to 2020. Five were performed in the USA, followed by three in Switzerland, two each in Korea, France

and Brazil, and one each in Lebanon, Australia, Denmark, Turkey, Singapore, Taiwan, Japan and the UK.

Fourteen of the articles described an intervention based on the use of active video games, either with the Nintendo Wii console (Bieryla & Dold, 2013; Fakhro et al., 2020; Franco et al., 2012; Jorgensen et al., 2013; Kwok & Pua, 2016; Lee et al., 2014; Maillot et al., 2012; Ray et al., 2012; Rendon et al., 2012; Toulotte et al., 2012; Whyatt et al., 2015) or with the Xbox 360 (Bacha et al., 2018; Karahan et al., 2015; Queiroz et al., 2017). In the remaining articles, the intervention was based on a simulation, with a virtual 3D television game (Adcock et al., 2020; Park & Yim, 2015), with dance-training video games (Eggenberger et al., 2015; Pichierri et al., 2012), with Microsoft Kinect exergames (Gschwind et al., 2015; Liao et al., 2019; Sato et al., 2015) or with an interactive augmented reality 3D exercise (Ku et al., 2019). The main characteristics of all these studies are listed in Table 2.

3.2 | Duration of intervention and adherence by participants

The duration of the intervention programmes ranged from 3 weeks (Franco et al., 2012) to 24 weeks (Eggenberger et al., 2015) and that of individual activities from 15 min (Franco et al., 2012) to 120 min (Gschwind et al., 2015). Compliance rates were high, ranging from 70% (Adcock et al., 2020) to 100% (Franco et al., 2012). The characteristics of each intervention are shown in Table 2.

3.3 | Meta-analysis of the effect size produced by each intervention on physical function

Sufficient data information were obtained to perform a meta-analysis of 10 variables: the 6-min walk test (metres), 30-s chair stand (repetitions), balance (measured on the Berg Balance Scale), cadence (steps/minute), gait speed (metres/second), grip strength (kg), knee extension strength (kg), Timed Up-and-Go (seconds), 8-Foot Up-and-Go and velocity (cm/second). The variable most commonly included was Timed Up-and-Go (in nine articles) while the least common were cadence, gait speed, knee extension strength and 8-Foot Up-and-Go (each were present in two articles). The largest sample size corresponded to the Timed Up-and-Go meta-analysis, with 233 participants in the intervention group and 241 in the control group. The heterogeneity index (I^2), illustrated in Figure 2a,b, were high for the following tests: 6-minute walk, balance, grip strength, knee extension strength and 8-Foot Up-and-Go; low values were recorded for the 30-second chair stand, cadence, gait speed, Timed Up-and-Go and velocity.

The overall effect size of the intervention was statistically significant for two variables: gait speed and Timed Up-and-Go (in favour of the experimental group in both cases). For gait speed, the difference was –0.10 metres/second (95%CI: –0.16, –0.05), and for Timed Up-and-Go it was –0.34 s (95%CI: –0.56, –0.12). For the following

tests, the differences between the control and experimental groups following the intervention were not statistically significant ($p > .05$): the 6-minute walk test (26.04: 95%CI: –0.58, 52.67); the 30-second chair stand (0.54: 95%CI: –0.65, 1.74); balance (1.69: 95%CI: –0.68, 4.07), cadence (0.54: 95%CI: –3.79, 4.87); grip strength (3.73: 95%CI: 0.07, 7.38); knee extension (–1.32: 95%CI: –7.73, 5.10), 8-Foot Up-and-Go (–0.15: 95%CI: –2.13, 1.82) and velocity (2.05: 95%CI: –1.11, 5.21). The forest plot for each variable is shown in Figure 2a,b, and the risk of bias is shown in Figure 3. The funnel plots did not reflect the presence of publication bias.

3.4 | Participants' perception of the intervention

In general, the participants were satisfied with the intervention programmes, with up to 81% reporting high levels of enjoyment and satisfaction (Bacha et al., 2018; Franco et al., 2012). Similarly, a high proportion of participants indicated that the Nintendo Wii was fun and motivating, and would consider buying one (Jorgensen et al., 2013). In the study by Karahan et al. (2015), 42.8% of participants rated the use of the Xbox 360 console as moderately pleasant, while for 21.4% it was fairly pleasant. Significant improvements were also observed in quality of life, social role functioning and body awareness (Karahan et al., 2015; Maillot et al., 2012). Furthermore, greater confidence in functional activities led to a reduced fear of falls (Kwok & Pua, 2016; Rendon et al., 2012).

4 | DISCUSSION

This systematic review and meta-analysis were undertaken to consider the effects produced by the use of active video games on parameters related to physical and motor function in independent community-dwelling older adults. A previous systematic review, with fewer studies and no meta-analysis, reported inconclusive results on the effectiveness or otherwise of virtual reality games in improving physical function in older adults (Molina et al., 2014). However, our own meta-analysis revealed a positive effects on clinical parameters such as gait speed and Timed Up-and-Go in older adults, corroborating previous meta-analyses in this respect (Pacheco et al., 2020; Taylor et al., 2018), which also reported that exergames were more effective than conventional exercise programmes for balance and the 30-s chair stand. On the other hand, our analysis revealed no such pre-post intervention improvement, possibly due to the inclusion of fewer studies in the previous meta-analyses, or because some of the studies included did not use the postintervention mean score of each group, or because postintervention statistical information was not shown in the forest plot, or because the studies considered were focused on older dependent people, who are at greater risk of falls (Pacheco et al., 2020; Taylor et al., 2018). Previous research has also observed beneficial results for the Timed Up-and-Go outcome, although only three studies addressed this parameter (Pacheco et al., 2020). This result was confirmed by our meta-analysis, which

TABLE 2 Characteristics of the included studies (*n* = 22)

Authors (year) country	Sample	Aim and Setting	Intervention
Adcock et al. (2020) Switzerland	*n* = 31 *n* CG = 16 *n* IG = 15 Mean age = 73.9 years Female = 51.6%	To analyse physical functions Clinic and research institute	CG: No intervention (Active@Home training was provided to enable voluntary training) IG: Active@Home Exergame (Tai Chi exercises +dancing + step-based cognitive games instructed by an avatar)
Bacha et al. (2018) Brazil	*n* = 46 *n* CG = 23 *n* IG = 23 Mean age = 69.3 (5.3) years Female = 73.9%	To analyse dynamic balance and cardiorespiratory fitness Clinic hospital	CG: Traditional physical therapy exercises (endurance and strength same duration as intervention group) IG: Xbox 360 (Kinect Adventures games)
Bieryla et al. (2013) USA	*n* = 12 *n* CG = 6 *n* IG = 6 Mean age = 81.5 (5.5) years Female = 88.3%	To improve clinical measures of balance Local senior living community	CG: No intervention (normal daily activities) IG: Nintendo's Wii Fit (yoga +aerobic + balance games)
Eggenberger et al. (2015) Switzerland	*n* = 47 *n* CG = 15 *n* IG1 = 15 *n* IG2 = 17 Mean age = 78.9 years Female = 64.8%	To analyse gait and physical training Geriatric clinic	CG: Treadmill walking IG1: Virtual reality video game dancing (DANCE) IG2: Treadmill walking with simultaneous verbal memory training (MEMORY)
Fakhro et al. (2020) Lebanon	*n* = 60 *n* CG = 30 *n* IG = 30 Mean age = 74.3 years Female = no data	To analyse dynamic and static balance Community- dwelling elders at low-income senior housing	CG: No intervention (normal daily activities) IG: Nintendo Wii Fit ('Soccer Heading' + 'Table Tilt' game)
Franco et al. (2012), USA	*n* = 32 *n* CG = 10 *n* IG1 = 11 *n* IG2 = 11 Mean age = 78.2 years Female = 78.1%	To analyse balance and functional mobility Independent living senior housing	CG: No intervention (normal daily activities) IG1: Nintendo Wii Fit games (balance games, yoga, aerobic +strength activities) IG2: Traditional exercise program (strength + balance training) in group sessions
Gschwind et al. (2015) Australia	*n* = 124 *n* CG = 61 *n* IG1 = 24 *n* IG2 = 39 Mean age = 80.9 years Female = 65.8%	To improve balance and lower extremity strength Participants' homes	CG: No intervention (educational booklet about health and fall prevention) IG1: Microsoft Kinect (strength +balance exergames) IG2: Step mat training (exergames by stepping)
Jorgensen et al. (2013) Denmark	*n* = 57 *n* CG = 30 *n* IG = 27 Mean age = 75 (6) years Female = 69%	To analyse improvements of muscle function, static postural balance and functional performance Geriatric research clinic	CG: ethylene vinyl acetate copolymer shoe insoles for 10 weeks IG: Nintendo Wii Fit (balance +muscle exercise games)
Karahan et al. (2015) Turkey	*n* = 90 *n* CG = 42 *n* IG = 48 Mean age = 71.5 years Female = 43.3%	To analyse balance and functional mobility Outpatient clinic	CG: Home exercise (balance, stretching +strength) IG: Xbox 360 (Kinect Adventures +Kinect Sports)
Ku et al. (2019) Korea	*n* = 34 *n* CG = 16 *n* IG = 18 Mean age = 64.8 years Female = 50%	To assess balance and movement parameters Hospital	CG: Conventional physical fitness program (lower-extremity strengthening and endurance) IG: Interactive augmented reality. 3D environment displayed on a large screen (balloon game, cave game +rhythm game)

Duration	Adherence rate	Instruments/ Main outcomes M (SD)		EL/RG
		Baseline (CG/IG)	Follow-up (CG/IG)	
3 sessions per week (30–40 min) for 16 weeks	70%	Gait Speed mean (m/s) 1.4 (0.2)/1.2 (0.2) 30-second chair-stand (repetitions) 16.5 (6)/13 (4.5) 2-min stepping test (repetitions) 74.5 (26)/66 (22.5)	Gait Speed mean (m/s) 1.4 (0.2)/1.2 (0.1) 30-second chair-stand (repetitions) 15.5 (6)/13 (2.5) 2-min stepping test (repetitions) 78.5 (7.7)/76 (14)	1b/A
14 sessions (60 min) for 4 weeks	91%	6-min step test (repetitions) 121.3 (24.6)/122.6 (23) Mini-Balance Evaluation Systems Test (score) 27.6 (2.6)/26.5 (3.2) Functional Gait Assessment (score) 27.3 (2.1)/26.6 (2.4)	6-min step test (repetitions) 144.7 (19.1)/134.3 (25.4) Mini-Balance Evaluation Systems Test (score) 29.8 (2)/29.6 (2.8) Functional Gait Assessment (score) 29.3 (0.9)/28.1 (2)	1b/A
3 sessions per week (30 min) for 3 weeks	-	Berg Balance Scale (score) 51 (10)/50 (4) Timed Up-and-Go Test (s) 10.8 (10)/12.8 (2.7)	Berg Balance Scale (score) 54(11.5)/53 (2) Timed Up-and-Go Test (s) 10.1 (7.8)/11.2 (3.7)	1b/A
52 sessions (60 min) for 26 weeks	79.8%	Velocity (cm/s) 115.8 (5.4)/123 (5.3)/109.4 (3.8) 6-minute walk test (m) 506 (18)/505 (25)/489 (16)	Velocity (cm/s) 131.1 (4.7)/133.4 (5.2)/126.3 (5.4) 6-minute walk test (m) 538 (21)/560 (21)/530 (20)	1b/A
40 min session for 8 weeks	-	Timed Up-and-Go Test (s) 19.5 (9)/15.4 (4.6) Centre of pressure (%) 6.7/13.3	Timed Up-and-Go Test (s) 21.8 (9)/14.1 (4.4) Centre of pressure (%) 6.7/33.3	1b/A
2 sessions per week (10–15 min) for 3 weeks	100%	Berg Balance Scale (score) 50.3 (3.7)/48.5 (9.1)/47.3 (8) Tinetti Gait and Balance (score) 25.8 (1.8)/25.8 (4.3)/25 (4.1)	Berg Balance Scale (score) 51.4 (2.9)/52 (5.4)/50.7 (6) Tinetti Gait and Balance (score) 26.8 (1.8)/26.7 (2.4)/26.4 (3.2)	1b/A
120 min per week for 16 weeks	-	Timed Up-and-Go Test (s) 12.4 (3.7)/11.5 (3.5)/11.5 (3.1) Knee extension strength (kg) 21.9 (8.6)/20.8 (9.4)/24.2 (10.3)	Timed Up-and-Go Test (s) 12.6 (4.4)/11.1 (3.3)/11.5 (2.6) Knee extension strength (kg) 23.8 (9.1)/26.2 (10.3)/25.8 (9.2)	1b/A
2 sessions per week (35–40 min) for 10 weeks	-	Rate force development (N/s) 3704 (2627)/3266 (2271) Timed Up-and-Go Test (s) 11 (5)/10.3 (3.8) 30-second chair-stand (repetitions) 11.2 (3)/11.5 (3.8)	Rate force development (N/s) 3622 (2423)/4143 (2831) Timed Up-and-Go Test (s) 10.9 (5.1)/9 (3.2) 30-second chair-stand (repetitions) 12.1 (3)/13.3 (3.2)	1b/A
30 exercise sessions (30 min) for 6 weeks	90%	Berg Balance Scale (score) 49.4 (3.7)/49.8 (3.8) Timed Up-and-Go Test (s) 8.6 (1.7)/8.7 (1.7)	Berg Balance Scale (score) 51.1 (4.1)/54.9 (2.6) Timed Up-and-Go Test (s) 8.6 (1.8)/8.1 (1.4)	1b/A
12 sessions (30 min) for 4 weeks	75%	Berg Balance Scale (score) 55.1 (1.1)/ 54.5 (1.5) Timed Up-and-Go Test (s) 7.9 (0.5)/7.8 (0.7)	Berg Balance Scale (score) 55.5 (0.8)/ 55.5 (0.9) Timed Up-and-Go Test (s) 7.7 (0.6)/7.3 (0.6)	1b/A

TABLE 2 (Continued)

Authors (year) country	Sample	Aim and Setting	Intervention
Kwok and Pua (2016) Singapore	$n = 80$ n CG = 40 n IG = 40 Mean age = 70.1 years Female = 85%	To analyse physical functions Outpatient centre	CG: Standard Gym-based exercise IG: Nintendo Wii Fit (cardiovascular training, resistance, strengthening +balance)
Lee et al. (2014) USA	$n = 82$ n CC = 42 n IG = 40 Mean age = 75.2 (6.6) years Female = 70.7%	To analyse benefit on gait parameters Centre for healthy living and longevity	CG: Traditional fitness (strength +balance training) IG: Nintendo Wii Fit (sport +balance)
Liao et al. (2019) Taiwan	$n = 52$ n CC = 25 n IG = 27 Mean age = 81.8 years Female = 69.2%	To assess the improvement in frailty status and physical performance Senior centre	CG: Traditional fitness (balance exercise + resistance + aerobic exercises) IG: Balance game virtual 3D full-body map + Tai-chi exercise +resistance + aerobic exercises
Maillot et al. (2012) France	$n = 32$ n CC = 16 n IG = 16 Mean age = 73.5 (6) years Female = 84.4%	To analyse an exergame training as a mode of physical activity Community senior centre	CG: No intervention (commitment to not modify their sedentary lifestyle over 14 weeks) IG: Nintendo Wii Fit (games of physically simulated sport)
Park et al. (2015) Korea	$n = 72$ n CG = 36 n IG = 36 Mean age = 73.5 years Female = 94.4%	To improve the cognitive function, muscle strength and balance Senior centre	CG: Conventional exercise program with stepping, walking, one-leg standing and cup tapping (30 min) IG: Virtual reality kayak program
Pichierri et al. (2012) Switzerland	$n = 31$ n CG = 16 n IG = 15 Mean age = 86.2 (4.6) years Female = 81.8%	To investigate the effects of training programs on physical parameters Hostels for the aged	CG: Conventional exercise program (progressive resistance +postural balance) IG: Exercise +video game dancing program
Queiroz et al. (2017) Brazil	$n = 27$ n CG = 14 n IG = 13 Mean age = 60.4 years Female = 59.2%	To compare the effects of exergame on the functional fitness Laboratory	CG: Aerobic exercise program (same duration as intervention) IG: Xbox 360 (Kinect sports games)
Ray et al. (2012) USA	$n = 87$ n CG = 18 n IG1 = 29 n IG2 = 40 Mean age = 75 years Female = 66.6%	To analyse the ability to maintain postural control Laboratory	CG: No intervention (no exercise prescribed) IG1: Nintendo Wii Fit (balance, bowling +boxing game) IG2: Fitness group
Rendon et al. (2012) USA	$n = 40$ n CG = 20 n IG = 20 Mean age = 84.5 (5.2) years Female = 65%	To analyse the improvement of dynamic balance Outpatient geriatric clinic	CG: No intervention (instructed to not alter their normal daily activities) IG: Nintendo Wii Fit (balance games+postural stability)

Duration	Adherence rate	Instruments/ Main outcomes M (SD)		EL/RG
		Baseline (CG/IG)	Follow-up (CG/IG)	
12 sessions once weekly (60 min) for 12 weeks	80%	Timed Up-and-Go Test (s) 12.3 (5.7)/11.7 (4.5) 6-minute walk test (m) 290.8 (85.3)/297.1 (69.9) Gait speed (4-m walk test) (m/s) 0.8 (0.3)/0.8 (0.2) Knee extension strength (kg) 24.9 (9.4)/24.5 (8.6)	Timed Up-and-Go Test (s) 9.1 (1.2)/9.1 (1.1) 6-minute walk test (m) 335.9 (26.3)/323.7 (25.9) Gait speed (4-m walk test) (m/s) 1.2 (0.1)/1.1 (0.1) Knee extension strength (kg) 34.6 (2.3)/30.4 (2.3)	1b/A
3 sessions per week (45 min) for 10 weeks	-	Velocity (cm/s) 121.4 (18.4)/120.7 (21.5) Stride length (cm) 129 (13.2)/126 (16.7) Cadence (steps/min) 112.9 (9.8)/115.2 (14.3)	Velocity (cm/s) 128.2 (22.1)/128.1 (21.3) Stride length (cm) 130(19.2)/131 (16.3) Cadence (steps/min) 119.4 (19)/117.5 (11.9)	1b/A
36 sessions (60 min) for 12 weeks	-	30-second sit-to-stand test (times) 8.9 (4.9)/9.9 (5.1) Timed Up-and-Go Test (s) 16.6 (9.9)/17 (8.4) Velocity (cm/s) 62 (24)/61 (33) Grip strength (kg) 13.7 (5.5)/17 (5.6)	30-second sit-to-stand test (times) 11.8 (5.4)/13 (5.8) Timed Up-and-Go Test (s) 15.4 (8.2)/15.1 (8.7) Velocity (cm/s) 68 (27)/74 (29) Grip strength (kg) 15.4 (5)/18.2 (5.4)	1b/A
24 sessions (60 min) for 14 weeks	97.50%	Mean Heart Rate 6-Min Walk (bpm) 100.2 (15.1)/106.8 (11.6) 6-minute walk test (m) 429.8 (61.5)/411.1 (84.6) 8-Foot Up and Go (s) 7.1 (1.6)/7.4 (1.3)	Mean Heart Rate 6-Min Walk (bpm) 96.4 (11.6)/114.2 (13.5) 6-minute walk test (m) 432.9 (26.5)/469.2 (40.4) 8-Foot Up and Go (s) 7.6 (1.1)/6.4 (0.6)	1b/A
50 min session for 6 weeks	-	Grip strength (Right) (kg) 20.3 (5.5)/21.3 (5.6) Grip strength (Left) (kg) 18.3 (5.1)/20.1 (6.8)	Grip strength (Right) (kg) 17.7 (5.1)/23.3 (4.8) Grip strength (Left) (kg) 15.2 (4.5)/23.1 (5.1)	1b/A
40 min sessions twice weekly for 12 weeks	75%	Medians (interquartile ranges) Velocity (cm/s) 69 (61.1–82.7)/80.4 (72.9–89.1) Cadence (steps/min) 93.9 (80.2–99.9)/95.5 (93.3–102.5)	Medians (interquartile ranges) Velocity (cm/s) 82.2 (73.8–101.8)/88.3 (69.2–106.2) Cadence (steps/min) 104.2 (89.9–112.3)/97.5 (96–111.8)	1b/A
36 sessions (60 min) for 12 weeks	90.6%	Timed Up-and-Go Test (s) 5.7 (0.6)/5.3 (0.8) 30-second chair-stand (repetitions) 13.5 (2.1)/14.3 (3.2) 2-min stepping test (repetitions) 87.2 (0.2)/92.9 (19.9)	Timed Up-and-Go Test (s) 5.1 (0.5)/4.8 (0.3) 30-second chair-stand (repetitions) 17.9 (4.5)/18.2 (3.2) 2-min stepping test (repetitions) 93.7 (22.8)/110.5 (16.1)	1b/A
3 sessions per week (45 min) for 15 weeks	-	6-minute walk test (m) 529.1 (111.3)/462 (101.9)/416 (157.1) 8-Foot Up and Go (s) 6.3 (1.2)/8 (1.5)/7.4 (1.4) Grip strength (kg) 27.3 (6.1)/23.4 (8.6)/25.9 (8.6) BMI 29.4 (1.4)/28 (4.7)/26.6 (6.2)	6-minute walk test (m) 409.6 (245.1)/508.3 (81)/441.9 (167.7) 8-Foot Up and Go (s) 6.2 (2)/7.1 (1.2)/6.8 (1) Grip strength (kg) 28.2 (9)/24.7 (7.7)/25.4 (9.8) BMI 29 (1.9)/27.5 (5.2)/26.4 (5.7)	1b/A
18 sessions (35–45 min) for 6 weeks	-	Median (min–max) 8-Foot Up and Go (s) 8.5 (5.1–17.3)/9.1 (5.6–18.3)	Median (min–max) 8-Foot Up and Go (s) 8.3 (5.2–19.5)/8.5 (5.1–16.5)	1b/A

TABLE 2 (Continued)

Authors (year) country	Sample	Aim and Setting	Intervention
Sato et al. (2015) Japan	n = 54 n CG = 26 n IG = 28 Mean age = 69.3 years Female = 79.6%	To analyse muscle strength and balance	CG: No intervention (instructed to continue with their daily lives as usual) IG: Kinect game (3D coordinated standing games)
Toulotte et al. (2012) France	n = 36 n CG = 9 n IG1 = 9 n IG2 = 9 n IG3 = 9 Mean age = 75.1 (10.3) years Female = 61.1%	To analyse physical training on the balance control Community senior centre	CG: No intervention (no physical training. Only television and board games) IG1: Physical activities training programme (step length, step height, cervical rachis mobility, ocular mobility) IG2: Nintendo Wii Fit (sport games) IG3: IG1 + IG2
Whyatt et al. (2015) UK	n = 82 n CG = 42 n IG = 40 Mean age = 76.9 years Female = 67.8%	To analyse the movement capabilities Community senior centre	CG: No intervention (continue with daily activity) IG: Nintendo Wii (sports games)

Abbreviations: CG, control group; EL, evidence level; IG, intervention group; RG, recommendation grade.

included nine studies in this respect and featured larger population samples, in both the control and the experimental groups.

In line with previous research, we find that active video game interventions have positive effects on participants' gait speed and mobility (Chao et al., 2015; Nicholson et al., 2015). Although some studies suggest that this kind of intervention might contribute to enhancing fine and gross motor skills and coordination (Szturm et al., 2011; Young et al., 2011), we found no benefits superior to those offered by conventional exercises for variables like strength, balance, cadence and velocity. However, some authors have found improvements in muscle strength in the upper and lower limbs (Shake et al., 2018). Moreover, some studies of video game-based interventions, although in this case without feedback, targets or challenges, found improvements in balance (higher scores on the Berg balance scale and for the unipedal stance and 8-Foot Up-and-Go tests) (Lai et al., 2013; Nicholson et al., 2015; Rica et al., 2020; Szturm et al., 2011). This outcome could be beneficial if it reduced the number of falls and the fear of falling (Daniel, 2012; Duque et al., 2013; Fu et al., 2015; Stanmore et al., 2019).

Active video games could also be of value for older adults with neurological and/or cognitive impairment. In this respect, some studies have reported beneficial results for scores on the Berg balance scale and the Timed Up-and-Go test (Shih et al., 2016), and others have observed improvements in perceived cognitive ability and gait speed (Gallou-Guyot et al., 2020; Hughes et al., 2014).

Active video games might also benefit certain variables not related to physical functioning, such as energy consumption (Daniel, 2012) or reducing the heart rate at rest (Rica et al., 2020). Finally, some participants have perceived improvements in areas such as knowledge of health-related issues (Shake et al., 2018), pain reduction (Stanmore et al., 2019), increased visual working memory and greater social interaction (Hughes et al., 2014; Iizuka et al., 2019).

Although the benefits of these interventions seem significant, their long-term persistence remains unclear. In this respect, one study reported that positive changes were still effective 8 weeks after the intervention (Orsega-Smith et al., 2012), but another observed a reduction in the effect at 9 months after the intervention (Duque et al., 2013).

This kind of training programme must be supported by appropriate motivation, which is fundamental to maintaining the frequency and intensity of the intervention (Goršič et al., 2017). Our study found a high adherence rate in the exercise video game group, which corroborates previous findings that active exercise video games can offer a valuable alternative or complement to conventional exercise activities (Choi et al., 2017; Nyman & Victor, 2012). Recruitment and adherence to conventional programmes can be low, due to a perceived lack of rewards, satisfaction or external stimuli; in contrast, interactive video games can be a source of stimulation, promoting interest due to their ease of use and to the challenge and feedback provided, which encourage the participant not only to remain active, but also to improve (Hughes et al., 2014; Mihelj et al., 2012; Stanmore et al., 2019; Young et al., 2011).

Duration	Adherence rate	Instruments/ Main outcomes M (SD)		EL/RG
		Baseline (CG/IG)	Follow-up (CG/IG)	
24 sessions (40–60 min) for 10 weeks	-	Velocity (cm/s) 228.6 (28.4)/220.9 (29) Cadence (steps/min) 124.6 (9.6)/124.6 (11.7) Berg Balance Scale (score) 55.6 (56)/55.3 (56) 30-second chair-stand (repetitions) 19 (18)/17.5 (17.5)	Velocity (cm/s) 240.3 (26.3)/239.8 (27.2) Cadence (steps/min) 127.4 (8.9)/129.7 (12.3) Berg Balance Scale (score) 55.6 (56)/55.9 (56) 30-second chair-stand (repetitions) 19.7 (19)/24.1 (23.5)	1b/A
60 min session for 20 weeks	-	Unipedal test eyes opened (times) 19 (6)/19.7 (3.3)/17.8 (3.7)/21.2 (1.6) Unipedal test eyes shut (times) 26.1 (9.3)/23.2 (3.1)/19.8 (5.1)/26.4 (4.1) Tinetti test Static (score) 16.1 (0.4)/16.5 (0.6)/15.2 (0.8)/15.2 (0.5) Tinetti test Dynamic (score) 4.3 (0.4)/4.5 (0.6)/4.2 (0.2)/4.1 (0.5)	Unipedal test eyes opened (times) 18.1 (5)/8.7 (5.2)/14.5 (2.1)/14.6 (3) Unipedal test eyes shut (times) 30.4 (7.7)/11.5 (2.8)/15 (5)/17.2 (4.8) Tinetti test Static (score) 16.9 (0.9)/13.5 (0.8)/13.2 (0.6)/13.6 (0.6) Tinetti test Dynamic (score) 4.3 (0.2)/3 (0.2)/3.8 (0.6)/2.7 (0.4)	1b/A
10 sessions (30 min) for 5 weeks	-	Berg Balance Scale (score) 46.4 (9.1)/45.9 (6.8)	Berg Balance Scale (score) 46.9 (9.2)/50.1 (6.4)	1b/A

4.1 | Study limitations and areas for future research

This study has several limitations. First, although our meta-analysis only included studies that used active video games in interventions with independent community-dwelling older adults, the fact that these participants presented different comorbidities and ranges of autonomy and mobility might limit the generalizability of the results obtained. Furthermore, there is considerable variability in the total duration of these intervention programmes and in the duration and number of individual sessions. Another difficulty is that some of the meta-analyses considered were based on just a few studies. To overcome these problems, randomized clinical trials should be conducted specifically addressing the use of active video games with respect to relevant outcomes (such as cadence, knee extension strength and the 8-Foot Up-and-Go test). It should also be noted that this type of exercise is not universally accessible, due to cost and technological barriers (Chu et al., 2021).

As a useful area for future work, an in-depth analysis should be made of physiological parameters such as blood pressure or weight control, in response to the use of the exercise programmes described, and even their association with healthy practices, such as adherence to the Mediterranean diet. In addition, more research is needed to determine optimum training schedules, times, duration and follow-up and to assess the effects of active video games in diverse populations of older adults, with respect to cost, barriers and adherence.

Finally, the combined use of exergames and conventional exercise might be an effective and preferable strategy for older people (Sadeghi et al., 2017). Tailored interventions to ensure the optimal design of active video games, with exergames that are customized to preserve physical function or specifically developed for persons with mobility limitations or disabilities, are issues of great importance that need to be addressed in future research (Wiemeyer et al., 2015).

4.2 | Implications for practice and research

This systematic review and meta-analysis highlights the potential impact of active video games, which can be used to improve clinical parameters such as gait speed and mobility in independent community-dwelling older adults. In addition, the study shows that active video games could usefully be combined with conventional exercises (the intervention group presented an improved functional status, whereas no such gain was observed in the control group). Active video games are a viable and well-accepted intervention that can encourage older adults to actively engage in physical activities. The use of this type of intervention can be a complementary tool in rehabilitation for older adults who may not be motivated to perform conventional exercise.

Health policies should promote awareness of the positive effects of physical exercise. To achieve this, health professionals are of vital importance in fostering lifestyle improvements and promoting

(a) 6 minute walk test

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Random, 95% CI
Eggenberg et al., 2015	133.4	5.2	15	131.1	4.7	15	28.7%	2.30 [-1.25 , 5.85]
Kwok et al., 2016	323.7	25.9	40	335.9	26.3	40	27.4%	-12.20 [-23.64 , -0.76]
Maillot et al., 2012	469.2	40.45	16	432.91	26.54	16	23.5%	36.29 [12.58 , 60.00]
Ray et al., 2012	508.3	81	29	409.6	25.1	18	20.5%	98.70 [67.02 , 130.38]
Total (95% CI)			100			89	100.0%	26.04 [-0.58 , 52.67]

Heterogeneity: Tau² = 640.07; Chi² = 49.55, df = 3 (P < 0.00001); I² = 94%
Test for overall effect: Z = 1.92 (P = 0.06)
Test for subgroup differences: Not applicable

(b) 30 second chair stand

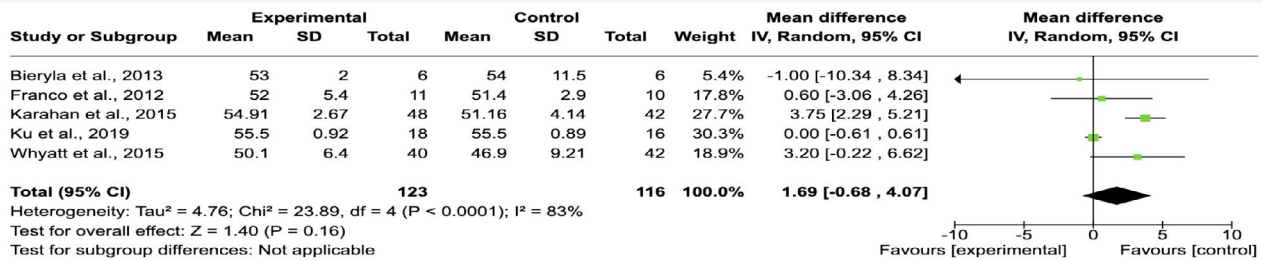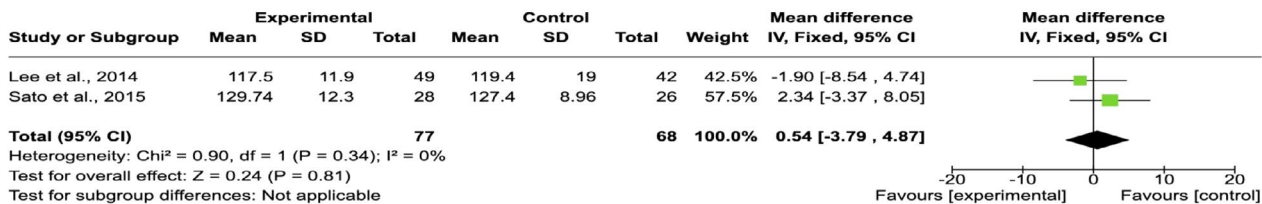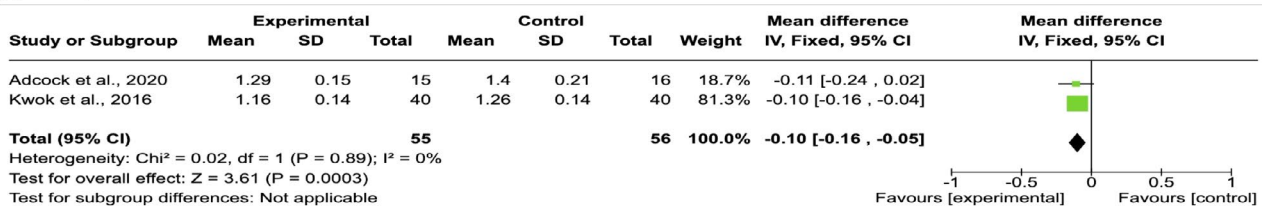| Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Fixed, 95% CI
Adcock et al., 2020	13	2.5	15	15.5	6	16	13.9%	-2.50 [-5.70 , 0.70]
Jorgensen et al., 2013	13.3	3.2	27	12.1	3	30	54.7%	1.20 [-0.42 , 2.82]
Liao et al., 2019	13	5.8	27	11.8	5.4	25	15.4%	1.20 [-1.84 , 4.24]
Queiroz et al., 2017	18.23	3.29	13	17.93	4.58	14	15.9%	0.30 [-2.69 , 3.29]
Total (95% CI)			82			85	100.0%	0.54 [-0.65 , 1.74]

Heterogeneity: Chi² = 4.31, df = 3 (P = 0.23); I² = 30%
Test for overall effect: Z = 0.89 (P = 0.37)
Test for subgroup differences: Not applicable

(c) Balance

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Random, 95% CI
Bieryla et al., 2013	53	2	6	54	11.5	6	5.4%	-1.00 [-10.34 , 8.34]
Franco et al., 2012	52	5.4	11	51.4	2.9	10	17.8%	0.60 [-3.06 , 4.26]
Karahan et al., 2015	54.91	2.67	48	51.16	4.14	42	27.7%	3.75 [2.29 , 5.21]
Ku et al., 2019	55.5	0.92	18	55.5	0.89	16	30.3%	0.00 [-0.61 , 0.61]
Whyatt et al., 2015	50.1	6.4	40	46.9	9.21	42	18.9%	3.20 [-0.22 , 6.62]
Total (95% CI)			123			116	100.0%	1.69 [-0.68 , 4.07]

Heterogeneity: Tau² = 4.76; Chi² = 23.89, df = 4 (P < 0.0001); I² = 83%
Test for overall effect: Z = 1.40 (P = 0.16)
Test for subgroup differences: Not applicable

(d) Cadence

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Fixed, 95% CI
Lee et al., 2014	117.5	11.9	49	119.4	19	42	42.5%	-1.90 [-8.54 , 4.74]
Sato et al., 2015	129.74	12.3	28	127.4	8.96	26	57.5%	2.34 [-3.37 , 8.05]
Total (95% CI)			77			68	100.0%	0.54 [-3.79 , 4.87]

Heterogeneity: Chi² = 0.90, df = 1 (P = 0.34); I² = 0%
Test for overall effect: Z = 0.24 (P = 0.81)
Test for subgroup differences: Not applicable

(e) Gait speed

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Fixed, 95% CI
Adcock et al., 2020	1.29	0.15	15	1.4	0.21	16	18.7%	-0.11 [-0.24 , 0.02]
Kwok et al., 2016	1.16	0.14	40	1.26	0.14	40	81.3%	-0.10 [-0.16 , -0.04]
Total (95% CI)			55			56	100.0%	-0.10 [-0.16 , -0.05]

Heterogeneity: Chi² = 0.02, df = 1 (P = 0.89); I² = 0%
Test for overall effect: Z = 3.61 (P = 0.0003)
Test for subgroup differences: Not applicable

(f) Grip strength

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean difference IV, Random, 95% CI
Liao et al., 2019	18.2	5.4	27	15.4	5	25	25.9%	2.80 [-0.03 , 5.63]
Park et al., 2015a	23.35	4.86	36	17.73	5.19	36	27.2%	5.62 [3.30 , 7.94]
Park et al., 2015b	23.1	5.18	36	15.27	4.51	36	27.4%	7.83 [5.59 , 10.07]
Ray et al., 2012	24.7	7.7	29	28.2	9	18	19.4%	-3.50 [-8.51 , 1.51]
Total (95% CI)			128			115	100.0%	3.73 [0.07 , 7.38]

Heterogeneity: Tau² = 11.37; Chi² = 19.72, df = 3 (P = 0.0002); I² = 85%
Test for overall effect: Z = 2.00 (P = 0.05)
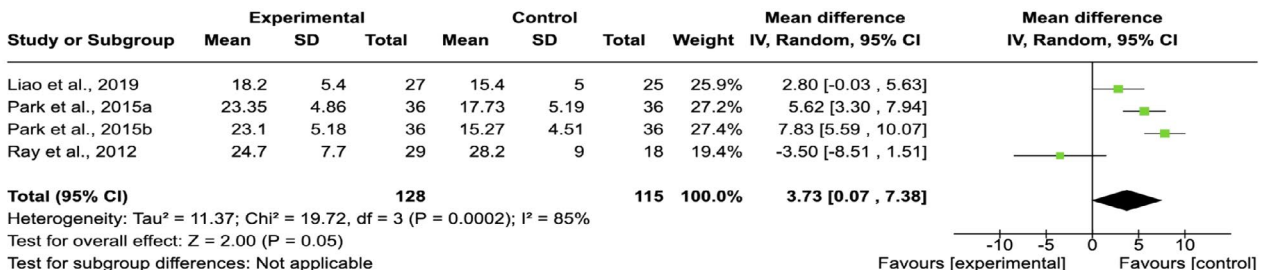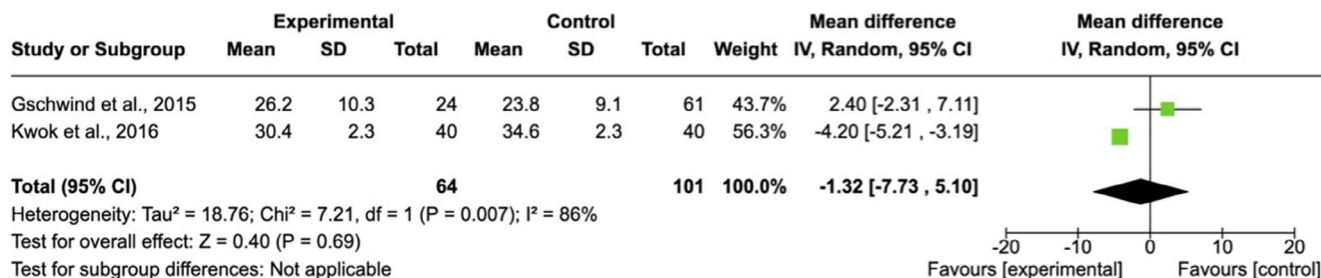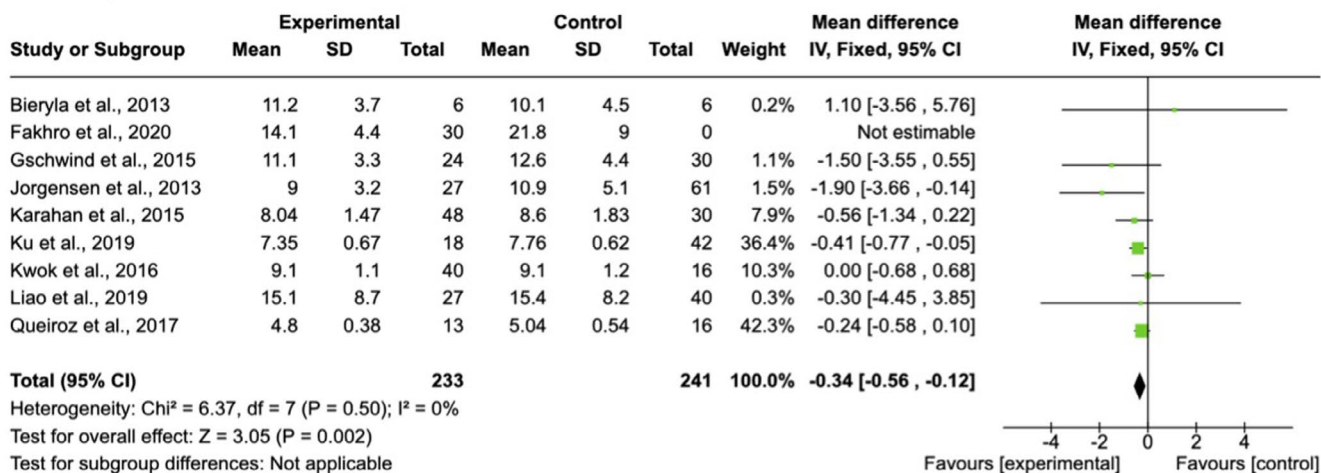Test for subgroup differences: Not applicable

FIGURE 2 Forest plot of the variables (a) 6-minute walk test (m), (b) 30-second chair stand (repetitions), (c) balance (Berg balance scale score), (d) cadence (steps/min), (e) gait speed (m/s) and (f) grip strength (kg), (g) knee extension strength (kg), (h) Time Up-and-Go (s), (i) 8-Foot Up-and-Go (s) and (j) velocity (cm/s)
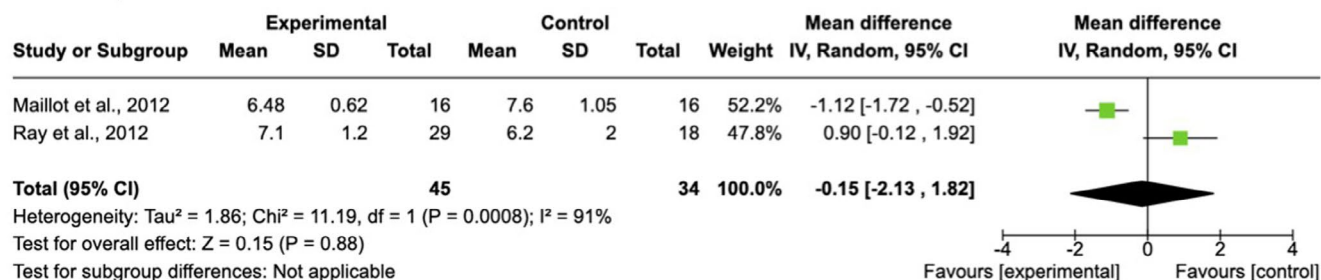
(g) Knee extension

Study or Subgroup	Experimental			Control			Weight	Mean difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Gschwind et al., 2015	26.2	10.3	24	23.8	9.1	61	43.7%	2.40 [-2.31 , 7.11]
Kwok et al., 2016	30.4	2.3	40	34.6	2.3	40	56.3%	-4.20 [-5.21 , -3.19]
Total (95% CI)			64			101	100.0%	-1.32 [-7.73 , 5.10]

Heterogeneity: Tau² = 18.76; Chi² = 7.21, df = 1 (P = 0.007); I² = 86%
Test for overall effect: Z = 0.40 (P = 0.69)
Test for subgroup differences: Not applicable

(h) Time Up and Go

Study or Subgroup	Experimental			Control			Weight	Mean difference IV, Fixed, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Bieryla et al., 2013	11.2	3.7	6	10.1	4.5	6	0.2%	1.10 [-3.56 , 5.76]
Fakhro et al., 2020	14.1	4.4	30	21.8	9	0		Not estimable
Gschwind et al., 2015	11.1	3.3	24	12.6	4.4	30	1.1%	-1.50 [-3.55 , 0.55]
Jorgensen et al., 2013	9	3.2	27	10.9	5.1	61	1.5%	-1.90 [-3.66 , -0.14]
Karahan et al., 2015	8.04	1.47	48	8.6	1.83	30	7.9%	-0.56 [-1.34 , 0.22]
Ku et al., 2019	7.35	0.67	18	7.76	0.62	42	36.4%	-0.41 [-0.77 , -0.05]
Kwok et al., 2016	9.1	1.1	40	9.1	1.2	16	10.3%	0.00 [-0.68 , 0.68]
Liao et al., 2019	15.1	8.7	27	15.4	8.2	40	0.3%	-0.30 [-4.45 , 3.85]
Queiroz et al., 2017	4.8	0.38	13	5.04	0.54	16	42.3%	-0.24 [-0.58 , 0.10]
Total (95% CI)			233			241	100.0%	-0.34 [-0.56 , -0.12]

Heterogeneity: Chi² = 6.37, df = 7 (P = 0.50); I² = 0%
Test for overall effect: Z = 3.05 (P = 0.002)
Test for subgroup differences: Not applicable

(i) 8-Foot Up and Go

Study or Subgroup	Experimental			Control			Weight	Mean difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Maillot et al., 2012	6.48	0.62	16	7.6	1.05	16	52.2%	-1.12 [-1.72 , -0.52]
Ray et al., 2012	7.1	1.2	29	6.2	2	18	47.8%	0.90 [-0.12 , 1.92]
Total (95% CI)			45			34	100.0%	-0.15 [-2.13 , 1.82]

Heterogeneity: Tau² = 1.86; Chi² = 11.19, df = 1 (P = 0.0008); I² = 91%
Test for overall effect: Z = 0.15 (P = 0.88)
Test for subgroup differences: Not applicable

(j) Velocity

Study or Subgroup	Experimental			Control			Weight	Mean difference IV, Fixed, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Eggenberg et al., 2015	133.4	5.2	15	131.1	4.7	15	79.5%	2.30 [-1.25 , 5.85]
Lee et al., 2014	128.1	21.3	40	128.2	22.1	42	11.3%	-0.10 [-9.49 , 9.29]
Liao et al., 2019	74	29	27	68	27	25	4.3%	6.00 [-9.22 , 21.22]
Sato et al., 2015	239.8	27.75	28	240.35	26.3	26	4.8%	-0.55 [-14.97 , 13.87]
Total (95% CI)			110			108	100.0%	2.05 [-1.11 , 5.21]

Heterogeneity: Chi² = 0.60, df = 3 (P = 0.90); I² = 0%
Test for overall effect: Z = 1.27 (P = 0.20)
Test for subgroup differences: Not applicable

FIGURE 2 (Continued)

healthy ageing. Now and in the future, society should seek to maximize the number of people who achieve a positive ageing trajectory, and an important element of this ambition is to enable access to tailored innovative interventions that promote optimal functional levels and a healthy lifestyle.

5 | CONCLUSIONS

Physical exercise, performed via active video games, has significant beneficial effects on clinical parameters such as gait speed and the Timed Up-and-Go score, for independent community-dwelling older
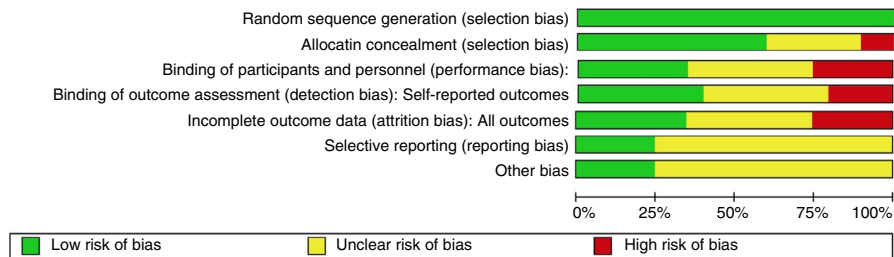
FIGURE 3 Risk of bias among the studies considered

adults. However, the effects produced on other parameters do not differ significantly from those obtained with conventional exercise training, and so the clinical importance of these benefits may be limited. Nevertheless, strategies based on active video games are viable and well-accepted, and can be helpful to promote exercise by older adults who otherwise lack motivation. Tailored randomized clinical trials should be conducted of diverse older adult populations to evaluate a wide range of variables related to physical function in order to determine the best training approach and the optimal design and duration of exercise programmes.

CONFLICT OF INTEREST

No conflict of interest has been declared by the authors.

AUTHOR CONTRIBUTIONS

All authors have agreed on the final version and meet all four following criteria [recommended by the ICMJE (http://www.icmje.org/recommendations/)]:

1. Have made substantial contributions to conception and design, analysis and interpretation of data.
2. Been involved in drafting the manuscript or revising it critically for important intellectual content.
3. Given final approval of the version to be published. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content.
4. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/jan.15138.

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