

Effectiveness of exergames for improving mobility and balance in older adults: A systematic review and meta-analysis.

Thaiana Barbosa Ferreira Pacheco (✉ thaianab@ufrn.edu.br)

Universidade Federal do Rio Grande do Norte Centro de Ciencias da Saude <https://orcid.org/0000-0002-8498-3862>

Candice Simões Pimenta de Medeiros

Universidade Federal do Rio Grande do Norte Centro de Ciencias da Saude

Victor Hugo Brito de Oliveira

Universidade Federal do Rio Grande do Norte Centro de Ciencias da Saude

Edgar Ramos Vieira

Florida International University

Fabrcia Azevêdo da Costa Cavalcanti

Universidade Federal do Rio Grande do Norte Centro de Ciencias da Saude

Research

Keywords: Video games, Aging, Gait, Balance

Posted Date: April 2nd, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-19993/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published on July 18th, 2020. See the published version at <https://doi.org/10.1186/s13643-020-01421-7>.

Abstract

Background: Exergaming is a fun, engaging, and interactive form of exercising and it may help overcome some of the traditional exercise barriers and help improve adherence by older adults providing therapeutic applications for balance recovery and functional mobility. The purpose of this systematic review is to summarize the effects of exergames in older adults' mobility and balance.

Methods: The PRISMA guidelines for systematic reviews were followed. The following databases were searched from inception to August 2019: Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, PEDro, CINAHL and INSPEC. We selected randomized controlled trials that assessed the effects of exergames on balance or mobility of older adults without neurological conditions, in comparison to no intervention or health education. Two review authors independently screened the trials titles and abstracts and identified trials for inclusion according to the eligibility criteria. Trial selection presented an almost perfect agreement between the authors regarding the interrater reliability ($\kappa = 0.84$; $p < 0.001$). Then, a descriptive analysis of the quantitative data was performed to summarize the evidence. Meta-analysis was carried using Revman. Random effects model was used to compute the pooled prevalence at 95% confidence interval.

Results: After screening 822 trials, twelve trials comparing exergames with no intervention were included. A total of 1520 older adults participated in the studies, with mean age of 76 ± 6 years for the experimental group and 76 ± 5 years for the control group. Three studies found significant improvements in balance based on center of pressure sway and Berg Balance Scale scores. Three studies found improved mobility based on the timed up and go, 30-second chair stand, and 8-foot up and go test.

Conclusions: Exergames improved balance and mobility in older adults without neurological disorders. High quality studies with standardized assessment protocols are necessary to improve evidence.

Background

Falls are a major public health problem (1) and fall-related injuries are the leading cause of death, morbidity and healthcare costs (2). Approximately one-third of older adults (age ≥ 65 years) fall once a year, and half of those are likely to fall again in the subsequent year (3). The incidence of falls varies among countries. For instance, the percentage of older adults that fall each year is six to 31% in China, 20% in Japan, 22% in Barbados, and 34% in Chile (4).

Activities of daily living require complex gait and balance adjustments. Gait and balance are essential for mobility and independence, and impairments increase the risk of falls in older adults (1,5). Numerous treatments exist to retain and restore gait and balance in older adults (6). Most treatments involve exercises. Low older adult adherence to traditional exercise and physical activity is associated with kinesiophobia, fear of injury, and lack of motivation(7).

One approach to improve gait and balance involves virtual reality (VR) based exercises, also known as exergames. Exergames involve constant self-correction (8) providing therapeutic applications for gait and balance recovery, executive function stimulation and multitask training (9). During exergames the user interacts with the game scenario stimulating sensorial, cognitive, psychological and motor functions (10,11). For being a fun, engaging, and interactive form of exercising (12), exergames help improve adherence by older adults (13) and help overcome some of the traditional exercise barriers like lack of motivation and negative perception of exercises outcome (14).

A variety of commercial and low-cost exergames have been used with older adults in health care (15). Microsoft® Xbox games (Washington , USA) use Kinect sensors and require motor control because the player only succeeds in the game if the movements are performed as they should. The use of Kinect games was reported as favorable to improve balance in older adults even when the games played with emphasis only on upper limb movements (16). The Nintendo® Wii (Kyoto, Japan) is the most used exergame platform for balance training in older adults because it includes the Wii Balance Board (17,18). Significant balance improvement was found in Nintendo® Wii users compared with the control groups (17).

Besides the popularity of commercial exergames in rehabilitation, a variety of exergames have been developed for therapeutic purposes and are called “serious games”. Serious games combine features that provide immersion and high concentration in which the player becomes absorbed in the game creating personal experiences in a balance between skills and challenges. In this sense, serious games offer a state of perception of individuals’ needs for mastery, autonomy, connectedness, arousal, fun, fantasy or challenge (19)

The impact of exergaming on the postural balance of older adults was reported (20). For neurological conditions, there is some evidence of the effectiveness of exergames in improving balance as supplemental therapy to usual stroke patient rehabilitation (21) and for Parkinson disease (22). For older adults without neurological diagnosis, a variety of studies have been developed, however inconsistent findings have been reported in order to update such results. A systematic literature review on this topic included studies with active and non-active control groups and different study designs, such as crossover, case controlled, quasi-experimental and non-randomized trials (23). Other study assessed the effects of exergame combined to other therapies on timed up and go test (TUG), falls efficacy scale (FES), activities-specific balance confidence (ABC) (24) and, a more recent study described the effects of exergaming on a frail older adults population, only (25).

Thus, facing such inconsistency and variability in selection criteria in previous studies, the aim of this systematic review was to integrate and summarize the effects of exergames on the mobility and balance of older adults without neurological conditions in comparison to no exercise or health education.

Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (additional file 1) for systematic reviews (26).

Eligibility criteria

PICO criteria (participants, interventions, comparisons and outcomes) were used to select the studies. This review included studies that: i) were randomized controlled trial (RCT); ii) were conducted in community-dwelling men and/or women aged 60 and older; iii) only included older adults without neurological conditions such as Stroke, Parkinson, peripheral neuropathies or neuromuscular diseases; iv) used exergames (commercial or serious games) to improve mobility or balance in older adults; v) compared the effects of the exergames to no intervention (e.g. no physical exercise) or to health education, or cognitive exercises with no physical activity, vi) reported mobility and/or balance measures as primary outcomes. We excluded studies that were performed in long term care centers, or that combined exergame and conventional exercises in experimental group or with active control group.

Intervention

We considered as commercial games: physical exercises with Nintendo® Wii, Xbox® and Playstation®, that are the most used commercial consoles in rehabilitation. In addition, we also included trials that used serious games that were developed specific to treat impaired conditions related to balance and functional mobility, including 3D immersive systems.

Outcomes

The primary outcomes assessed in this review were: i) Postural Balance measured with valid instruments such as Berg Balance Scale, Force Platform parameters, Tinetti Test, Balance Master System and ii) Functional mobility measured with physical performance instruments such as Short Physical Performance Battery, Functional Reach Test, Functional Ambulatory Categories, Activities-specific Balance Confidence scale, 8-foot up and go test, 30-second chair stand and Timed Up and Go Test.

Secondary outcomes included: i) Motivation (questionnaire or self-reported impression); ii) Safety (self-reported impression); iii) Adherence (questionnaire or self-report that described the level of adherence to virtual therapies); iv) Adverse Effects (any kind of non-expected effects described in the studies including motion sickness, pain, injury, falls and death); v) Quality of life (questionnaire or self-report)

Database search

We searched the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, PEDro, CINAHL, AMED and INSPEC. We also searched the following trials registries: The World Health Organization International Clinical Trials Registry Platform (www.who.int/trialsearch); ReBEC (<http://www.ensaioclinicos.gov.br>) and ClinicalTrials.gov (www.clinicaltrials.gov). Search strategy was conducted using keywords for population, intervention, comparator and outcome (PICO). The search terms included: ("Older adult" OR senior OR elder OR elderly OR aged OR "older person" OR "older people"

OR gerontological OR geriatric) AND (“Virtual reality” OR exergames OR “videogame” OR “video game” OR Wii OR Kinect OR “balance board”) AND (Mobility OR “physical disability” OR “physical function” OR “physical performance” OR balance OR gait OR motor OR walk OR dizziness OR vertigo OR posture OR postural OR “physical fitness” OR “physical health”). We searched the reference lists of all included trials and any relevant systematic reviews identified for additional trials. We contacted experts and organizations to obtain additional information on relevant trials. Searches were not limited by date until August 2019, language or publication status.

Selection of studies and data extraction

Two review authors (TP and CM) independently screened the titles and abstracts of the trials identified by the search. Then, the same authors screened the full-text articles and identified trials for inclusion according to the eligibility criteria. In case of any disagreements, a third review author (FC) resolved it. The authors identified and excluded duplicate trials and multiple reports of the same trial. Table 1 shows an almost perfect agreement between the authors regarding the interrater reliability of trial selection ($k = 0.84$; $p < 0.001$). The complete process is detailed in the PRISMA flow diagram in figure 1 (26).

Data extraction and management

Two review authors (CM, TP) extracted information from the included trials and transferred data into the software Review Manager 5.3 (27). We piloted the data extraction form using a sample of studies in order to identify any missing or unclear items. We used a standardized data extraction form to record the following items: authors, funding source, notable conflicts of interest, study duration, method of recruitment, sample size, comparability of groups, age (mean and range), sex, characteristics of the exergame (type of immersion, type of the game, system), intervention duration, adherence, safety/adverse events, and outcomes measures (balance, functional mobility and quality of life).

Assessment of risk of bias

The risk of bias of the included studies was assessed by two independent researchers (TP and CM) based on recommendations in the *Cochrane Handbook for Systematic Reviews of Interventions* (28). The risk of bias was classified as “high”, “low” or “unclear” based on sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment; incomplete outcome data; selective outcome reporting; and other bias. Table 01 shows the interrater reliability for risk of bias assessment. Disagreements were resolved by consensus. Risk of bias was assessed using the *Cochrane Handbook for Systematic Reviews of Interventions* (28) recommendations (figures 2 and 3).

Table 1. Interrater agreement between two assessors for study selection and risk of bias.

Items	% Complete Agreement	Kappa value	p
Study selection	95%	0.847	<0.001
Risk of bias:			
1. Random sequence generation (selection bias)	83%	0.733	<0.001
2. Allocation concealment (selection bias)	83%	0.724	0.001
3. Blinding of participants and personnel (performance bias)	75%	0.581	0.008
4. Blinding of outcome assessment (detection bias)	83%	0.733	<0.001
5. Incomplete outcome data (attrition bias)	92%	0.860	<0.001
6. Selective reporting (reporting bias)	67%	0.429	0.054
Overall agreement for risk of bias	81%	0.676	0.010

Data Synthesis

Given the considerable methodological heterogeneity of studies some of them could not be combined by means of meta-analysis, thus the results were presented using descriptive synthesis. The descriptive synthesis was undertaken by one reviewer (TP) and crosschecked by two others (CM, FC). In addition, some data regarding the primary outcomes were included in meta-analysis, in terms of mean difference with 95%CI (TUG test and Berg Balance Scale) and in terms of standardized mean difference (CoP sway). We used the Review Manager 5.3 software to calculate treatment effects (27). Heterogeneity of trial results was calculated with application of the Chi² test (with a P value of 0.10 to indicate statistical significance) and by applying the I² statistic. We considered the I² statistic with a value of 50% as a moderate level of heterogeneity (28). The summary value for each study was described in forest plots, considering a fixed-effect model to determine the actual effects of the intervention.

Results

Study Characteristics

Database search resulted in 822 studies (figure 1). Three duplicated studies were removed. After analyzing titles and abstracts, 761 of studies did not meet the inclusion criteria. From the remaining 58 studies, six were not available in full text. Review of the full texts of the remaining 52 studies resulted in the exclusion of additional 40 that also did not meet the inclusion criteria: 13 had an active control group (e.g. other type of exercise or therapy), 11 were not RCT, four did not assess balance or mobility, five were conducted in long term care facilities, four did not include older adults, one did not involve exergames,

and two performed exergames combined with other interventions. We included the remaining 12 studies in the systematic review.

Participants and intervention characteristics

A total of 1520 older adults participated in the 12 studies included, 903 (61%) were women. One trial did not report the sex of the participants (29). The mean age was 76 ± 6 for the exergame group and 76 ± 5 for the no exercise or health education group.

Regarding the exergame type, most studies used the commercial non-immersive Nintendo Wii® system (1,29–36). The remaining studies used the following serious games: the Balance Rehabilitation Unit (BRU™) - a customized rehabilitation program that contains a immersive environment in which the user interact through three dimensional glasses (37); the LegSys™ (BioSensics LLC, MA, USA) - an interactive exergame interface with five wearable joint angle and position sensors (30); and two studies used Kinect-based exergames – the iStoppfalls system (38), and the exergame program with the following serious games: apple game, tightrope standing, balloon popping and one-leg stand (39).

The mean of time of exposure to exergames was 825 minutes (number of sessions x duration of each session), ranging from 360 (30,37) to 1440 minutes (1). The mean number of sessions was 21 varying from eight (30) to 48 (38), and duration varied from four (30) to 16 weeks(38).

Seven studies had no intervention as a comparison control group (1,29,30,33–35,39). In one study, the control group performed cognitive exercises (32); in another study, the control group wore E.V.A. (Ethylene Vinyl Acetate) insoles in their shoes everyday (31). In three studies, the control group received education on falls prevention and physical activity(36–38). The intervention characteristics are detailed in table 2.

Outcomes

The instruments used to assess balance and mobility varied among studies. Three studies used the Timed Up and Go (TUG) test (30,31,33), the Berg Balance Scale (BBS) – three studies (32,33,39), the 30-second stand test – three studies (1,31,39), and the 8 feet up and go test – three studies (1,30,35). The other instruments used were the Functional Reaching Test (33), the Activities-specific Balance Confidence Scale (32,35), the Tinetti balance test and the unipedal stance test (36), the MiniBESTest and the functional gait assessment (34). The center of pressure based balance parameters the were assessed using force plates were velocity (31), sway (29,30,37) and limits of stability (37). Table 3 shows detailed information about center of pressure parameters. The trials included in the systematic review did not have enough data collected using the same mobility and balance instruments/tests to allow pooling the data for the calculation of summary statistics in a meta-analysis.

[INSERT TABLE 02 HERE]

[INSERT TABLE 03 HERE]

Regarding secondary and descriptive outcomes, four studies reported adverse events (30–32,34), safety – two studies (30,34) and adherence – five studies (30,32,34,37,38). Other outcomes were motivation – two studies (31,34), user experience – two studies (30,34), quality of life – two studies (1,32) and physical activity enjoyment – one study (32).

Effects on balance

Considering the outcomes related to center of pressure (CoP) based variables, there was no significant effect of exergaming on CoP velocity (<0.23 mm²/s; CI = -4.1 to 4.6; $p = 0.92$) (31). However, Cho et al (29) found significant CoP excursion improvement (decrease) both with eyes open and closed after an exergame intervention ($p<0.01$). Significant balance improvements were also observed by Schwenk et al (30) in CoP sway area ($p=0.007$; effect size = 0.23), and on the limits of stability and CoP sway area ($p<0.01$) (37) Figure 04a shows the effects of exergames considering the CoP sway with eyes open and closed. BBS score. Data suggest an effect in favor to the exergames regarding CoP sway (SMD = -0.89; 95% CI = -1.26 to -0.51) and heterogeneity of 58%.

The effects of exergaming on the BBS was evaluated in three studies (32,33,39). Padala et al (32) reported a significant improvement in BBS scores after four and eight weeks of exergaming (CI = 2.3 to 4.8 after four weeks, and CI = 4.3 to 6.7 after eight weeks; $p<0.001$). Sato et al (39) also found significant improvement in BBS scores in the exergame group in comparison to a control group, but the effects were smaller (CI = 0.22 to 1.9; $p<0.01$). Similarly, Jung et al(33) found significant improvement in BBS scores in the Nintendo Wii exercise group compared to a control group ($p<0.001$).

Figure 04b shows the effects of exergames considering the BBS score. In a total of $n = 51$ participants in the experimental groups versus $n = 51$ in the control group, data suggest an effect in favor to the exergames regarding postural balance assessed by BBS (MD = 2.15; 95% CI = 1.77 to 2.53), although a substantial heterogeneity was observed ($I^2 = 96\%$).

In respect to other types of balance assessment, it was observed inconsistent findings on the effect of exergames based on changes in the Activity-specific Balance Confidence Scale (ABC) scores (32,35) Also, no between groups' difference was observed using the Tinetti's balance test (36) the MiniBEST Test (34)

Effects on mobility

The effects of exergames on TUG time were reported by three studies. Jung et al(33) found a significant difference between groups with better TUG performance in the exergame group than in the control group ($p<0.001$). Similarly, Jorgensen et al(31) reported a between group difference in TUG time of -1.4 seconds (CI = -2.5 to -0.4; $p= 0.01$), and Schwenk et al (30) also found a significant better performance in TUG test in the exergame group. Figure 04c shows the effects of exergames considering the TUG test. A total of $n = 50$ participants in the experimental groups versus $n = 53$ in the control group. Data suggest an effect in

favor to the exergames regarding TUG (MD = -2.48; 95% CI = -3.83 to -1.12) with no heterogeneity ($I^2 = 0\%$).

The other studies that assessed mobility used the following instruments: 8-foot up and go test (1,30,35), 30-second chair stand test (1,31,39) and MiniBEST test (34), Functional Reach Test (39,40), the 6-meter Walking Test (1) and the Functional Gait Assessment (34) They all found significant better mobility for the exergame groups than for the control groups ($p < 0.05$).

The effects of exergaming on the 8-foot up and go test was evaluated in three studies (1,30,35), Rendon et al (35) reported a significant improvement in 8-foot up and go test after six weeks of exergaming (median = 8.8; min = 5.1; max = 23.44; $p = 0.045$). Significant improvement in 8-foot up and go test in the exergame group in comparison to control (change = -1.07 ± 0.74 ; $p < 0.01$) was found (1). Schwenk et al (30) found significant improvement in 8-foot up and go test (19% of change; $p = 0.037$). Figure 04d shows the combined effect of exergames considering the 8-foot up and go test. In a total of $n = 39$ participants in the experimental groups versus $n = 41$ in the control group, data suggest an effect in favor to the exergames (MD = -1.88; 95% CI = -2.40 to -1.38), with heterogeneity of $I^2 = 53\%$.

Adverse Effects

Four studies that used Nintendo Wii® reported no adverse effects (30–32,34). The remaining studies did not mention adverse effects.

Adherence

The studies using Nintendo Wii® reported good adherence: 100% (32), 93% (30) and 80% (34). The participants who did not adhere reported transportation issues, back pain and unrelated medical. Similarly, the studies that used the BRU™ (37) and the iStoppFalls system (38) reported a 97% and 81% of adherence. The causes for no adherence were transportation issues (37), motivation, personal, health and system-related issues (32).

Quality of life

Quality of life was investigated in two trials. Padala et al(32) found no difference between experimental and control groups on SF-36 scores. Maillot et al(1) found significant improvements in the social functioning ($p < 0.05$) and global mental health ($p < 0.01$) domains of the SF-36 in the experimental group that played Nintendo Wii® games.

Safety

Safety information was extracted from the user experience questionnaire (30). The older adults could “completely disagree” (0), “moderately disagree” (1), “neutral” (2), “moderately agree” (3) or “absolutely agree” (4) with 10 statements. The following six were safety-related: “I never lost my balance while using the exercise technology” (4 ± 1). “I was afraid to tumble or to fall during the exercise” (0.2 ± 0.6). “I required

balance support while conducting the exercises" (0.5±1). "I feel that the exercises were going too fast for me" (0.2±0.4). "Some of the movements were difficult to perform" (1±0.9). "I felt safe using the exercise technology" (4±0.4). Gomes et al(34) used a "Game Satisfaction Questionnaire". One of the questions was "Did you feel safe playing the games? If not, why?". All participants from the experimental group stated that they felt safe.

Motivation and enjoyment

One study investigated enjoyment (32) and two assessed motivation (31,34) of the participants who played exergames in the Nintendo Wii®. Based on the Physical Activity Enjoyment Scale (PACES), 83% of the participants rated the Wii-Fit to be high on the measure of pleasure, 75% considered the Nintendo Wii® as fun, 75% considered pleasant, 67% rated it as invigorating, 83% as gratifying, 83% as exhilarating, 92% as stimulating and 92% as refreshing. Motivation was assessed using a Likert scale for the sentence (31): "I find the Nintendo Wii training both fun and motivating", and 70% of the participants strongly agreed; 25% agreed, and 5% were undecided. The "Game Satisfaction Questionnaire" assessed motivation using two questions (34): "Did you feel motivated to play the games?" and "Would you like to play the games with someone?", and 83% of the participants said they were "very motivated" and would like to play the games with someone, and 17% said they were "motivated" and would not play with someone.

Risk of bias in the included studies

The risk of selection bias was low in five of the twelve studies (31)^{24,26,28,32} for both sequence generation and for allocation concealment. Two studies showed low risk of bias for sequence generation, and unclear for allocation concealment (1,40). The level of risk of bias was unclear in four studies (29,33,35,37), and high in one study (36).

High risk for performance bias was observed in two studies (34,36). The performance bias risk was unclear for six studies (29,32,33,35,38,39), and it was low risk for four trials (1,30,31,37). The risk of detection bias was low risk in six of the twelve studies (30,31,34,35,37,38); unclear in four trials^{1,23,27,33}, and high in two study (32,36). Attrition bias was low in six trials (31–35,39), unclear in four trials (1,29,30,38), and high in two (36,37). For reporting bias, five of the twelve studies had low risk (30–32,34,36), six trials were unclear^{1,23,27,29,32,33}, and the risk of reporting bias was high for one trial (37). Other source of risk of bias was considered high in one study (Nintendo lent the equipment for the training) (36).

Discussion

This review summarized the evidence regarding the effects of exergames in older adults with impaired balance. The use of exergames in geriatric rehabilitation is increasing, and it brings a necessity to investigate their benefits. It was observed that exergames improve balance and mobility and can be useful in geriatric rehabilitation.

Aging is associated with physiological changes in the structure and function of different biological systems. Such modifications may lead to a decline in visual acuity, causing decreases in spatial orientation ability. In addition, the reduction in proprioception leads to a decrease in the capacity of perception and precision of the movements (1). Slowness in controlling center of mass oscillations (41) impairs static and dynamic balance (42). All these changes increase the risk of falls. However, some impairments can be repaired or compensated by practicing physical activities involving balance training such as time-reaction practice and reactive recovering (43). Thus, although this study focused on healthy older adults, it raises the discussion of using exergames in order to keep the older adults physically active, preventing fragility or other conditions that could impair their functional mobility. Indeed, a study with virtual exercises and visual biofeedback found improvements in functional abilities and reaction time in older people possibly due to the attentional demand requirements of the interactive and ludic virtual environments (44). Interaction with game scenarios and the action-observation of the avatar movements provides sensorial perception (45,46) and thus, the multisensorial approach may contribute to a better processing of sensorial affordance necessary to keep balance.

Regarding the included studies that used commercial virtual games, all of them used Nintendo Wii[®]. These games offer variation in feedback, improve motor learning, gait and reduce the risk of falls (33). The favorable evidences for balance found by Jorgensen et al (31) were associated with postural challenging environments, in which older adults need to control their CoP in multiple directions. The favorable results for exergames regarding CoP sway may represent the sensitivity of exergames in integrating sensory modalities (vestibular, proprioceptive, auditory and visual systems) necessary for balance (47).

The studies that assessed mobility with TUG found positive effects of exergames. This is relevant because older adults who are able to complete TUG in less than 10s have low risk of falls (48). Good timing in executing TUG represents independence for activities of daily living, especially regarding the International Functional Classification (ICF) domain "Activity and Participation". According to the ICF, "Activity" is the execution of a task or action by an individual, whereas "participation" is an individual's involvement in a real-life situation (49). Therapeutic approaches in which intend to recover older adults' functional mobility play a relevant role in older adults' daily living, and so, in the qualification of the domain "activity and participation". Exergames may be a good strategy to maintain older adults' functional abilities.

A meta-analysis found no significant TUG time differences (-2.3s, 95%CI: -5.2 to 0.6s) between exergame and conventional exercises or no intervention. However, they found improvements on the number of 30-second chair stands (4, 95%CI: 2 to 6) in comparison to no exercises(50). Our review also found significant improvements in the three trials that assessed 30-second chair stands (1,31,39), and differently from the previous meta-analyses, we found improvements in TUG time (30,31,33). The differences may be explained by the fact that Taylor et al(50) evaluated TUG effects considering active and non-active control groups together, while we limited the investigation of the effects of exergames in comparison to no treatment only. Neri et al (51) found significant effects of exergames on TUG time

compared to no treatment after three to six weeks (-1.2s; 95%CI: -1.6 to -0.8) and after eight to twelve weeks (-0.9s; 95%CI = -1.4 to -0.3). Despite the amount of literature about exergames, there is still scarce dose-response information (52). We found a range of time of exposure to exergames from 360 to 1400 minutes (number of sessions x duration of each session). The iStoppFalls exposure time higher than 90 minutes/week reduced falls risk ($p = 0.031$) (38).

It is relevant to highlight the positive effects on motivation and physical activity enjoyment found for Nintendo Wii® games (31,32,34). This was also previously identified by another systematic review (23). Motivation is key for rehabilitation to maintain treatment frequency and intensity (53). Intrinsic motivation is related to self-satisfaction, while extrinsic motivation relates to external demands or rewards (54). Most therapeutic programs are supported by extrinsic motivation (53). However, exergaming features stimulate intrinsic motivation to improve “scores”; participants are challenged and encouraged by the interactive features of the games (55). Levels of intrinsic motivation between exergames and conventional therapy for postural control in adults were compared and, although they found similar effects in balance outcomes, the exergame group had higher levels of intrinsic motivation(54). Therefore, exergaming may help keep patients active. High level of adherence and no adverse events were reported in non-commercial exergaming (30,37). Vaziri et al (38) interviewed participants who played the iStoppFalls game and found that ease of use, challenge and feedback were the main features associated with motivation. Therefore, exergames need to balance therapeutic and entertaining elements in order to keep motivation.

In rehabilitation, serious games are designed to facilitate therapeutic exercises in a more appealingly way (56). The exergames requiring cognitive attention, control for external stimuli, and elicit fast reaction times (57). Serious games have been found to present positive effects on older adults’ reaction time (13). The health-promoting effects of serious games include engaging treatments, prevention, and education(58).

This systematic review presents some limitations. Due to the variety of the instruments used to measure balance, the data extracted were heterogeneous. Also, some trials only reported the results in graphs that did not provide the actual numbers. For these reasons, our meta-analysis was conducted with a limited number of studies and outcomes. Another limitation is that some trials may have been missed despite our attempt to use a broad search strategy.

Conclusions

This review indicates that in comparison to no treatment, exergames improve balance and mobility in older adults with impairments but without neurological diseases. The type of exergame (commercial or serious game) had similar effects on balance. Further investigation is needed to evaluate the effects of exergaming on quality of life, and to establish ideal dosage (time of each session, frequency, and program duration)

Abbreviations

AMED: Allied and Complementary Medicine Database .

BBS: Berg Balance Scale.

BRU: Balance Rehabilitation Unit.

CINAHL: Cumulative Index of Nursing and Allied Health Literature.

CM: Candice Simões Pimenta de Medeiros.

CoP: Center of Pressure.

EMBASE: Excerpta Medica database.

EV: Edgar Ramos Vieira.

EVA: Ethylene Vinyl Acetate.

FC: Fabrícia Azevêdo da Costa Cavalcanti.

MD: Mean Difference.

MEDLINE: Medical Literature Analysis and Retrieval System Online.

PEDro: Physiotherapy Evidence Database.

PICO: Population, Intervention, Comparator and Outcome.

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

RCT: Randomized Controlled Trial.

ReBEC Brazilian Register of Clinical Trials.

TP: Thaiana Barbosa Ferreira Pacheco.

TUG: Timed Up and Go.

VO: Victor Hugo Brito de Oliveira.

VR: Virtual Reality.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001”

Authors' contributions

TP and VO conceptualized the review. TP and CM screened the articles. TP and CM extracted the data. EV drafted the introduction. TP, CM and FC drafted the methods and results. FC, CM and TP drafted the discussion. All authors reviewed, edited and approved the final manuscript.

Acknowledgements

The authors are greatly thankful for the Physical Therapy Postgraduate Program of Federal University of Rio Grande do Norte, Natal, Brazil for providing high quality knowledge to support this study and the Florida International University, Miami, United States, for providing valuable bibliographic advice.

References

1. Maillot P, Perrot A, Hartley A, Do M-C. The Braking Force in Walking: Age-related Differences and Improvement in Older Adults With Exergame Training. *J Aging Phys Act* [Internet]. 2014 Oct;22(4):518–26. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=103914387&lang=pt-br&site=ehost-live&authtype=ip,cookie,uid>
2. Sherrington, Catherine; Tiedemann, Anne; Fairhall, Nicola J; Hopewell, Sally; Michaleff, Zoe A; Howard, Kirsten; Clemson, Lindy; Lamb SE. Exercise for preventing falls in older people living in the community. *Cochrane Database Syst Rev* [Internet]. 2016;(11):1–15. Available from: http://ovidsp.tx.ovid.com.proxy.lib.sfu.ca/sp-3.22.1b/ovidweb.cgi?&S=GFFJFPKDFMDDHNIANCHKNCDANMHAA00&Link+Set=S.sh.22%7C1%7CsI_50

3. Jones TS, Ghosh TS, Horn K, Smith J, Vogt RL. Primary care physicians perceptions and practices regarding fall prevention in adult's 65 years and over. *Accid Anal Prev* [Internet]. 2011 Sep 1 [cited 2017 Dec 2];43(5):1605–9. Available from: <https://www.sciencedirect.com/science/article/pii/S0001457511000649>
4. World Health Organization. WHO Global Report on Falls Prevention in Older Age. Community Health (Bristol) [Internet]. 2007;53. Available from: http://www.who.int/ageing/publications/Falls_prevention7March.pdf
5. Stemplewski, R; Maciaszec, J; Salamon, A; Tomczak, M; Osin'ski W. Effect of moderate physical exercise on postural control among 65–74 years old men. *Arch Gerontol Geriatr*. 2012;54(2012):e279–83.
6. Patterson SL, Forrester LW, Rodgers MM, Ryan AS, Ivey FM, Sorkin JD, et al. Determinants of Walking Function After Stroke: Differences by Deficit Severity. *Arch Phys Med Rehabil*. 2007;88(1):115–9.
7. Mustafaoğlu R, Unver B, Karatosun V. Evaluation of stair climbing in elderly people. *J Back Musculoskelet Rehabil*. 2015;28(3):509–16.
8. Cho S-H, Shin H-K, Kwon Y-H, Lee MY, Lee Y-H, Lee C-H, et al. Cortical activation changes induced by visual biofeedback tracking training in chronic stroke patients. *NeuroRehabilitation* [Internet]. 2007;22(2):77–84. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/17656831>
9. Levin MF. Can virtual reality offer enriched environments for rehabilitation? *Expert Rev Neurother Rehabil*. 2011;11(2):153–5.
10. Peñasco-Martín B, Reyes-Guzmán A, Gil-Agudo A, Bernal-Sahún A, Pérez-Aguilar B, Peña-González A. Aplicación de la realidad virtual en los aspectos motores de la neurorrehabilitación. *Rev Neurol*. 2010;51(8):481–8.
11. Schultheis MT, Rizzo AA. The application of virtual reality technology in rehabilitation. *Rehabil Psychol* [Internet]. 2001;46(3):296–311. Available from: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0090-5550.46.3.296>
12. Proffitt R, Lange B, Chen C, Winstein C. A Comparison of Older Adults' Subjective Experiences With Virtual and Real Environments During Dynamic Balance Activities. *J Aging Phys Act* [Internet]. 2015 Jan;23(1):24–33. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=103870557&lang=pt-br&site=ehost-live&authtype=ip,cookie,uid>
13. Wiemeyer J, Kliem A. Serious games in prevention and rehabilitation-a new panacea for elderly people? *Eur Rev Aging Phys Act*. 2012;9(1):41–50.
14. Justine M, Azizan A, Hassan V, Salleh Z, Manaf H. Barriers to participation in physical activity and exercise among middle-aged and elderly individuals. *Singapore Med J*. 2013;54(10):581–6.
15. Hall CD, Clevenger CK, Wolf RA, Lin JS, Johnson II TM, Wolf SL. Feasibility of a Low-Cost, Interactive Gaming System to Assess Balance in Older Women. *J Aging Phys Act* [Internet]. 2016 Jan;24(1):111–8. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=112457919&lang=pt-br&site=ehost-live&authtype=ip,cookie,uid>

16. Hsieh W-M, Chen C-C, Wang S-C, Tan S-Y, Hwang Y-S, Chen S-C, et al. Virtual reality system based on Kinect for the elderly in fall prevention. *Technol Health Care*. 2014;22(1):27–36.
17. Bonnechère B, Jansen B, Omelina L, Van Sint Jan S. The use of commercial video games in rehabilitation. *Int J Rehabil Res [Internet]*. 2016;39(4):277–90. Available from: <http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00004356-201612000-00001>
18. Perrier-Melo RJ, Coelho TDAS, Brito-Gomes JL, Oliveira SFM de, Costa MDC. Video Games Ativos, equilíbrio e gasto energético em idosos: uma revisão sistemática. *ConScientiae Saúde [Internet]*. 2014;13(2):5585. Available from: <http://www4.uninove.br/ojs/index.php/saude/article/view/4551>
19. Desmet A, Ryckeghem D Van, Compennolle S, Baranowski T, Crombez G, Poels K, et al. A Meta-Analysis of Serious Digital Games for Healthy Lifestyle Promotion. 2015;32(0):95–107.
20. Donath L, Rössler R, Faude O. Effects of Virtual Reality Training (Exergaming) Compared to Alternative Exercise Training and Passive Control on Standing Balance and Functional Mobility in Healthy Community-Dwelling Seniors: A Meta-Analytical Review. *Sport Med [Internet]*. 2016 Sep;46(9):1293–309. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=117649271&lang=pt-br&site=ehost-live&authtype=ip,cookie,uid>
21. Laver, Lange B, George S, Deutsch J, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation (Review). 2017;
22. Zeng N; Pope Z; Lee JE; Gao Z. A systematic review of active video games on rehabilitative outcomes among older patients. *J Sport Heal Sci*. 2017;6:33–43.
23. Choi SD, Guo L, Kang D, Xiong S. Exergame technology and interactive interventions for elderly fall prevention: A systematic literature review. *Appl Ergon [Internet]*. 2016;1–12. Available from: <http://dx.doi.org/10.1016/j.apergo.2016.10.013>
24. Tahmosybayat R, Baker K, Godfrey A, Caplan N, Barry G. A systematic review and meta-analysis of outcome measures to assess postural control in older adults who undertake exergaming. *Maturitas [Internet]*. 2017;98:35–45. Available from: <http://dx.doi.org/10.1016/j.maturitas.2017.02.003>
25. Zheng L, Li G, Wang X, Yin H, Jia Y, Leng M, et al. Effect of exergames on physical outcomes in frail elderly: a systematic review. *Aging Clin Exp Res [Internet]*. 2019;(0123456789):6–10. Available from: <https://doi.org/10.1007/s40520-019-01344-x>
26. Moher D, Liberati A, Tetzlaff J, Altman DG TPG. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med*. 2009;6(7).
27. The Cochrane Collaboration. Review Manager (RevMan). Copenhagen: The Nordic Cochrane Centre; 2014.
28. Higgins JPT GS (editors). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]*. 2011.
29. Cho GH, Hwangbo G, Shin HS. The Effects of Virtual Reality-based Balance Training on Balance of the Elderly. *J Phys Ther Sci*. 2014 Apr;26(4):615–7.

30. Schwenk M, Grewal GS, Honarvar B, Schwenk S, Mohler J, Khalsa DS, et al. Interactive balance training integrating sensor-based visual feedback of movement performance: a pilot study in older adults. *J NeuroEng Rehabil* [Internet]. 2014;11:164 (13 pp.)-. Available from: <http://dx.doi.org/10.1186/1743-0003-11-164>
31. Jorgensen MG, Laessoe U, Hendriksen C, Nielsen OBF, Aagaard P. Efficacy of Nintendo Wii training on mechanical leg muscle function and postural balance in community-dwelling older adults: a randomized controlled trial. *J Gerontol A Biol Sci Med Sci*. 2013 Jul;68(7):845–52.
32. Padala KP, Padala PR, Lensing SY, Dennis RA, Bopp MM, Parkes CM, et al. Efficacy of Wii-Fit on Static and Dynamic Balance in Community Dwelling Older Veterans: A Randomized Controlled Pilot Trial. *J Aging Res*. 2017;2017.
33. Jung D-I, Ko D-S, Jeong M-A. Kinematic effect of Nintendo Wii(TM) sports program exercise on obstacle gait in elderly women with falling risk. *J Phys Ther Sci*. 2015 May;27(5):1397–400.
34. Gomes GCV, Simões M do S, Lin SM, Bacha JMR, Viveiro LAP, Varise EM. Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit Plus™ for frail older adults: a randomized feasibility clinical trial. *Maturitas* [Internet]. 2018;118:20–8. Available from: <https://doi.org/10.1016/j.maturitas.2018.10.002>
35. Rendon AA, Lohman EB, Thorpe D, Johnson EG, Medina E, Bradley B. The effect of virtual reality gaming on dynamic balance in older adults. *Age Ageing*. 2012;41(4):549–52.
36. Montero-Alía P, Miralles-Bassedá R, López-Jiménez T, Muñoz-Ortiz L, Jiménez-González M, Prat-Rovira J, et al. Controlled trial of balance training using a video game console in community-dwelling older adults. 2019;(May):506–12.
37. Duque G, Boersma D, Loza-Diaz G, Hassan S, Suarez H, Geisinger D, et al. Effects of balance training using a virtual-reality system in older fallers. *Clin Interv Aging*. 2013;8:257–63.
38. Vaziri DD, Aal K, Gschwind YJ, Delbaere K, Weibert A, Annegarn J, et al. Analysis of effects and usage indicators for a ICT-based fall prevention system in community dwelling older adults. *Int J Hum Comput Stud* [Internet]. 2017;106(May):10–25. Available from: <http://linkinghub.elsevier.com/retrieve/pii/S1071581917300769>
39. Sato K, Kuroki K, Saiki S, Nagatomi R. Improving Walking, Muscle Strength, and Balance in the Elderly with an Exergame Using Kinect: A Randomized Controlled Trial. *Games Health J* [Internet]. 2015;4(3):161–7. Available from: <http://online.liebertpub.com/doi/10.1089/g4h.2014.0057>
40. Jung D-I, Ko D-S, Jeong M-A. Kinematic effect of Nintendo Wii(TM) sports program exercise on obstacle gait in elderly women with falling risk. *J Phys Ther Sci*. 2015 May;27(5):1397–400.
41. Lockhart W and S. Effects of age-related gait changes on the biomechanics of slips and falls. 2015;27(3):320–31.
42. Souza LB De, Paim CDRP, Imamura M, Alfieri FM. Use of interactive video game for stroke rehabilitation. *Acta Fisiátrica* [Internet]. 2011;18(4):217–21. Available from: <http://www.gnresearch.org/doi/10.5935/0104-7795.20110010>

43. Franco JR, Jacobs K, Inzerillo C, Kluzik J. The effect of the Nintendo Wii Fit and exercise in improving balance and quality of life in community dwelling elders. *Technol Health Care*. 2012;20(2):95–115.
44. Bisson E, Contant B, Sveistrup H, Lajoie Y. Functional Balance and Dual-Task Reaction Times in Older Adults Are Improved by Virtual Reality and Biofeedback Training. *CyberPsychology Behav [Internet]*. 2007;10(1):16–23. Available from: <http://www.liebertonline.com/doi/abs/10.1089/cpb.2006.9997>
45. Lucca LF. Virtual reality and motor rehabilitation of the upper limb after stroke: A generation of progress? *J Rehabil Med*. 2009;41(12):1003–6.
46. Saposnik G, Mamdani M, Bayley M, Thorpe KE, Hall J, Cohen LGY, et al. Effectiveness of Virtual Reality Exercises in STroke (EVREST): Rationale, Design, and Protocol of a Pilot Randomized Clinical Trial Assessing the Wii Gaming System. *Int J Stroke*. 2010;5(February):47–51.
47. Merriman NA, Whyatt C, Setti A, Craig C, Newell FN. Successful balance training is associated with improved multisensory function in fall-prone older adults. *Comput Human Behav [Internet]*. 2015;45:192–203. Available from: <http://dx.doi.org/10.1016/j.chb.2014.12.017>
48. Silva AS, Urbano JJ, Oliveira EF De, Vicente L, Oliveira F. Physical activity level, functional mobility and fall risk in the elderly. 2017;(313053):6–11.
49. World Health Organization. *Classificação Internacional da Funcionalidade, Incapacidade e Saúde*. 2017;
50. Taylor LM, Kerse N, Frakking T, Maddison R. Active Video Games for Improving Physical Performance Measures in Older People: A Meta-analysis. *J Geriatr Phys Ther*. 2018;41(2).
51. Neri SGR, Cardoso JR, Cruz L, Lima RM, de Oliveira RJ, Iversen MD, et al. Do virtual reality games improve mobility skills and balance measurements in community-dwelling older adults? Systematic review and meta-analysis. *Clin Rehabil [Internet]*. 2017 Oct;31(10):1292–304. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=c8h&AN=125308653&lang=pt-br&site=ehost-live&authtype=ip,cookie,uid>
52. Darekar A, Mcfadyen BJ, Lamontagne A, Fung J. Efficacy of virtual reality-based intervention on balance and mobility disorders post-stroke: a scoping review. ??? [Internet]. 2015;1–14. Available from: ???
53. Gor M, Cikajlo I, Novak D. Competitive and cooperative arm rehabilitation games played by a patient and unimpaired person: effects on motivation and exercise intensity. 2017;1–18.
54. Fitzgerald D, Trakarnratanakul PN, Smyth B, Caulfield PB. Effects of a Wobble Board-Based Therapeutic Exergaming System for Balance Training on Dynamic Postural Stability and Intrinsic Motivation Levels. 2010;40(1):11–9.
55. Olens A. Virtual Rehabilitation Environment Using Principles of Intrinsic Motivation and Game Design. 2012;21(1):1–15.
56. Madeira RN, Antunes A, Postolache O, Correia N. Serious...ly! Just Kidding in Personalised Therapy Through Natural Interactions with Games. 2018;726–45. Available from: http://link.springer.com/10.1007/978-3-319-76270-8_50

57. Tarnanas I. Reliability of a novel serious game using dual-task gait profiles to early characterize aMCI. 2015;7(April):1–15.
58. Rahmani E BS. Videogames and Health Improvement: A Literature Review of Randomized Controlled Trials. Games Heal J. 2012;1(5):331–41.

Figures

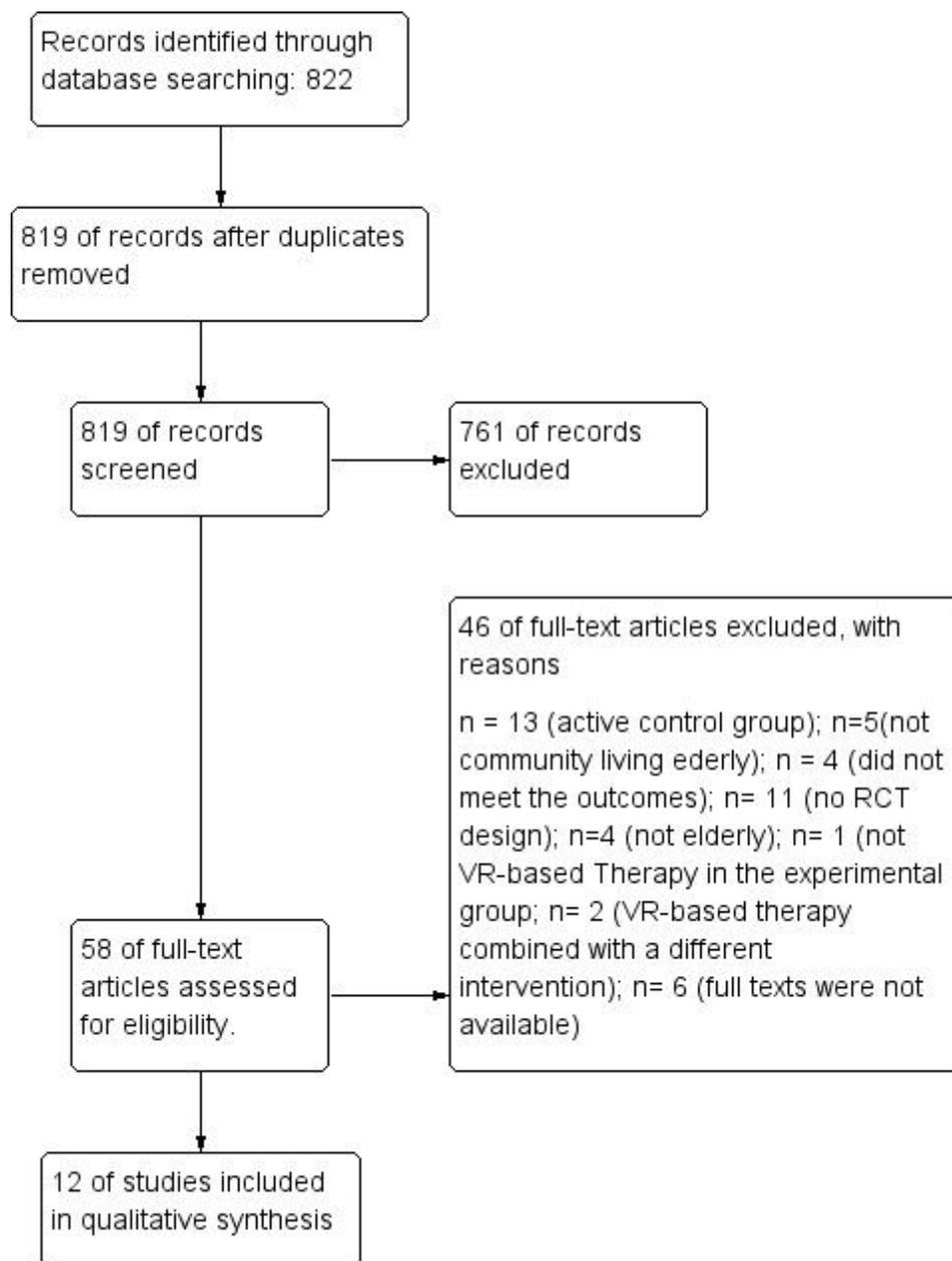


Figure 1

Flowchart for the selection of the studies

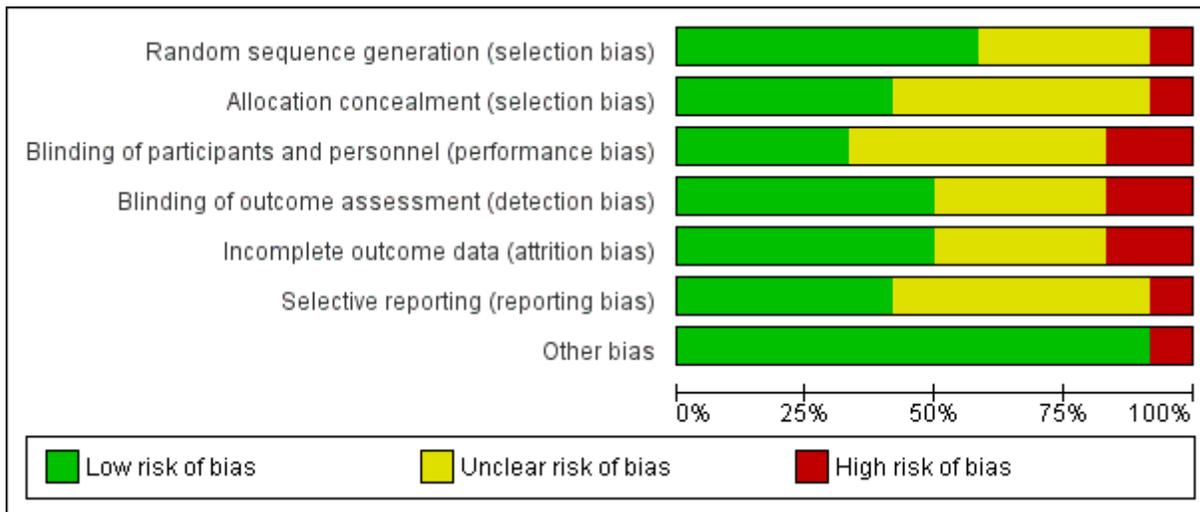


Figure 2

Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Cho [29]	?	?	?	?	?	?	+
Duque [37]	?	?	+	+	-	-	+
Jorgensen [31]	+	+	+	+	+	+	+
Jung [33]	?	?	?	?	+	?	+
Maillot [1]	+	?	+	?	?	?	+
Montero-Alía [36]	-	-	-	-	-	+	-
Padala [32]	+	+	?	-	+	+	+
Rendon [35]	?	?	?	+	+	?	+
Sato [39]	+	?	?	?	+	?	+
Schwenk [30]	+	+	+	+	?	+	+
Vaziri [38]	+	+	?	+	?	?	+
Vieira Gomes [34]	+	+	-	+	+	+	+

Figure 3

Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

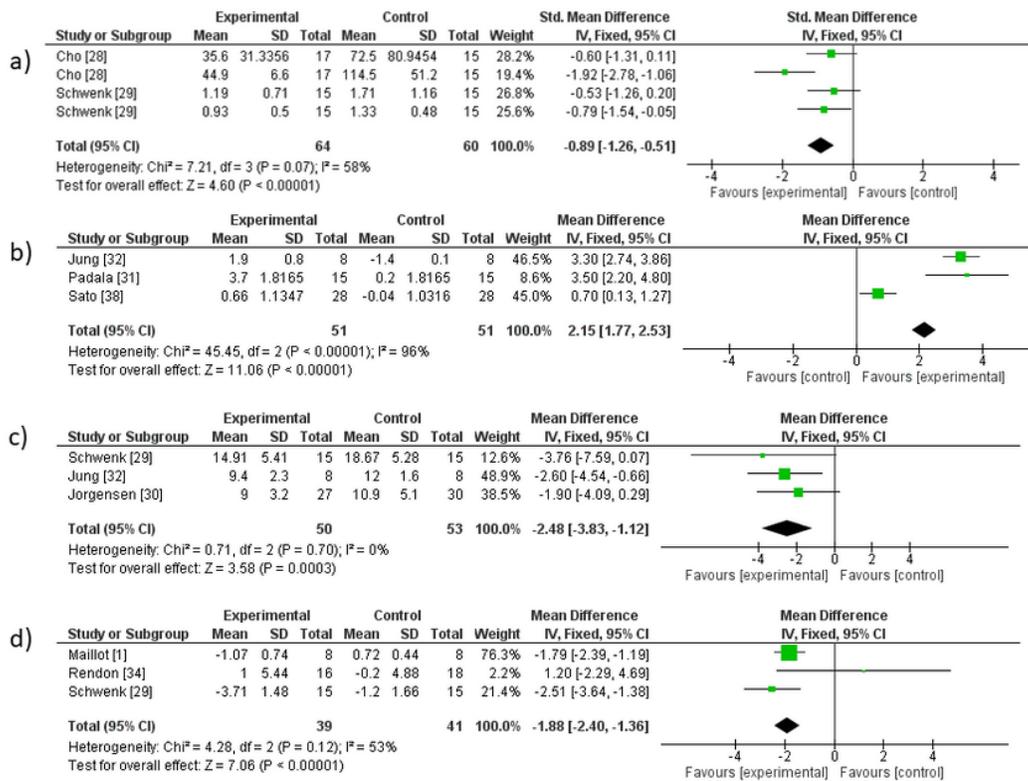


Figure 4

Pooled adjusted estimates the effect of exergame in comparison to control group on the following outcomes: a) CoP; b) Berg Balance Scale; c) Timed up and Go; d) 8-foot up and go. Estimates from the same author in figure 4a indicates different data that were extracted from same study (The first citation is the CoP measured with eyes closed and the second citation with eyes open, for both studies). The square indicates the study-specific effect estimate. Bars indicate the width of the corresponding 95% confidence interval. The diamond centered on the summary effect estimate, and the width indicates the corresponding 95% confidence interval.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AdditionalFile01PRISMA.doc](#)
- [AdditionalFileTable02.docx](#)
- [AdditionalFileTable03.docx](#)