Exergame-Assisted Rehabilitation for Preventing Falls in Older Adults at Risk: A Systematic Review and Meta-Analysis

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Review Article
Exergame-assisted rehabilitation for preventing falls in older adults at risk: A systematic review and meta-analysis

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Short Title: Exergame-assisted rehabilitation for preventing falls in older adults

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Abstract

Introduction. Exergaming is increasingly employed in rehabilitation for older adults. However, their effects on fall rate and fall risk remain unclear. **Methods.** We conducted a systematic review and meta-analysis that included randomized controlled trials (RCTs) comparing exergame-assisted rehabilitation with control groups, published in French or English, from Web of Science, CINHAL, Embase, Medline and CENTRAL (last search in June 2021). Two reviewers independently assessed studies. Risk of bias was assessed using RoB2, PEDRO scale and the GRADE system. The outcomes of interest were: a) Fall rate, b) Risk of falling, measured by the Short Physical Performance Battery (SPPB), Timed up and Go (TUG), One-Leg Stance or Berg Balance Scale (BBS), c) Fear of falling, measured with the Fall Efficacy Scale (FES-I) or the Activities-specific Balance Confidence (ABC) score. Data was pooled and mean differences (MD) between exergame and control groups calculated using a random-effects model. **Results.** Twenty-seven RCTs were included (1415 participants, including 63.9% of women, mean age ranged from 65 to 85.2 years old). Exergame-assisted interventions were associated with a reduction in the incidence of falls (4 studies, 316 participants, MD=-0.91 falls per person per year; 95% CI: -1.65 to -0.17, p =0.02, moderate quality). Regarding fall risk (20 studies included, low-quality evidence), SPPB did not change (MD=0.74; 95% CI: -0.12 to 1.60, p= 0.09), but all other scores were improved: BBS (MD= 2.85; 95% CI: 1.27 to -4.43, p=0.0004), TUG (MD=-1.46; 95%: CI -2.21 to -0.71, p=0.0001) and One-leg stance (MD=7.09; 95% CI: 4.21 to 9.98, p<0.00001). Fear of falling scores (FES-I and ABC) showed no difference. **Conclusion.** There is moderate quality evidence of a reduction in the fall rate with exergame-assisted rehabilitation and low-quality evidence suggesting a mild reduction of the risk of falling. Statistically significant benefits from exergame-assisted rehabilitation did not achieve clinically meaningful changes in risk of falling assessments.

Introduction

Older adults are at higher risk of developing disabilities that can lead to falls [1]. Twenty to 30% of older adults fall every year, among them, 50% will relapse within a year [2]. Fall consequences include injuries, loss of independence, social isolation [2]. Eighty-five percent of fallers develop fear of falling [3,4], which is associated with reduced activities and increased risk of falling [5]. Among the 75 year-old and older, 41.5% express fear of falling; in long-term care, this percentage rises to 63% [5,6].

Rehabilitation programs that combine different exercise categories have demonstrated to be effective in reducing the risk of falling among older adults[7–9]. The review of Skjaeret et al. (2016) found that exercise through exergames may increase physical functions [10]. Studies included in their review showed that, used in rehabilitation, exergames can lead to improvement in functions important for fall prevention such as mobility, muscular strength, balance control and cognition. However, results regarding the effects of exergaming on motivation and adherence remain mixed across studies [11,12]. The study of Subramanian et al. (2020) reports that older adults are motivated to use exergames because of the perceived health benefits and the enjoyment of play [13].

Several systematic reviews have been published on the use of exergames in older adults. However, most of them targeted specific conditions such as stroke, Parkinson's disease or other neurological diseases [14–16]. These studies did not cover all older adults at risk of falling. Conversely, Fang et al. (2020) focused on the effect of exergames on balance in healthy older adults, finding a moderate effect in favor of the exergames regarding balance and balance confidence [17]. Other systematic reviews studying exergames in older adults have analyzed balance training, quality of life or walking capacity, but not risk of falling [18–20]. Finally, a systematic review that aimed to synthesize the available research on exergames and other interactive interventions for fall prevention in older adults, found mitigated, inconclusive results and conducted no meta-analysis on the data retrieved [18]. Some studies were conducted more than five years ago [16,19]. Considering how quickly exergames evolve, the results of such systematic reviews could differ nowadays. Moreover, most of previous studies did not focus on exergames used in rehabilitation programs but assessed exergames used in playful settings. Using exergames as part of a rehabilitation program with rehabilitation objectives and supervised by rehabilitation professionals (e.g., physiotherapist, occupational therapist) might lead to more effective results on fall prevention. Therefore, our aim was to conduct an up-to-date systematic review and meta-analysis evaluating the effect of exergame-assisted rehabilitation programs on the risk and fear of falling in the general population of older adults at risk of falling.

Methods

Study Design

A systematic review and meta-analysis, following the Standards for the conduct of Cochrane intervention reviews [21] was conducted to answer the following research question: "what are the effects of exergames assisted rehabilitation programs on older adults' fall rate, risk of falls and fear of falling?". The protocol was registered in the PROSPERO database (CRD42021237667). One modification in the registered protocol was introduced afterwards: fall rate, which was initially only mentioned as an outcome of interest, was subsequently included in the research question, as we felt it might be important for making therapeutic decisions.

Inclusion Criteria

Criteria for including studies were the following:

1. Peer-reviewed studies.
2. Randomized controlled trials (RCTs) comparing participants receiving rehabilitation interventions assisted by exergames (whether in group or in individual sessions) with participants not receiving them. Control groups could receive usual rehabilitation programs or no rehabilitation. We employed the definition of exergame by Tanaka et al. [20]: "exergaming platforms are designed to track body motion or body reactions and provide both fun and exercise for game players". Interventions needed to be supervised by a rehabilitation professional.
3. Participants had to be older adults (at least 60 years old, or mean age of at least 75 years old) addressed to rehabilitation either because they had declared fear of falling or were assessed as at risk of falling. Number of falls prior to the study was not a criterion. We decided to include participants with various fall risk, as this corresponds to usual clinical practice, as patients with different profiles and various causes of falls are often treated in the same health setting.
4. Studies reporting any of the outcomes of interest: fall rate, risk of fall or fear of falling.

Outcomes of Interest

Outcomes of interest were the following: 1) Fall rate: incidence rate of falls, measured as the mean number of falls per patient per year; 2) Risk of falling: measured by the Short-Physical Performance Battery (SPPB) score, Test Up and Go (TUG) or One-Leg Stance (OLS) and Berg Balance Scale (BBS); 3)

Fear of falling: as measured by the Falls Efficacy Scale-International (FES-I) and Activities-specific Balance Confidence (ABC) Scale. All outcomes were assessed at baseline and at the last follow-up measurement performed after the intervention had been completed.

Search Methods for Identification of Studies

CINHAL, Embase, Medline Pubmed, Web of Science and CENTRAL were searched from their inception to June 2021. The following MesH terms were searched in the title, abstract, keywords and full text: *((Exergame* OR Video game* OR Virtual reality OR Technolog* OR Gerontechnolog* OR Telehealth OR Telecare) AND (Rehab* OR Intervention* OR Prevention) AND (Fall risk* OR balance OR fear of fall*) AND (Aged OR Geriatr* OR Geronto* OR Aging OR Older not older than OR Senior OR Elderly OR services for the aged))*.

Only studies published in English or French were included. Reference lists of included studies were searched for additional studies. The search process followed the Standards for the conduct of Cochrane intervention reviews [21].

Data Collection

After searching the databases, reference lists were pooled and duplicates removed. Two co-authors first independently screened titles and abstracts and then assessed full papers of any study deemed possible candidates for inclusion. They compared their responses and documented the reasons for the exclusion. Two co-authors then independently extracted data from included studies, using a predefined form. Any disagreement between investigators was resolved by discussion and consensus or, if a consensus was not reached, by a third co-author.

When data was missing from the report, corresponding authors were contacted. The following information was collected: 1) the source (title, authors, conflicts of interests, sources of funding, dates, journal, Source Normalized Impact per Paper ([22]); 2) the study (study design, aim, setting, sampling procedures, recruitment location, length of follow-up) 3) participants (total number, number of participants per group, gender and age, health condition, frequency of falls, cognitive status), 4) intervention (duration, frequency and length of the sessions, professional involved, face-to-face or telerehabilitation, group or individual sessions, hardware and software used, participants’ satisfaction and adverse outcomes), 5) outcomes: mean and standard deviation (SD, calculated when needed from the standard error) in each group at the last post-intervention assessment available.

Analysis

Data Synthesis

Data was pooled and mean differences (MD) between intervention and control groups were calculated using an inverse variance method. We employed a random-effect model to anticipate some heterogeneity between studies. Multi-arm studies were included and addressed with multiple pairwise comparisons, dividing the exergames group into equal groups with smaller sample size, to include two (or more) different comparisons [23]. The moderator effects of age and type of control group (active exercise or passive) were tested with fixed effect models. Post-hoc moderate effect analyses were also conducted to determine the effect of the training dose. Sensitivity analyses were performed selectively pooling: a) studies at low risk of bias in all domains in their RoB2 assessment, or having some concerns in only one domain; and b) studies with a sample size of at least 100 participants. Statistical analyses were performed using RStudio© and RevMan©.

Risk of Bias Assessment

Non-reporting biases were assessed by generating funnel plots for outcomes including 10 or more studies [23]. The risk of bias of included studies was evaluated using RoB2 which assesses the risk of bias in five domains: randomization, deviation from intended interventions, missing data, outcome measurement and selection of reported results [24]. The quality of studies was also assessed using the PEDRO scale [25]. The GRADE system was employed to assess the certainty of the overall evidence for each outcome analyzed [26]. GRADE assesses the evidence from a given set of studies as very low, low, moderate or high quality / certainty [27].

Heterogeneity Investigation

The presence of heterogeneity between included studies was assessed using the I^2 statistics [23]. If significant heterogeneity was found, we searched for an explanation based on differences in characteristics of patients or interventions applied between included studies. If the studies were found to be clinically very dissimilar, they were not statistically combined.

Subgroup Analysis

Subgroup analyses were performed with studies with a passive control group (no exercise program) compared with studies (or arms) with active control group (i.e., following an exercise program, non-assisted with exergames).

Results

Twenty-seven studies were included in the systematic review and the meta-analysis, involving 1415 participants. There were a majority of women (63.9%); mean age ranged from 65 to 85.2 years old. The inclusion process is presented in supplementary material (Figure A1). For the eligibility and the inclusion stages, the inter-rater agreements were 92.1% and 84.8% respectively. For every disagreement, the raters were able to reach an agreement without requiring a third part intervention.

Characteristics of Included Studies

A synthesis of the characteristics of the 27 included studies [15,28–53] is presented in Table 1. Details for each study, including the type of information on the sample, recruitment setting and the exergame-assisted rehabilitation program, are presented in supplementary materials (Table A1).
Insert Table 1 about here

Out of the 27 included studies, 12 studies (44.4%) had a passive controlled group [28,30,33,37,40,42,45,47,48,50,52,53], 12 (40.7%) had an active controlled group (e.g., balance training or conventional rehabilitation) [15,29,31,34–36,38,43,44,46,49,51], three had both passive and active controlled groups [32,39,41]. Interventions were individual sessions in 21 of the 27 studies (77.8%) [15,28–31,33,34,36–39,41–43,45,48–53] and groups sessions in three studies (11.1%)[32,35,40]; three studies did not provide this information [44,46,47]. Settings included individual's homes (n=2, 7.4%)[48,54], community settings (n=9, 33.3%)[29,30,33,37–39,43,45,51], outpatient rehabilitation settings (n=1, 3.7%)[53], inpatient rehabilitation settings (n=5, 18.5%)[44,46,47,55] and long term care facilities (n=1, 3.7%)[56]. Two studies (7.4%) were conducted in rehabilitation setting without specifying if there were inpatient or outpatient settings [57,58]. For one study (3.7%), the intervention was performed at the participants' convenience space[32]. Five studies (18.5%) did not specify were the intervention was set[28,34,36,40,42]. Participants' type of fall risks were: 1) history of falls resulting in serious consequences (n=1, 3.7%)[28], 2) history of falls whatever their consequences (n=2, 7.4%)[36], 3) risk of falling revealed by an assessment or presence of risk factors for falling (n=24, 88.9%) [15,29–35,37–53].

Risk of Bias Assessment

The mean PEDRO score was 6.22 /11. This score is explained by the absence of blinding of subjects and therapists in many studies, and missing information regarding the concealment of the randomization and the type of analysis (intention-to-treat or per-protocol). Among the 27 studies, 15 (55.6%) were singled blinded [15,28–31,33,36–38,43,46,47,51–53], and in 5 (18.5%) the assessor was aware of the group assigned to the participants[35,39,40,44,45].

The assessment of risk of bias according to RoB2 is presented in the supplementary materials (Table A2 and Figure A3). Most studies had some concerns in one domain, mainly related to lack of information regarding the randomization process and allocation concealment methods.

Only two studies (7.4%) reported a conflict of interest [29], 20 studies (74.1%) reported no conflict of interest [15,28,30,34–38,40–48,50] and five studies (18.5%) did not specify this element [31–33,39,49]. Only the TUG and the BBS included 10 or more studies, thus funnel plots were generated only for these two outcomes.

Effect on Fall Rate

Four studies, including 316 participants, assessed fall incidence rate [28,29,31,43]. All of the included studies showed some concerns for bias in one or more domains, but none was serious. Overall, we assessed the evidence available for this outcome as of moderate certainty.

The mean intervention duration was 9.0 weeks (SD = 3.5). Exergame-assisted rehabilitation was significantly associated with a reduction in the fall incidence (MD = -0.91 falls per person/year; 95% CI: -1.65 to -0.17, p =0.02) (Figure 1). There was a significant heterogeneity between studies (I^2 = 97%).

Insert Figure 1

The type of control group (active or passive), the age of participants and the length of the intervention did not show any significant moderator effect on fall rates.

Effect on Risk of Falling

Regarding risk of falling, rehabilitation assisted with exergames showed an improvement in all scores analyzed, TUG, BBS and OLS, with the only exception of SPPB, for which no effect appeared in the meta-analysis.

a) Short-Physical Performance Battery (SPPB) score

Seven studies, cumulating 441 participants, assessed the SPPB score [15,35,39,41,44,46,52]. Regarding their risk of bias, 4 of the 7 included studies have some or serious concerns regarding allocation concealment or blinding. Overall, we considered this group of studies as low-quality evidence.

The mean intervention duration was 9.7 weeks (SD = 7.6). Exergame-assisted rehabilitation showed no effect on the SPPB score (MD = + 0.74 points; 95% CI: -0.12 to 1.60, p= 0.09) (Figure 2). There was heterogeneity between studies (I^2 =85%).

Insert Figure 2

b) Test Up and Go (TUG)

Sixteen studies, cumulating 675 participants, assessed TUG [15,30,32–34,36,37,39,41–43,47–49]. Regarding their risk of bias, most of the included studies have some concerns in at least one domain, especially regarding allocation concealment during the randomization process (Table A2 and Figure A3). The funnel plot showed no significant selection bias (test for asymmetry: z= -1.6665, p=0.09) (supplementary material, Figure A1). Overall, we considered this group of studies as low-quality evidence.

The mean intervention duration was 8.3 weeks (SD = 4.3). Exergame-assisted rehabilitation showed a positive effect on the TUG (MD = -1.46 seconds; 95% CI: -2.21 to -0.71, p=0.0001) (Figure 3). There was heterogeneity between studies (I^2 =65%).

Insert Figure 3

The type of control group had a significant moderator effect on the TUG score (p=0.0005): the effect was more pronounced when the control group was passive (MD -1.76, p<0.0001). However, the age and the length of the intervention did not have a significant moderator effect.

c) One-Leg Stance

Seven studies, cumulating 252 participants, assessed the OLS [33,36,38,41,42,47,48]. Most of the included studies for the OLS showed low risk of bias in all domains, except for the randomization process, where some risks were identified in most of the studies (Table A2). We considered this group of studies as moderate quality evidence.

The mean intervention duration was 9 weeks (SD = 2.9). Exergame-assisted rehabilitation showed a positive effect on OLS test (MD = + 7.09 seconds; 95% CI: 4.21 to 9.98, p<.00001) (Figure 4). There was no heterogeneity between studies (I^2 =0.00%).

Insert Figure 4

The type of control group, the participants' age and the length of the intervention did not have a significant moderator effect.

d) Berg Balance Scale (BBS)

Eleven studies, cumulating 601 participants, assessed the Berg Balance Scale [15,29,33,36,38,42,45,47,49–51,53]. Most of the included studies showed some concerns on the randomization process (supplementary materials, Table A2 and Figure A3). The funnel plot showed no significant selection bias: z= 0.8309, p=0.4060 (supplementary material, Figure A2). We considered this group of studies as moderate quality evidence.

The mean intervention duration was 7.5 weeks (SD = 3.47). Exergame-assisted rehabilitation showed a positive effect on BBS score (MD = + 2.85 points; 95% CI: 1.27 to 4.43, p=0.0004) (Figure 5). There was heterogeneity between studies (I^2 =76%).

Insert Figure 5

The type of control group, the age and the length of the intervention did not have a significant moderator effect.

Effect on fear of falling

a) Falls Efficacy Scale (FES-I)

Four studies, cumulating 255 participants, assessed the FES-I [29,35,36,44]. All included studies showed some concerns or high risks regarding the randomization process and half of them showed some concerns for deviation from intervention (Table A2). Overall, we considered this group of studies as very low-quality evidence.

The mean intervention duration was 10.0 weeks (SD = 9.7). Exergame-assisted rehabilitation showed no significant effect on the FES-I score (MD = + 0.39 points; 95% CI: -0.70 to 1.49, p=0.48) (Figure A4).

b) Activities-Specific Balance Confidence (ABC) Scale

Three studies, cumulating 151 participants, assessed the ABC Scale [15,32,45]. They showed a low risk on all the RoB2 domains except for randomization where one study fell into each category (low risks, some risks and high risks) (Table A2). We considered this group of studies as moderate quality evidence.

The mean intervention duration was 7.2 weeks (SD = 6.9). Exergame-assisted rehabilitation showed a positive effect on the ABC scale (MD = +5.00 points; 95% CI: -1.17 to 11.17, p= 0.11) (Figure A5). However, this result was not statistically significant and the confidence interval included the possibility of no effect or a slight negative effect. There was no heterogeneity between studies (I^2 =0.00%). The age of the participants and the length of the interventions did not have any moderator effect. The moderator effect of the type of group could not be calculated due to the small number of studies included.

Sensitivity Analyses

No study included 100 or more participants; thus, sensitivity analyses were performed only selectively pooling studies at low risk of bias in all domains, or having some concerns in only one domain at RoB2 assessment. Sensitivity analyses revealed similar yet not significant results for fall incidence (MD = – 0.54; 95% CI: -1.404 to 0.34, p= 0.232), SPPB (MD= + 1.05; 95% CI: -0.66 to 2.76, p= 0.227), BBS (MD = + 4.01; 95% CI: -0.26 to 8.27, p= 0.065) and TUG (MD = -0.98; 95% CI: -1.67 to -0.29, p= 0.0051). For FES-I, results were still not significant. For OLS, sensitivity analyses revealed significant better results in the exergame group (MD = + 7.16; 95% CI: 2.23 to 12.12, p= 0.0045). Regarding ABC, sensitivity analyses could not be performed because only one study remained when removing studies with some concerns in more than one domain.

Other outcomes

Only two studies assessed adherence, with contradictory results: Fang et al. found that exergames facilitated engagement [14], while Perrochon et al. found a higher dropping rate in the exergame group, compared to controls [11]. Seven studies assessed participants' satisfaction regarding exergames and all reported positive results [27,29–33,38].

Discussion

Overall, this systematic review finds evidence suggesting that exergames in rehabilitation programs for older adults at risk of falling may reduce fall rates and improve several scores measuring risk of falling, regardless of their baseline condition. Compared with other meta-analyses, the present study includes more studies and deals with various aspects of fall risk, including the actual fall rate and the fear of falling. However, the evidence currently available is not completely conclusive: most studies included few participants, quality of included studies is low to moderate, there is significant heterogeneity between studies – caused by the diversity of participants, setting and type and duration of exergames employed – and the effect observed in fall rates does not remain significant in sensitivity analysis. The heterogeneity of participants might explain the lack of significant results for some outcomes. Altogether, that indicates that more research is needed.

Other meta-analyses studied, though less comprehensively, the effect of exergaming on risk of falling. The study of Fang et al. (2020) explored the impact of exergames on healthy older adults' balance [17]. They did not evaluate the OLS, the SPPB, or fall rates [17]. Their meta-analysis showed no significant improvement on static balance. However, in concordance with our results, they detected an improvement on more advanced balance control tests like the TUG. We found in this systematic review that exergames-assisted programs also improved BBS and OLS, other scores measuring the risk of falling. Regarding the results on the SPPB, our study converges with the results of Choi et al., (2017)'s review, which could not conclude on whether or not exergames were more effective than conventional rehabilitation[18].

No other meta-analysis, to the best of our knowledge, studied the effect of exergames on fall rates. In our meta-analysis, exergame-assisted rehabilitation programs were significantly associated with a reduction in the fall incidence over a period of time ranging from three to 12 months after the beginning of the rehabilitation program. These results suggest that the effect of exergames to prevent falls persists after the end of the rehabilitation. This result should be confirmed in further RCTs.

Our meta-analysis found no significant improvement in scores measuring the fear of falling. These results differ from those obtained in the meta-analysis of Kendrick et al., (2014), who found that exercise-based interventions lead to a small to moderate reduction in fear of falling [59]. This difference is probably explained because Kendric et al. included studies assessing any kind of exercise intervention and not limited to exergames.

Implications for Practice

The improvements found in this meta-analysis are small. It has been suggested that, to be clinically meaningful, an improvement on the OLS should be of at least 24.1 seconds [60]. Likewise, the study of Thrane et al. (2007) shown that to be clinically meaningful, an improvement on the TUG should be of at least 1.9 seconds among male older adults [61]. The improvement found in our meta-analysis (MD = -1.46 seconds) approaches this threshold but does not reach it. For the BBS, the present meta-analysis demonstrated a positive effect of exergames (MD = 2.6 points). However, to be clinically meaningful, it has been suggested that changes should be of at least 6.5 on the total score [62].

The small improvement in scores measuring risk of falling contrasts with our finding of an actual reduction in the incidence of falls. Although small, this reduction in fall incidence should not be disregarded, since a single fall can have serious consequences for older adults. Thus, though the observed effects in risk of falling scores are small and under the theoretical threshold for clinical relevance, they point to an improvement translated in a reduction in the number of falls.

Mean duration of the exergame interventions in studies included in our review was 8.4 weeks with an average of 2.6 sessions of 45 minutes per week. The study of Lesinski et al., (2015) found that the optimal balance training in healthy older adults should be for 11 to 12 weeks with three sessions of 31 to 45 min a week [63]. However, these recommendations cannot be applied to all rehabilitation settings and the duration of rehabilitation varies largely in different countries, between 3-4 weeks and up to 12 weeks. Interventions in many of the included studies were shorter than Lesinski's recommendation; this might explain why improvements were noted for some of the outcomes only.

Study Limitations

This study presents some limitations. The search in the databases was completed in June 2021; given the rapid changing nature of this topic, we believe that the results may evolve over time and that future meta-analyses should include more recent studies. The search excluded studies published in languages other than English or French, which represents a potential restriction in study inclusion. Additionally, the interpretation of the results must consider the important heterogeneity observed between studies in most outcomes, which is not imputable to one particular study. Heterogeneity between studies has also been highlighted in other meta-analysis on exergames and fall prevention among older adults [14,17,64]. It is probably explained by differences regarding the type of participants included and the exergame programs applied. Participants were included from diverse settings (e.g., living independently, nursing homes) and probably had different functional status and risk of falling at their inclusion. Likewise, the interventions applied – exergames and concomitant rehabilitation programs – differed in terms of length, frequency and types. For instance, the type of control group, whether active or passive, had a moderator effect on the BBS and SPPB scores. Consequently, it is not sure that the findings could be applied to all subgroups of older adults or to all types of exergames. Further studies on exergame-assisted rehabilitation programs are needed to better define the participants are more likely to benefit, as well as which are the best programs and way of implementing them.

Finally, despite selecting only RCTs, the overall quality of the studies included was suboptimal, due to the absence of double-blinding and lack of information on details of the randomization process, especially on allocation concealment. Even if blinding is challenging in rehabilitation research, it is important that future studies on exergame-assisted rehabilitation improved the randomization and blinding methods.

Conclusion

In this systematic review, which included 27 RCTs cumulating 1415 participants, we found moderate quality evidence of a reduction in the fall rate with exergames-assisted rehabilitation (four studies with 316 participants assessed this outcome), and low-quality evidence suggesting a mild reduction of the risk of falling, in older adults at risk. The effect of exergames on the fear of falling, however, was uncertain.

These results are not conclusive, given the small number of studies and participants available for each outcome, and the heterogeneity between studies. Further high-quality RCTs are needed to better define the effectiveness of exergames in preventing falls and reducing the fear of falling in this population.

Statements

Statement of Ethics

An ethics statement is not applicable because this study is based exclusively on published studies that received informed consent from their respective participants. We conducted this systematic review following the PRISMA guidelines (see PRISMA 2020 in supplementary material for abstract checklist). The study protocol is registered in the PROSPERO database (CRD42021237667).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Nolwenn Lapierre: conceptualization, methodology, investigation, data curation, formal analysis, and writing – original draft. Nathavy Um Din: investigation, data curation, supervision, and writing – review and editing. Joël Belmin.: conceptualization, methodology, investigation, supervision, and writing – review and editing. Carmelo Lafuente-Lafente.: conceptualization, methodology, investigation, supervision, and writing – review and editing.

Data Availability Statement

All data generated or analyzed during this study are included in this article and its supplementary material files. Further enquiries can be directed to the corresponding author.

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Figure Legends

Fig. 1. Forest Plot: Effect of exergames on fall incidence.

Notes: Fall incidence rate is given as the mean number of falls per patient at three to 12 months follow-up. A negative mean difference means a reduction in fall incidence in the exergames group.

Fig. 2. Forest plot for SPPB score.

Fig. 3. Forest plot for the Timed up and go. Notes: A reduction in the score of the Timed Up and Go means a reduction in fall risk, thus a negative mean difference means a reduction in fall risks in the exergame group.

Fig. 4. Forest plot for the One-leg stance.

Fig. 5. Forest plot for the BBS score.

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