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Effects of Exergaming on Frailty: A Systematic Review and Meta-Analysis

Lily Yuen Wah Ho[1] | Jodie Hau Yi Tse[1] | Wayne Lap Sun Chan[2] | Daphne Sze Ki Cheung[1,3,4]

[1]School of Nursing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR | [2]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR | [3]School of Nursing and Midwifery, Faculty of Health, Deakin University, Burwood, Melbourne, Victoria, Australia | [4]Centre for Quality and Patient Safety Research/Alfred Health Partnership, Institute for Health Transformation, Deakin University, Burwood, Melbourne, Victoria, Australia

Correspondence: Lily Yuen Wah Ho (lily.yw.ho@polyu.edu.hk)

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ABSTRACT

Aim: To evaluate the effects of exergaming on physical frailty in older adults.

Design: Systematic review with meta-analysis.

Methods: Six electronic databases were searched for randomised controlled trials evaluating the effects of exergaming on frailty in older adults. Data were synthesised using narrative synthesis and meta-analysis. The risk of bias and the certainty of the evidence were assessed.

Data Sources: CINAHL, Cochrane Library, Embase, PubMed, Web of Science, and China Academic Journal Network Publishing Database were searched from their inception through February 2024.

Results: Five studies ($n = 391$) were included. Exergaming, which was delivered in 20–36 sessions over 8–12 weeks, resulted in improvements in frailty scores and indices, frailty status, and frailty phenotypes, including exhaustion, low physical activity levels, gait speed, and muscle weakness over time. There was no effect on unintentional weight loss. Meta-analyses showed that the effects of exergaming were not significantly different from those observed in the control groups. The rate of adherence to the intervention of the exergaming group was slightly higher than that of the comparison group (87.3%–87.7% vs. 81.1%–85.4%). The overall risk of bias was high in all studies. The certainty of the evidence was very low.

Conclusion: Exergaming exerts effects on frailty comparable to those of conventional physical exercises. Participants appeared to have better adherence to exergaming. Future studies with robust designs are warranted.

Implications for the Profession and/or Patient Care: With effects comparable to those of conventional physical exercises, exergaming could be considered in clinical settings to address frailty.

Impact: This review addressed the effects of exergaming on frailty instead of physical outcomes. Exergaming was comparable to conventional physical exercises in improving frailty scores and indices, frailty status, and four frailty phenotypes. The findings provide insights to healthcare providers on the design of exergames.

Reporting Method: PRISMA guidelines.

Protocol Registration: PROSPERO number: CRD42023460495.

Patient or Public Contribution: No Patient or Public Contribution.

Summary

- What does this paper contribute to the wider global clinical community?
  - Exergaming led to improvements in frailty scores and indices, frailty status, and frailty phenotypes (including exhaustion, low physical activity levels, gait speed, and muscle weakness) over time, and the effects were comparable to those of conventional physical exercises.
  - Exergames need to consist of several types of exercise to act on the physical components of frailty.
  - Exergaming alone may not be effective at preventing unintentional weight loss, and additional interventions may be necessary.

1 | Introduction

With rapidly ageing populations, frailty is becoming an important concern. Fried et al. (2001) defined physical frailty as a clinical syndrome that is characterised by the presence of three or more of the following features: self-reported exhaustion, low physical activity levels, slow gait speed, weakness (grip strength), and unintentional weight loss. Internationally, physical frailty has been defined in a consensus statement as "a medical syndrome with multiple causes and contributors that is characterized by diminished strength, endurance, and reduced physiologic function that increases an individual's vulnerability for developing increased dependency and/or death" (p. 393) (Morley et al. 2013). Recently, a meta-analysis showed that the pooled prevalence of physical frailty and prefrailty was 12% and 46%, respectively, in adults aged ≥ 50 (O'Caoimh et al. 2021). A cross-sectional study of community-dwelling adults aged ≥ 60 reported that 22.1% were classified as frail and 45.6% as prefrail (Kwan et al. 2019). Frailty increases the risk of mortality by 1.8–2.3 times, loss of activities of daily living by 1.6–2.0 times, hospitalisation by 1.2–1.8 times, physical limitation by 1.5–2.6 times, and falls and fractures by 1.2–2.8 times in adults aged ≥ 65 (Vermeiren et al. 2016).

Frailty is reversible. A scoping review showed that 9.4%–32.8% of older adults improved in frailty status, while 11.0%–34.0% worsened over 2–6.4 years (Ho et al. 2021). One key strategy for reversing the progression of frailty is to promote physical activity (Cheung et al. 2020), which is any movement of the body generated by skeletal muscles (Dasso 2019) with energy consumption of > 1.5 metabolic equivalents (Falck et al. 2023). A subcategory of physical activity, exercise is planned, structured, and repetitive, with the goal of improving or maintaining physical fitness (Dasso 2019). According to the International Conference on Frailty and Sarcopenia Research task force (Dent et al. 2019), a physical activity programme with multiple types of exercises is a first-line therapy for physical frailty. A randomised controlled trial found that physical exercise was 4 times more likely to reduce frailty in prefrail and frail older adults than in the control group (Ng et al. 2015). Physical exercises can improve frailty by exerting positive effects on skeletal muscles and cardiovascular, respiratory, and metabolic systems through decreasing age-related oxidative damage and chronic inflammation, increasing autophagy, improving mitochondrial function, and increasing insulin sensitivity (Angulo et al. 2020).

Exergaming appears to be superior to conventional physical exercises (Chen et al. 2021). Exergaming is a physical activity that requires players to do physical exercises to play a video game (American College of Sports Medicine 2013). Exergaming interventions can improve upper limb muscle strength and aerobic endurance in older adults (De Queiroz et al. 2017). It can also improve balance when compared with the usual care (Chan et al. 2023). The use of exergaming is increasing because exergaming is enjoyable and provides the motivation to increase physical activity levels (Chan et al. 2024; Pacheco et al. 2020). Exergaming is acceptable to older adults, offers multisensory feedback and opportunities for repetitive practice, and promotes positive behavioural changes and adherence to exercise (Manser, Herold, and de Bruin 2024). A systematic review showed that the median adherence rate to technology-based exercise programmes was 91.3% – higher than that found in conventional exercise programmes (median 83.6%; Valenzuela et al. 2018).

Previous systematic reviews have reported that exergaming has positive effects on individual physical outcomes for older adults, such as postural control (Chen et al. 2021), balance (Chen et al. 2021; Fang et al. 2020; Pacheco et al. 2020; Zheng et al. 2020), gait speed (Suleiman-Martos et al. 2022), and mobility (Janhunen et al. 2021; Pacheco et al. 2020; Suleiman-Martos et al. 2022; Zheng et al. 2020). However, while exergaming might have positive effects on individual physical outcomes, it cannot be assumed that it also has positive effects on physical frailty. This is because physical frailty is not merely a physical outcome but a syndrome that is characterised by a decline in various physical functions. Therefore, whether exergaming is effective at combating physical frailty has yet to be systematically reviewed.

2 | Aim

The aim of this systematic review and meta-analysis was to evaluate the effect of exergaming on preventing the worsening of physical frailty and promoting its reversal in robust, prefrail, or frail older adults.

3 | Methods

3.1 | Search Strategy

The protocol of this review was registered with the Prospective Register of Systematic Reviews (PROSPERO). This review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist (Page et al. 2021). Originally, five electronic databases (CINAHL, Cochrane Library, Embase, PubMed, and Web of Science) were searched from their inception through February 2024. After registering the review protocol, the China Academic Journal Network Publishing Database (CNKI) was added to increase the chances of identifying relevant articles. Keywords and MeSH terms for population (aged [MeSH] OR elder* OR "older adult*" OR "older people"), intervention (exergaming [MeSH] OR exergam* OR kinect OR Nintendo OR "computer feedback training" OR "video games" [MeSH] OR video-gam*

OR "virtual reality" [MeSH] OR "virtual realit*" OR Wii), and outcome (frailty [MeSH] OR frail*) were used in the search (Appendix A). Backward and forward citations were screened, and clinical trial registries were also searched.

3.2 | Eligibility Criteria

During the procedure of screening titles, abstracts, and full texts, studies were selected based on the following eligibility criteria.

3.2.1 | Participants

In this systematic review, we included older adults, defined by the United Nations as aged 60 or above (United Nations High Commissioner for Refugees 2024), in any state of frailty and regardless of the presence or absence of other comorbidities.

3.2.2 | Interventions

Exergaming is a physical activity that requires players to do physical exercises to play a video game (American College of Sports Medicine 2013). It can be of any type and any format. Excluded were studies in which exergaming was combined with other interventions, such as nutritional interventions.

3.2.3 | Comparators

The comparators could be any intervention without exergaming, including conventional physical exercises without game components, the usual care, a waiting list control, or no treatment.

3.2.4 | Outcomes

Studies in which physical frailty was measured using a validated frailty phenotype scale such as Fried's frailty phenotype (Fried et al. 2001) or a frailty index were included.

3.2.5 | Types of Studies

Only randomised controlled trials were included.

3.3 | Study Selection

To remove duplicates, all articles were imported into EndNote 21. The titles and abstracts of all studies were screened for eligibility. Full texts were retrieved and screened for relevant studies. Two reviewers (LH and JT), working independently, selected the articles. During the screening procedures, studies were included only when they fit the eligibility criteria on participants, interventions, comparators, outcomes, and types of studies. The inter-rater agreement in terms of the kappa statistic was 1.0, which was calculated using the formula, $(p_o - p_e)/(1 - p_e)$, where p_o was relative observed agreement amongst raters and p_e was hypothetical probability of chance agreement.

3.4 | Data Extraction

Data were extracted independently by two reviewers (LH and JT) using Microsoft Excel. The data extracted included study region, sample size, setting, participant characteristics, intervention characteristics (duration of the programme, duration of each session, frequency of the intervention, and exercise intensity and density [between-session recovery time]), comparators, scales for measuring frailty, effect on frailty, data collection time points, adverse events, attendance adherence, and attrition rate. Whenever possible, study authors were contacted through email twice for any required missing data. The inter-rater agreement in terms of the kappa statistic was 1.0. The extracted data were reported in tables and in the form of a narrative synthesis.

3.5 | Data Analysis

A meta-analysis was conducted using Review Manager 5.4.1 (RevMan) when data from two or more separate studies were available (Deeks, Higgins, and Altman 2023). In the absence of the required information in all trials to calculate the standard deviations for the within-group changes over time, it is suggested that the values should not be imputed (Higgins, Li, and Deeks 2023). Therefore, data were taken from post-intervention measurements. The standardised mean difference (SMD) with a 95% confidence interval (CI) was reported for frailty scores or indices. The risk ratio (RR) with a 95% CI was reported for frailty phenotypes. Heterogeneity was assessed using I^2 statistics. A random-effects model was used because intervention effects vary across studies. Publication bias was assessed using a fail-safe N analysis to determine the number of additional negative studies required to make a p-value non-significant.

3.6 | Risk of Bias and Certainty of the Evidence

The risk of bias and certainty of the evidence were assessed by two independent reviewers (LH and JT). The risk of bias was assessed using the Cochrane risk-of-bias tool for randomised trials (RoB 2; Higgins et al. 2019), which covers the randomisation process, deviations from the intended interventions, missing outcome data, outcome measurements, and the selection of the reported result. Each study was judged to be at a "low risk of bias" or "high risk of bias", or as raising "some concerns". The certainty of the evidence was assessed using the online GRADEpro software (https://www.gradepro.org/). The inter-rater agreement in terms of a kappa statistic was 1.0. The results are reported in the tables.

4 | Results

4.1 | Study Selection

A total of 953 records were retrieved. After removing duplicates, screening titles and abstracts, and assessing the eligibility of the reports, five studies published in six reports fulfilled the criteria for inclusion in this review. Two of the six reports came from the same study. Frailty was the primary outcome in one study (Biesek et al. 2021) and a secondary outcome in another (Melo Filho et al. 2022). Data were thus collected from Biesek et al.'s study (2021) in this review. A PRISMA flow diagram (Figure 1) shows the study selection process.

4.2 | Study Characteristics

The five studies included 391 older adults with a mean age of 70.40–85.05 years. The characteristics of each study are summarised in Table 1. In two studies, prefrail older adults were recruited from the community (Biesek et al. 2021; Moreira et al. 2021). In two other studies, both prefrail and frail older adults were recruited from nursing homes and/or day care centres (González-Bernal et al. 2021; Liao, Chen, and Wang 2019). One did not specify the frailty status, and participants were recruited from day care centres and memory clinics (Karssemeijer et al. 2019). One study specifically recruited participants with dementia (Karssemeijer et al. 2019), while particular disease groups were not specified in the remaining studies. Fried's frailty phenotype was used to assess frailty in four studies (Biesek et al. 2021; González-Bernal et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021), while the Evaluative Frailty Index for Physical Activity was used in one study (Karssemeijer et al. 2019). All studies measured frailty before and after the intervention.

Regarding the exergames, a combination of different types of physical exercises with a game platform was used in four studies (Biesek et al. 2021; González-Bernal et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021), while in one study a stationary bike was connected to a video screen (Karssemeijer et al. 2019). According to the Position Stand of the American College of Sports Medicine (Garber et al. 2011), exercise intensity ranged from low to vigorous in three trials (Karssemeijer et al. 2019; Liao, Chen, and Wang 2019; Moreira et al. 2021). Authors of all trials were contacted for information about density. One replied with a between-session recovery time of 2–3 days (Moreira et al. 2021). The exergaming interventions consisted of 20–36 sessions. The intervention duration ranged from 8 to 12 weeks. Each session ranged from 30 to 60 min. Details are shown in Table 1.

Comparison groups varied amongst the studies. Three studies adopted an active control group (Karssemeijer et al. 2019; Liao, Chen, and Wang 2019; Moreira et al. 2021). One study compared exergaming with conventional physical treatments and therapies, which were also offered to the exergaming group (González-Bernal et al. 2021). The remaining study only adopted usual activities as the comparison group (Biesek et al. 2021; Table 1).

4.3 | Risk of Bias and Certainty of the Evidence

The overall risk of bias was high in the included studies (Table 2). In the randomisation process, "some concerns" were expressed in all studies because information about the concealment of the allocation sequence was unavailable.

In deviations from the intended interventions, "some concerns" were expressed in two studies (González-Bernal et al. 2021; Karssemeijer et al. 2019) using intention-to-treat analysis because of inadequate information on deviations from the intended intervention. The remaining three studies (Biesek et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021) using per-protocol analysis were judged as being of "high risk" because deviations from the intended intervention were likely to have affected the outcome.

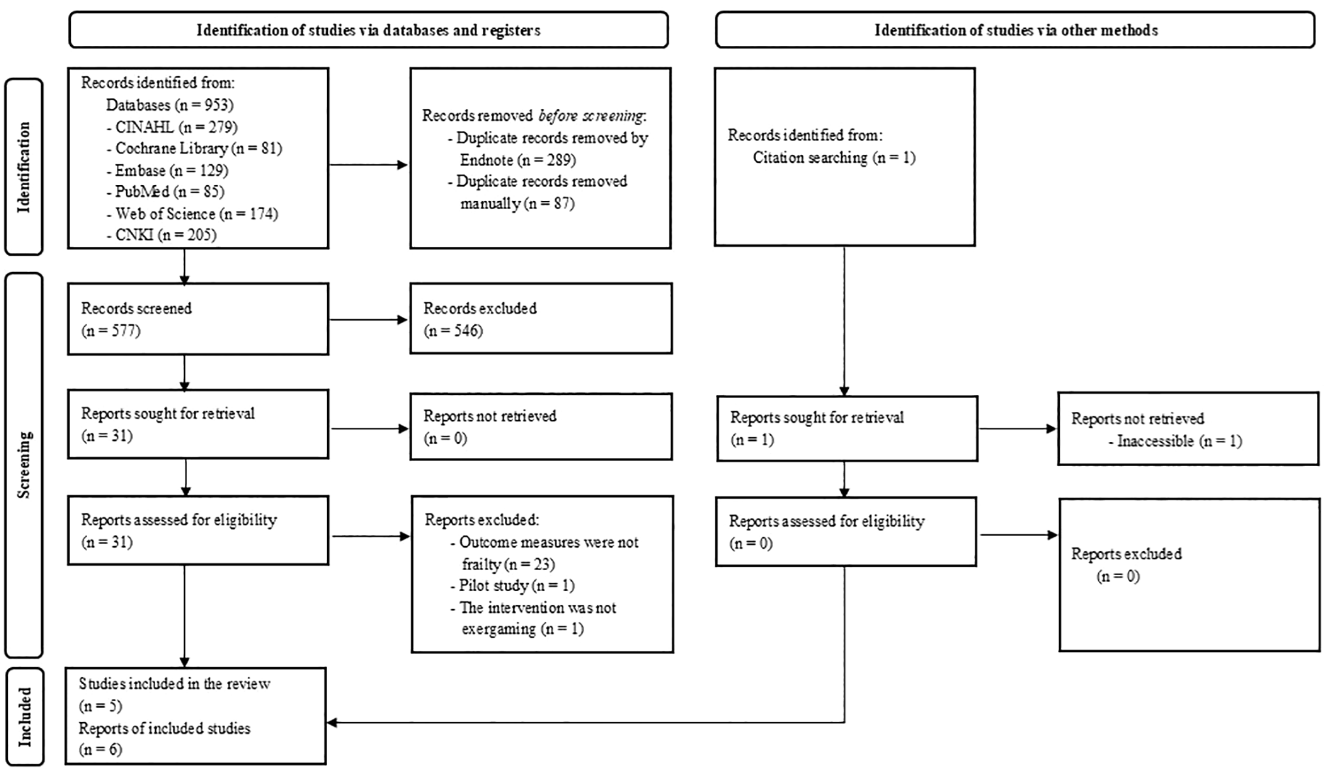

FIGURE 1 | PRISMA flow diagram.

TABLE 1 | Summary of the study characteristics of the included studies.

Author	Study region	Number of participants at baseline (intervention/control group)	Settings	Participant characteristics • Age: mean ± SD • Proportion of women: *n* (%)	Intervention • Duration of the programme • Duration of each session • Frequency	Comparator • Duration of the programme • Duration of each session • Frequency	Scale for measuring frailty	Adherence rate	Attrition rate
Biesek et al. (2021)	Brazil	18/18	Community	Prefrail community-dwelling women. Intervention group • Age: 71.20 ± 4.20 • Women: 18 (100.0%) Control group • Age: 70.40 ± 3.90 • Women: 18 (100.0%)	Warm-up, neuromotor, and resistance exercises (vest load progressively increased with an additional 1%–2% of body mass every 2 weeks) and cooling down via Nintendo Wii Fit Plus using the Balance platform • 12 weeks • 50 min • 2 sessions/week	Keeping usual activities • 12 weeks • NA • NA	Fried's frailty phenotype	EG: 87.7% CG: NA	EG: 33.3% CG: 33.3%
González-Bernal et al. (2021)	Spain	40/40	Day care centre and nursing home	Prefrail and frail adults. Intervention group • Age: 85.05 ± 8.63 • Women: 22 (55.0%) Control group • Age: 83.25 ± 8.78 • Women: 23 (57.5%)	Conventional physical treatments and therapies plus balance, gait, stability, and aerobic exercises, and muscle stretching via Nintendo Wii Fit • 8 weeks, total 20 sessions • 40 min • 2 and 3 sessions/week alternately	Conventional physical treatments and therapies • 8 weeks • NA • NA	Fried's frailty phenotype	EG: NA CG: NA	EG: 0% CG: 0%

(Continues)

TABLE 1 | (Continued)

Author	Study region	Number of participants at baseline (intervention/control group)	Settings	Participant characteristics • Age: mean ± SD • Proportion of women: *n* (%)	Intervention • Duration of the programme • Duration of each session • Frequency	Comparator • Duration of the programme • Duration of each session • Frequency	Scale for measuring frailty	Adherence rate	Attrition rate
Karssemeijer et al. (2019)	The Netherlands	38/38 (control group 1)/39 (control group 2)	Memory clinics and day care centres	People with dementia. Intervention group • Age: 79.00 ± 6.90 • Women: 18 (47.4%) Control group 1 • Age: 80.90 ± 6.10 • Women: 17 (44.7%) Control group 2 • Age: 79.80 ± 6.50 • Women: 18 (46.2%)	Cognitive-aerobic bicycle training (65%-75% of heart rate reserve) on a stationary bike connected to a video screen • 12 weeks • 30 min • 3 sessions/week	Control group 1: Aerobic bicycle training on a stationary bike • 12 weeks • 30 minutes • 3 sessions/week Control group 2: Relaxation and flexibility exercises • 12 weeks • 30 min • 3 sessions/week	Evaluative Frailty Index for Physical Activity	EG: 87.3% CG1: 81.1% CG2: 85.4%	EG: 10.5% CG1: 13.2% CG2: 12.8%
Liao, Chen, and Wang (2019)	Taiwan	31/30	Day care centres	Prefrail and frail adults. Intervention group • Age: 79.60 ± 8.50 • Women: 19/27 (70.4%) Control group • Age: 84.10 ± 5.50 • Women: 17/25 (68.0%)	Tai Chi, resistance (gradually increasing from 1.1 kg to 3.1 kg), aerobic (50%–75% of the maximal heart rate with the ideal perceived exertion score of 13–14), and balance exercises by Kinect systems • 12 weeks • 60 min • 3 sessions/week	Resistance, aerobic, balance exercises • 12 weeks • 60 min • 3 sessions/week	Fried's frailty phenotype	EG: NA CG: NA	EG: 12.9% CG: 16.7%

(Continues)

TABLE 1 | (Continued)

Author	Study region	Number of participants at baseline (intervention/control group)	Settings	Participant characteristics • Age: mean ± SD • Proportion of women: *n* (%)	Intervention • Duration of the programme • Duration of each session • Frequency	Comparator • Duration of the programme • Duration of each session • Frequency	Scale for measuring frailty	Adherence rate	Attrition rate
Moreira et al. (2021)	Brazil	49/50	Community	Prefrail adults. Intervention group • Age: 70.84 ± 4.53 • Women: 49 (100%) Control group • Age: 70.76 ± 5.60 • Women: 50 (100%)	Warm-up, strengthening (with gradual weight increment), balance and cardiorespiratory exercises and cooling down (Borg Rating of Perceived Exertion scale score of 10–15) by Xbox 360 with Microsoft Console and Kinect. Exercise was progressively increased by increasing the number of repetitions. • 12 weeks • 50 min • 3 sessions/week	Warm-up, strengthening, balance, and cardiorespiratory exercises, and cooling down • 12 weeks • 50 min • 3 sessions/week	Fried's frailty phenotype	EG: NA CG: NA	EG: 34.7% CG: 32.0%

Abbreviations: CG, control group; EG, exergaming group; NA, not applicable; SD, standard deviation.

TABLE 2 | Risk of bias of each study.

Study	Randomisation process	Deviations from the intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
			Intention-to-treat analysis			
González-Bernal et al. (2021)	Some concerns	Some concerns	Low risk	High risk	Some concerns	High risk
Karssemeijer et al. (2019)	Some concerns	Some concerns	Low risk	High risk	Low risk	High risk
			Per-protocol analysis			
Biesek et al. (2021)	Some concerns	High risk	High risk	High risk	High risk	High risk
Liao, Chen, and Wang (2019)	Some concerns	High risk	Low risk	High risk	Some concerns	High risk
Moreira et al. (2021)	Some concerns	High risk	High risk	High risk	Some concerns	High risk

Regarding missing outcome data, three studies (González-Bernal et al. 2021; Karssemeijer et al. 2019; Liao, Chen, and Wang 2019) were judged as being of "low risk". The remaining two (Biesek et al. 2021; Moreira et al. 2021) were judged as being of "high risk" because more than 5% of the outcome data were missing, likely related to the health status of the participants, and that might have had some impact on the effect of the intervention.

In measuring the outcome, all studies were judged as being of "high risk" (Biesek et al. 2021; González-Bernal et al. 2021; Karssemeijer et al. 2019; Liao, Chen, and Wang 2019; Moreira et al. 2021) because frailty was assessed using a patient-reported outcome measure, which could be influenced by the participants' knowledge of the intervention.

In selecting the reported result, one study (Karssemeijer et al. 2019) was judged as being of "low risk". "Some concerns" were expressed in three studies (González-Bernal et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021) because a pre-specified statistical plan was not available. The remaining study (Biesek et al. 2021) was judged as being of "high risk" because of inconsistencies with the protocol (Vojciechowski et al. 2018). The certainty of the evidence was rated as very low (Table 3).

4.4 | Effect of Exergaming

4.4.1 | Frailty Score or Index

Two studies evaluated the effect of exergaming on frailty scores or indices (Karssemeijer et al. 2019; Liao, Chen, and Wang 2019; Table 4). Exergaming led to improvements in frailty scores and indices after the intervention, but the improvement was not significantly different from that observed amongst the active control. Liao et al.'s study (2019) showed that both the exergaming group and the control group (who took part in a combination of physical exercises) experienced a significant improvement in frailty scores, but there was no significant difference between the groups. Karssemeijer et al. (2019) found that the reduction in the frailty index in the exergaming group was significant in relation to the group with relaxation and flexibility exercises but not in relation to the aerobic training group. The meta-analysis shows that exergaming had a positive effect on frailty in the intervention group in relation to the control group, but the effect was insignificant (SMD = −0.1, 95% CI = −0.41 to 0.22, $p = 0.55$, $I^2 = 0\%$, df = 2, $p = 0.87$, Figure 2).

4.4.2 | Frailty Status

Four studies evaluated the effect of exergaming on frailty status (Biesek et al. 2021; González-Bernal et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021; Table 4). Two of them showed that exergaming improved frailty status when compared with the usual care or treatment (Biesek et al. 2021; González-Bernal et al. 2021). The remaining two studies showed that exergaming had comparable effects to the active control on frailty status (Liao, Chen, and Wang 2019; Moreira et al. 2021). However, the level of significance was not reported in Moreira et al.'s study (2021).

4.4.3 | Frailty Phenotype

Three studies evaluated the effect on each frailty phenotype after the intervention (Biesek et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021; Table 4). Exergaming significantly reduced the proportion of older adults with exhaustion, but this was not the case for the groups that received a combination of exercises (Liao, Chen, and Wang 2019) or the usual care (Biesek et al. 2021). Although the proportion of older adults with exhaustion was greatly reduced in the exergaming group in Moreira et al.'s study (2021), a statistical difference between the groups was not reported. The meta-analysis shows that exergaming had no effect on exhaustion

TABLE 3 | GRADE certainty of the evidence.

Certainty assessment							No. of patients		Effect		
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Exergaming	Control	Relative (95% CI)	Absolute (95% CI)	Certainty
Frailty score											
2	Randomised trials	Very serious[a]	Not serious	Not serious	Serious[b]	None	65	102	—	SMD 0.1 lower (0.41 lower to 0.22 higher)	⨁◯◯◯ Very low
Exhaustion											
3	Randomised trials	Very serious[a]	Serious[c]	Not serious	Serious[b]	None	15/74 (20.3%)	21/74 (28.4%)	RR 1.01 (0.22–4.53)	Two more per 1000 (from 158 fewer to 716 more)	⨁◯◯◯ Very low
Low physical activity levels											
3	Randomised trials	Very serious[a]	Not serious	Not serious	Serious[b]	None	10/74 (13.5%)	9/74 (12.2%)	RR 1.08 (0.52–2.25)	Ten more per 1000 (from 58 fewer to 152 more)	⨁◯◯◯ Very low
Weakness											
3	Randomised trials	Very serious[a]	Not serious	Not serious	Serious[b]	None	15/74 (20.3%)	20/74 (27.0%)	RR 0.73 (0.41–1.29)	73 fewer per 1000 (from 159 fewer to 78 more)	⨁◯◯◯ Very low
Unintentional weight loss											
3	Randomised trials	Very serious[a]	Serious[c]	Not serious	Serious[b]	None	6/74 (8.1%)	13/74 (17.6%)	RR 0.59 (0.15-2.24)	72 fewer per 1000 (from 149 fewer to 218 more)	⨁◯◯◯ Very low

Abbreviations: CI, confidence interval; RR, risk ratio; SMD, standardised mean difference.
[a]Most of the information was drawn from studies with a high risk of bias. Participants were aware of the arm to which they were allocated.
[b]95% confidence interval includes no effect.
[c]Variation in point estimates.

TABLE 4 | Comparison of the effects of exergaming with the control.

		Exergaming			Active control			Usual care			
		Pre-intervention	Post-intervention	Within-group difference, *p*-value	Pre-intervention	Post-intervention	Within-group difference, *p*-value	Pre-intervention	Post-intervention	Within-group difference, *p*-value	Between-group difference, *p*-value
Frailty index and score											
Karssemeijer et al. (2019)	Frailty index	0.27 ± 0.12	0.23 ± 0.12		Aerobic training 0.26 ± 0.13	0.24 ± 0.13					> 0.05
					Relaxation and flexibility exercises 0.23 ± 0.09	0.23 ± 0.12					0.012
Liao, Chen, and Wang (2019)	Frailty score	3.00 ± 1.30	1.80 ± 1.50	< 0.001	3.00 ± 1.40	2.10 ± 1.30	< 0.001				0.075
Frailty status											
Biesek et al. (2021)	Frail	0 (0%)	0 (0%)	0.001				0 (0%)	1 (6.7%)	0.016	
	Prefrail	15 (100%)	4 (26.7%)					15 (100%)	7 (46.6%)		
	Robust	0 (0%)	11 (73.3%)					0 (0%)	7 (46.7%)		
González-Bernal et al. (2021)	Frail	17 (42.5%)	6 (15.0%)					10 (25.0%)	14 (35.0%)		0.039
	Prefrail	23 (57.5%)	34 (85.0%)					30 (75.0%)	26 (65.0%)		
Liao, Chen, and Wang (2019)	Frail	16 (59.3%)	9 (33.3%)		16 (64.0%)	10 (40.0%)					0.442
	Prefrail	11 (40.7%)	10 (37.0%)		9 (36.0%)	11 (44.0%)					
	Robust	0 (0%)	8 (29.6%)		0 (0%)	4 (16.0%)					
Moreira et al. (2021)	Prefrail	32 (100.0%)	5 (16.0%)		34 (100.0%)	2 (6.0%)					
	Robust	0 (0%)	27 (84.0%)		0 (0%)	32 (94.0%)					
Frailty phenotype											

(Continues)

TABLE 4 | (Continued)

		Exergaming			Active control			Usual care			
		Pre-intervention	Post-intervention	Within-group difference, *p*-value	Pre-intervention	Post-intervention	Within-group difference, *p*-value	Pre-intervention	Post-intervention	Within-group difference, *p*-value	Between-group difference, *p*-value
Biesek et al. (2021)	Exhaustion	7 (46.7%)	0 (0%)	0.016				5 (33.3%)	3 (20%)	0.688	
	Low physical activity level	0 (0%)	0 (0%)					1 (6.7%)	1 (6.7%)	1	
	Slow gait speed	1 (6.7%)	0 (0%)	1				0 (0%)	0 (0%)		
	Weakness	8 (53.3%)	3 (20.0%)	0.125				9 (60.0%)	7 (46.7%)	0.625	
	Unintentional weight loss	2 (13.3%)	1 (6.7%)	1				2 (13.3%)	0 (0%)	0.5	
Liao, Chen, and Wang (2019)	Exhaustion	20 (74.1%)	10 (37.0%)	0.002	14 (56.0%)	11 (44.0%)	0.25				0.092
	Low physical activity level	18 (66.7%)	10 (37.0%)	0.008	15 (60.0%)	8 (32.0%)	0.016				0.898
	Slow gait speed	21 (77.8%)	11 (40.7%)	0.002	19 (76.0%)	13 (52.0%)	0.031				0.301
	Weakness	20 (74.1%)	12 (44.4%)	0.008	21 (84.0%)	13 (52.0%)	0.008				0.901
	Unintentional weight loss	3 (11.1%)	3 (11.1%)	1	5 (20.0%)	3 (12.0%)	0.5				0.464
Moreira et al. (2021)	Exhaustion	31 (96.9%)	5 (15.6%)		22 (64.7%)	1 (2.9%)					
	Low physical activity level	8 (25.0%)	0 (0%)		18 (52.9%)	0 (0%)					
	Slow gait speed	0 (0%)	0 (0%)		0 (0%)	0 (0%)					
	Weakness	3 (9.4%)	0 (0%)		3 (8.8%)	0 (0%)					
	Unintentional weight loss	2 (6.3%)	2 (6.3%)		10 (29.4%)	10 (29.4%)					

Note: The results are expressed in terms of mean ± SD or frequency (%).

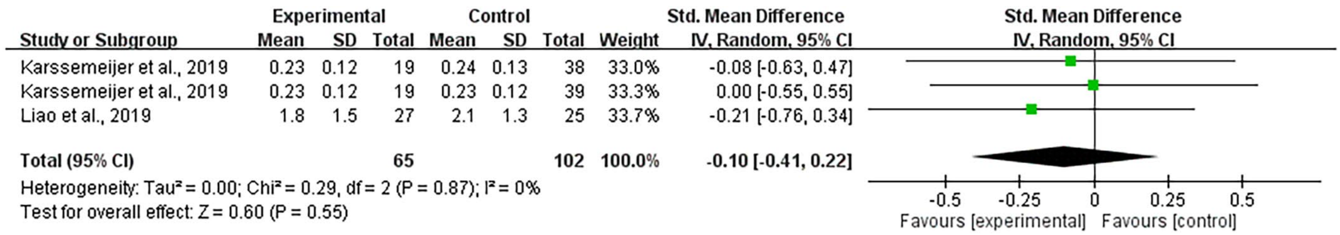

FIGURE 2 | Forest plot of the effect of exergaming on frailty after the intervention. [Colour figure can be viewed at wileyonlinelibrary.com]

in the intervention group in relation to the control group (RR = 1.01, 95% CI = 0.22–4.53, $p = 0.99$; $I^2 = 54\%$, df = 2, $p = 0.11$, Figure 3A).

In one study, exergaming significantly reduced the proportion of older adults with low physical activity levels, although there was no difference from those in the control group, who received a combination of exercises (Liao, Chen, and Wang 2019). Moreira et al.'s study (2021) similarly showed that exergaming reduced that proportion, but the level of significance was not reported. In Biesek et al.'s study (2021), there were no participants with low physical activity levels in the exergaming group. The meta-analysis shows that exergaming had no effect on low physical activity levels (RR = 1.08, 95% CI = 0.52–2.25, $p = 0.84$; $I^2 = 0\%$, df = 1, $p = 0.45$, Figure 3B).

In one study, exergaming significantly reduced the proportion of older adults with slow gait speed, although there was no difference from those in the control group, who received a combination of exercises (Liao, Chen, and Wang 2019). There were no participants with slow gait speed in the control group in Biesek et al.'s study (2021), while there were no participants with slow gait speed in both the exergaming and control groups in Moreira et al.'s study (2021). Therefore, a meta-analysis was not conducted.

Exergaming also significantly reduced the proportion of older adults with weakness, although there was no difference from those in the control group, who received a combination of exercises (Liao, Chen, and Wang 2019). While there was a reduction in the proportion of older adults with weakness in the exergaming group in Biesek et al.'s study (2021), the reduction was not statistically significant. Moreira et al.'s study (2021) did not provide any *p*-value. The meta-analysis shows that exergaming had no effect on weakness (RR = 0.73, 95% CI = 0.41–1.29, $p = 0.28$; $I^2 = 11\%$, df = 1, $p = 0.29$, Figure 3C).

In all of the studies, exergaming did not change the proportion of older adults with unintentional weight loss (Biesek et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021). The meta-analysis shows that exergaming had no effect on unintentional weight loss (RR = 0.59, 95% CI = 0.15–2.24, $p = 0.43$; $I^2 = 39\%$, df = 2, $p = 0.20$, Figure 3D).

4.5 | Adverse Events

Adverse events were reported in two studies, which reported no serious adverse events in the exercise interventions (Karssemeijer et al. 2019; Moreira et al. 2021). Although the authors of the remaining studies were contacted to obtain relevant information, there was no reply.

4.6 | Attendance Adherence and Attrition Rate

The attendance was 83.1% for the exergaming group and 81.2% for the control group in Moreira et al.'s study (2021). Attendance adherence was not reported in the remaining studies. Instead, the rate of adherence to the intervention was reported in two studies (Biesek et al. 2021; Karssemeijer et al. 2019). The adherence rate of the exergaming group was 87.3%–87.7%–slightly higher than the comparison group's 81.1%–85.4% (Table 1). However, how adherence was defined in the studies was not reported. The attrition rate of the exergaming group ranged from 0%–34.7% while that of the comparison group ranged from 0% to 33.3% (Table 1).

4.7 | Publication Bias

Fail-safe N analyses showed that no additional studies were required to analyse the effect of exergaming on frailty scores or indices, exhaustion, low physical activity levels, weakness, and unintentional weight loss.

5 | Discussion

This is the first systematic review and meta-analysis to report the effects of exergaming on frailty. Exergaming appeared to improve frailty status compared to the usual care and treatment. Exergaming was comparable to conventional physical exercises in improving frailty scores and indices, frailty status, and four frailty phenotypes, namely, self-reported exhaustion, low physical activity levels, gait speed, and muscle weakness.

Echoing previous studies, which showed that a combination of several types of physical exercises, such as aerobic and resistance training, effectively improved frailty scores (Tarazona-Santabalbina et al. 2016) or decreased the number of frailty phenotypes (Meng et al. 2020), in this review exergaming improved physical frailty, although a meta-analysis showed no difference from the active control. The effect was positive, probably because the exergaming in this review consisted of several types of physical exercises, such as aerobics, resistance, and balance training, to act on the physical components of frailty. Muscle mass and muscle strength are lost in the progression to frailty (Taylor et al. 2023). A combination of muscle power, balance, and gait training promotes muscle hypertrophy by increasing the

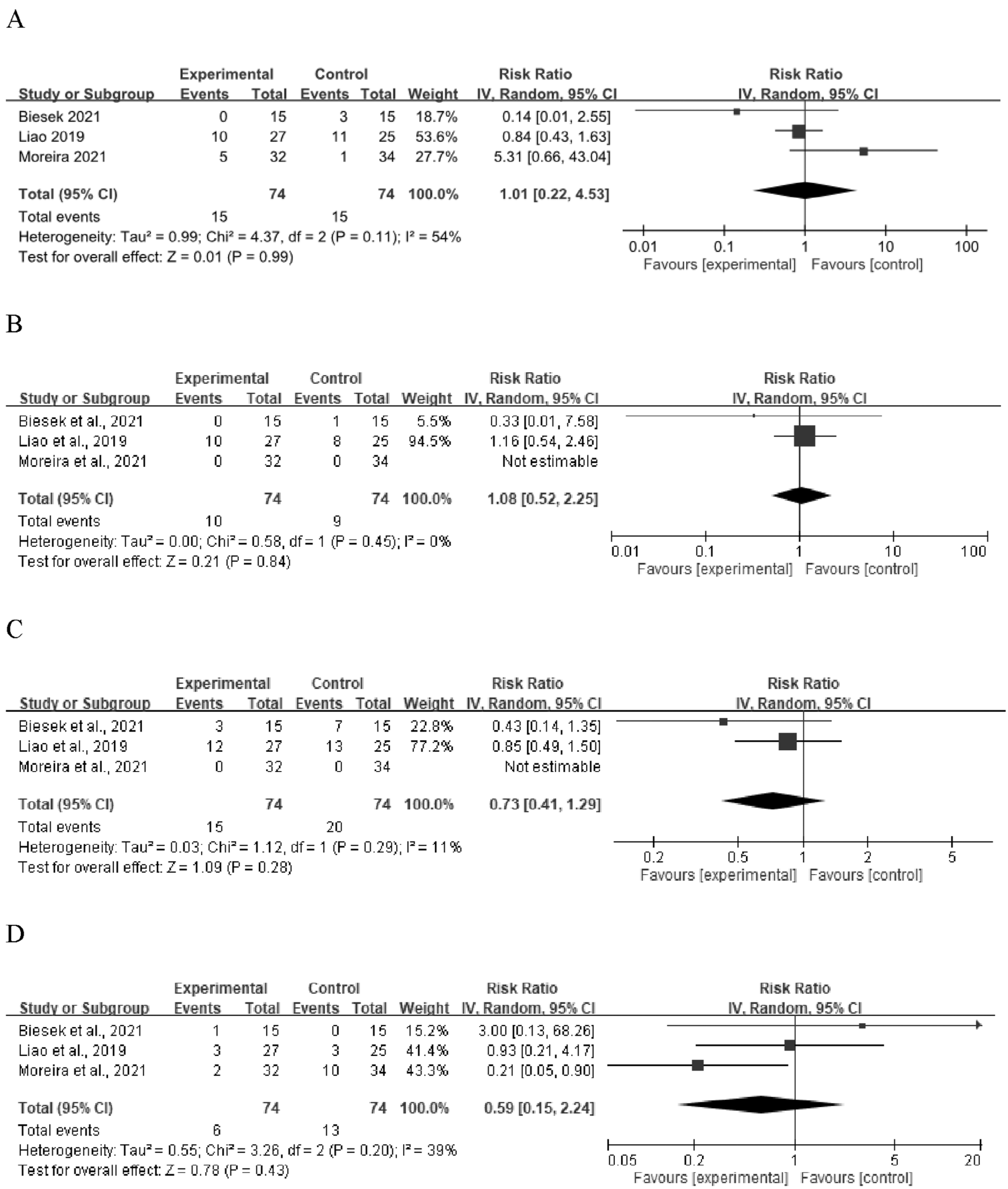

FIGURE 3 | Forest plot of the effect of exergaming on (A) exhaustion; (B) low physical activity levels; (C) weakness; and (D) unintentional weight loss after the intervention.

total and high-density muscle cross-sectional area and results in increased muscle strength and power (Cadore et al. 2014). Training interventions, including aerobic and resistance training, improve the strength of knee extensors, knee flexors, and leg press and gait speed (Meng et al. 2020). Exergames with resistance training enhance muscle strength, while exergames with balance training improve balance and mobility functions (Zheng et al. 2020). With improvements in muscle mass and strength, the feeling of exhaustion may be reduced. Therefore, combining different types of physical exercises maximises the impact on components of frailty, exhaustion, gait speed, and weakness.

Cognitive stimulation in exergaming may also play a role in frailty. A randomised controlled trial showed that improvement in cognition was only found in the group receiving exercise supplemented by cognitive stimulation but not the group receiving exercise alone (Tan et al. 2023). A previous study revealed that grip strength and walking endurance are associated with cognitive function in older adults (Zhao, Huang, and Du 2022). Cognitive stimulation in exergaming may improve cognitive function to better execute physical tasks requiring grip strength and walking endurance. Future studies could further evaluate the role of cognitive stimulation on frailty.

Another possible reason why exergaming improved physical frailty might be related to exercise intensity. Exercise intensity in the included studies ranged from low to vigorous. A systematic review also reported that e-health interventions promoting physical activity were effective at increasing energy expenditure (Kwan et al. 2020). Exergaming is associated with increased energy expenditure, and the increase can be up to 300% above resting levels (Sween et al. 2014). Therefore, individuals who are willing to participate in exergaming will have their physical activity levels increased.

Regarding the frailty phenotypes, our meta-analyses showed no difference between the exergaming and the control groups, although exergaming led to improvements in self-reported exhaustion, low physical activity levels, and muscle weakness. One possible reason for this relates to the comparison group. Exergaming had a comparable effect to the active control, and two of the three studies comparing exergaming with an active control (Liao, Chen, and Wang 2019; Moreira et al. 2021) contributed to a large weight in the forest plots. Another reason relates to gender. Two studies (Biesek et al. 2021; Moreira et al. 2021) involved only females, while females composed about 70% of the sample size in one study (Liao, Chen, and Wang 2019). Changes in body strength and whole-body fat-free mass in response to resistance training were found to be smaller in older females than males (Hawley et al. 2023). Based on the large number of female participants, the magnitude of the improvements in self-reported exhaustion and muscle weakness might thus be limited. Last, baseline frailty status also played a role. Two studies (Biesek et al. 2021; Moreira et al. 2021) involved only prefrail older adults, and only one study (Liao, Chen, and Wang 2019) recruited both prefrail and frail older adults. There may be less room for improvement in prefrail than frail older adults. Future studies can further explore the effect of exergaming on the frailty phenotype.

Despite our meta-analyses showing no difference in frailty score or index, exhaustion, physical activity levels, weakness, and unintentional weight loss between the exergaming and the control groups, the comparable effect of exergaming to conventional physical exercises on frailty and its phenotypes found in this review was similar to that in Skjæret et al. (2016), which showed that for older adults, the effect of exergaming on physical function was comparable to other physical exercises. Undoubtedly, this was because similar exercises were adopted in both the exergaming and conventional physical exercises in the included studies. This finding indicates that since exergames can improve frailty and its phenotypes, exergaming is a possible alternative to conventional physical exercises.

Exergaming had no effect on unintentional weight loss because physical exercise alone may not be sufficient to counteract unintentional weight loss. With weight loss or undernutrition, protein/caloric supplementation is recommended (Dent et al. 2019). As shown in a previous randomised controlled trial, protein supplementation with physical exercises led to a significantly greater increase in relative lean body mass when compared with physical exercise alone (ten Haaf et al. 2019). Intake of amino acids is necessary for muscle protein synthesis (Dickinson, Volpi, and Rasmussen 2013). Yet this review only evaluated the effect of exergaming without nutritional support.

Although in this review the rate of adherence to the intervention of the exergaming group was only slightly higher than that by the comparison group, it was similar to a previous review in which the rate ranged from 80%–100% in older adults (Pacheco et al. 2020). Exergaming promotes adherence through game scenarios in which multiple sensory modalities (auditory, visual, and proprioceptive systems) are stimulated (Wu et al. 2022). Elements of exergames also make exergaming enjoyable, including the need to concentrate on the screen, the presentation of challenges, the clear goal of winning points, the giving of scores as feedback, immersion in the game, the ability to control characters in the game, the offering of an appropriate level of difficulty, and opportunities for social interaction with other people (Meekes and Stanmore 2017). As shown in a previous review, up to 81% of participants reported high levels of enjoyment and satisfaction (Suleiman-Martos et al. 2022). It is worth making further comparisons of adherence and motivation between exergaming and conventional physical exercises to determine the potential of using exergaming as a substitute for conventional physical exercises, particularly unsupervised exercises.

5.1 | Limitations

There are several limitations to this review. First, the number of studies was small, making it impossible to identify the most optimal exercise intensity and combination of types of exercise for older adults. Nor was it possible to conduct a subgroup analysis based on a comparison group. In addition, the influence of covariates could not be analysed. Second, the search terms used were fewer than those in previous systematic reviews (Manser, Herold, and de Bruin 2024; Zheng et al. 2020), although Medical Subject Headings terms were used in the search in this review. Third, the study participants mainly came from the community, day care centres, memory clinics, and nursing homes, and two studies involved only females, affecting the generalizability of the findings. Fourth, the high risk of bias and very low quality of the evidence affected estimations of the treatment effects.

5.2 | Implications for Research

This review offers some points of consideration for future studies. First, the optimal exercise intensity and combination of types of physical exercises should be investigated to better tailor exergames to meet individual needs and levels of performance of older adults in any state of frailty. Second, different from recreational games, which aim to provide entertainment, serious games are designed with purposes beyond play (Berglund et al. 2024). It has been proposed that serious games need to adopt three fundamental concepts, namely, user-centred design, structural activities software engineering, and gamification elements (Beristain-Colorado et al. 2021). In this review, a commercially available game platform that might not properly address frailty was used in four studies (Biesek et al. 2021; González-Bernal et al. 2021; Liao, Chen, and Wang 2019; Moreira et al. 2021). Further studies could compare the effects of recreational games and serious games on frailty. Third, future studies could consider reducing the risk of bias and adopting a robust study design. For example, adopting consoles that are not specific to exergames to help conceal the true nature of the intervention in the control group. Fourth, future studies could report attendance adherence as a standard outcome. To inform future public health actions, reporting of attendance adherence in both exergaming and comparison groups is urgently needed. Fifth, a wider range of keywords, such as "play station" and "interactive computer game," could be considered.

5.3 | Implications for Clinical Practice

In clinical settings, exergaming may be an alternative due to its comparable effects on frailty-related outcomes to conventional physical exercises. It has been shown that movement of gross body muscles can be promoted with preferred music (Cheung et al. 2022). Similarly, physical exercises may be promoted with games. Although exergaming can be easily incorporated into existing treatment plans and adopted in the community, older adults' attitude towards exergames, impairments due to ageing and health conditions, and the knowledge and skills required to engage in exergaming need to be considered (Ning et al. 2022). Consideration could be given in future exergames to adopting a user-centred design, structural activities, software engineering, and gamification elements (Beristain-Colorado et al. 2021) to help older adults develop the habit of exercising and improve their motivation to exercise to prevent or reverse frailty.

6 | Conclusions

This review suggests that the effects of exergaming were comparable to those of conventional physical exercises on frailty scores and indices, frailty status, exhaustion, low physical activity levels, gait speed, and muscle weakness. Clinicians could consider using exergaming as an alternative to conventional physical exercises due to its motivating features. More studies with robust designs are needed to investigate the optimal exercise intensity and combination of exercises for older adults.

Author Contributions

Conceptualization: L.Y.W.H., D.S.K.C. Methodology: L.Y.W.H., J.H.Y.T., D.S.K.C. Software: L.Y.W.H., J.H.Y.T. Validation: L.Y.W.H. Formal analysis: L.Y.W.H., J.H.Y.T., W.L.S.C., D.S.K.C. Investigation: L.Y.W.H., J.H.Y.T. Resources: L.Y.W.H., J.H.Y.T. Data Curation: L.Y.W.H. Writing – Original Draft: L.Y.W.H. Writing – Review and Editing: J.H.Y.T., W.L.S.C., D.S.K.C. Visualisation: L.Y.W.H. Supervision: L.Y.W.H. Project administration: L.Y.W.H.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data underpinning this study are available in the article and in its Data S1. The protocol of this review was registered in PROSPERO (registration number: CRD42023460495).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Appendix A

Search Strategy

Database	Search terms
CINAHL	1. (MH “Aged”) OR elder* OR “older people” OR “older adult*” 2. (MH “Exergames”) OR exergam* OR Kinect OR Nintendo OR Wii OR “computer feedback training” OR (MH “Video Games”) OR video-gam* OR (MH “Virtual Reality”) OR “virtual realit*” 3. frail* OR frailty 4. #1 AND #2 AND #3
Cochrane Library	1. MeSH descriptor: [Aged] explode all trees 2. MeSH descriptor: [Frailty] explode all trees 3. MeSH descriptor: [Video Games] explode all trees 4. MeSH descriptor: [Exergaming] explode all trees 5. MeSH descriptor: [Virtual Reality] explode all trees 6. elder* OR “older people” OR (older adult*) 7. exergam* OR Kinect OR Nintendo OR Wii OR “computer feedback training” OR video-gam* OR (virtual realit*) 8. frail* 9. #1 OR #6 10. #2 OR #8 11. #3 OR #4 OR #5 OR #7 12. #9 AND #10 AND #11
Embase	1. elder* OR ‘older adult*’ OR ‘older people’ OR ‘aged’/exp. 2. ‘exergam*’ OR ‘Kinect’ OR ‘nintendo’ OR ‘wii’ OR ‘video-gam*’ OR ‘virtual realit*’ OR ‘computer feedback training’ OR ‘video games’/exp. OR ‘exergaming’/exp. OR ‘virtual reality’/exp. 3. frail* OR ‘frailty’/exp. 4. #1 AND #2 AND #3
PubMed	1. aged [MeSH] OR elder* OR “older adult*” OR “older people” 2. exergaming [MeSH] OR exergam* OR kinect OR Nintendo OR “computer feedback training” OR “video games” [MeSH] OR video-gam* OR “virtual reality” [MeSH] OR “virtual realit*” OR Wii 3. frailty [MeSH] OR frail* 4. #1 AND #2 AND #3
Web of Science	1. ALL=(aged OR elder* OR “older people” OR “older adult*”) 2. ALL=(exergam* OR Kinect OR Nintendo OR Wii OR “computer feedback training” OR video-gam* OR “virtual realit*”) 3. ALL=(frail*) 4. #1 AND #2 AND #3
CNKI	1. (主题=老年) OR (全文=老年) 2. (主题=体感互动游戏) OR (全文=体感互动游戏) OR (全文=Kinect) OR (全文=Nitendo) OR (全文=Wii) OR (全文=电脑反馈训练) OR (主题=电子游戏) OR (全文=电子游戏) OR (主题=虚拟现实) OR (全文=虚拟现实) 3. (主题:衰弱 (精确)) OR (全文:衰弱 (精确)) 4. ((主题=老年) OR (全文=老年)) AND ((主题=体感互动游戏) OR (全文=体感互动游戏) OR (全文=Kinect) OR (全文=Nintendo) OR (全文=Wii) OR (全文=电脑反馈训练) OR (主题=电子游戏) OR (全文=电子游戏) OR (主题=虚拟现实) OR (全文=虚拟现实)) AND ((主题:衰弱 (精确)) OR (全文:衰弱 (精确)))同义词扩展 學術期刊